***Same/Different* Reversal Learning in Pigeons (*Columba livia*)**

by

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A thesis submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Master of Science

Auburn, Alabama
August 6, 2011

Keywords: Abstract-Concept Learning, Reversal Learning, Transfer

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Abstract

Reversal learning is a common procedure for studying discrimination learning, but has yet to be studied in a *same/different* abstract-concept learning task. In the present study, the ability to learn a *same/different* task with repeated contingency reversals was assessed in 4 pigeons with extensive experience in a two-item *same/different* task. Subjects were shown a sample picture and required peck the stimulus a Fixed-Ratio 14 (FR 14), then, simultaneously presented below the sample, another picture and a white rectangle. If the two pictures were the *same*, the correct response was to touch the lower picture. If the two pictures were *different*, the correct response was to touch the rectangle. Once steady-state performance was obtained, the contingencies were reversed such that if the two pictures were the *same*, the correct response was to touch the rectangle. If the two pictures were *different*, the correct response was to touch the lower picture. Upon reaching criterion, a reversal back to the initial contingency was implemented and followed by subsequent repeated contingency reversals. After 12 such reversals, a transfer test was given to assess discrimination of novel stimuli. The results indicate subjects' can flexibly learn reversals and transfer to novel stimuli. Given the successful full transfer, performance is interpreted to characterize relational rule use in an abstract-concept learning task with reversals.

Acknowledgments

The author would like to thank Dr. Jeffrey Katz for his assistance with computer programming, statistical analysis, and earlier drafts of this manuscript. The author would also like to thank the members of his committee; Dr. Ana Franco-Watkins and Dr. Martha Escobar, for their careful review of earlier drafts of this manuscript. Thanks are also due to John Magnotti and Thomas A. Daniel for their support and assistance during the course of this investigation.

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List of Abbreviations

S/D	*same/different*
MTS	*matching-to-sample*
ITI	Inter-trial Interval
CP	Correction Procedure
s	Second
SEM	Standard Error of the Mean
FR	Fixed Ratio

Same/Different **Reversal Learning in Pigeons (*Columba livia*)**

Research in comparative psychology and biology has revealed characteristics which are common and uncommon across the kingdoms of contemporary taxonomy. In *The Descent of Man*, Darwin (1872) stressed the importance of these comparisons within the animal kingdom contributing vastly to the understanding of both physical and behavioral characteristics in humans. Recently, Shettleworth (2010) defined Comparative Cognition as a field which explores general and specific processes by examining evidence of known cognitive processes across different species. Exploration of cognitive processes has lead to a greater understanding of a variety of processes that underlie learning, memory, and intelligence (Domjan, 2010). Although much is known about these phenomena and the mechanisms mediating these processes, historical debates still exist whether specific species have been demonstrated to utilize a particular cognitive process or not (e.g., numerosity, language, mental representation). One area of contention has been whether non-human animals have the ability to acquire and maintain an abstract concept (e.g., Penn, Holyoak, & Povinelli, 2008).

This thesis will show how pigeons learn a *same/different* task using a contingency reversal procedure. The following sequence of topics is presented. First, the rationale for the use of pigeons is briefly presented. Second, abstract-concept learning and it's distinction from item-specific learning is discussed. Third, a select review of abstract-concept learning literature is presented. Forth, a review and rationale for reversal learning is presented. Next, the experiments are proposed. Evidence for abstract-concept learning with reversals is presented and discussed.

Finally, implications of the experimental analysis are discussed.

Pigeons as Experimental Subjects

Pigeons possess qualities which have made them excellent candidates for visual cognition research (Cook, 2000). The range in experimentation of which one can design and implement a study with pigeons allows for such research to be flexibly and easily included in supplement to other comparative findings. Pigeons have excellent vision and visual discrimination abilities (e.g., Wright & Cummings, 1971). Such perceptual abilities allows for the use of a wide variety of visual stimuli to be used in tasks to examine perception, learning, and memory. Although pigeons differ greatly from humans in regard to phylogeny and nervous system, similar patterns have been observed at the level of elementary processing in the visual system to that of humans (e.g., Blough & Blough, 1997). Although study of a mammalian species may provide perhaps a closer analog to understanding human cognition, the commonalities which exist within the visual system of avians and mammals allows for research with pigeons to contribute vastly to the understanding of cognitive processes. Hence, a comparative examination of processing in the visual domain in pigeons can serve to provide evidence of general principles and mechanisms which have been demonstrated to apply across many species despite their diversity in evolutionary history and physiology (e.g., Shettleworth, 2010).

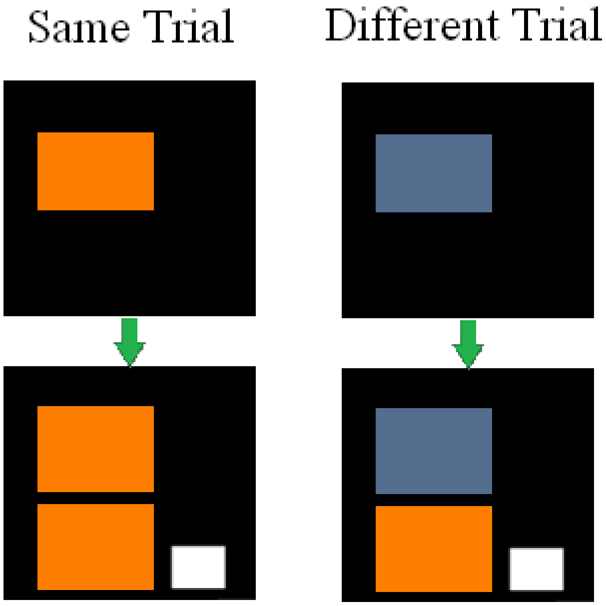
Abstract-concept Learning

Abstract-concepts are rules about relationships among stimuli said to go beyond individual features of the stimuli (e.g., higher than, less than, identical). Abstract-concepts are said to be a form of higher-order learning because they require an organism to acquire rules beyond specific features of the stimuli and depend instead on the ability to judge these relations (e.g., Katz, Bodily, & Wright, 2008). Abstract-concepts differ from “natural” concepts (e.g. flowers, tables, dogs) because they are not based on specific features common to stimuli, but instead, are based on relational learning. This distinction is important as natural concepts and abstract concepts are sometimes confused.

Same/different and *matching-to-sample* tasks are two procedures which have been used to examine the abstract-concept of sameness or identity. Although they can be targeted at exploiting a common form of learning, the tasks are distinct in their requirements. In a typical *matching-to-sample* procedure, a subject (e.g., a pigeon) is presented with a single stimulus called the sample (e.g., orange circle) and then with two choice stimuli called the comparisons (e.g., blue circle, orange circle). The pigeon is rewarded for pecking the comparison that matches the sample (e.g. orange circle). In the two-item *same/different* task used in this thesis seen in figure 1, a pigeon is presented with a single stimulus (e.g., orange rectangle) called the sample and then with the comparison stimuli (the lower colored rectangle and the white rectangle). The pigeon pecks either the rectangle right under the sample or the white rectangle to designate a *same* or *different* trial. If the two items are identical, as seen in the left panel of figure 1, the trial is designated a *same* trial and the correct response is to peck the lower stimulus. If the two items are not identical, seen in the right panel of figure 1, the trial is designated a *different* trial and the correct response is to peck the white rectangle.

Same/different and *matching-to-sample* tasks can be learned by either item-specific or relational rules. Carter & Werner (1978) identified item-specific learning and relational learning as two types of learning which may account for performance in *same/different* and *matching-to-sample* tasks. Item-specific learning is characterized as simple stimulus-response learning and is also known as rote memorization. In item-specific learning, the subject might have learned the configural array of the stimulus displays or the *if-then rule* for each of the stimulus combinations

Figure 1



Caption: *Figure 1*. Example of a *same* and *different* trial progression.

in the task. Configural learning refers to learning the whole gestalt of each display and learning which comparison choice to make based on this global pattern. For example, pigeons may learn, “If orange sample, orange lower stimulus, and white rectangle, then peck orange stimulus,” as one rule, and learn, “If blue sample, orange lower stimulus, and white rectangle, then peck white rectangle,” as another rule. *If-then rule learning* refers to learning specific stimulus-response chains to the sample and correct choice stimuli. For example the pigeon may learn, “If orange sample, then peck orange lower stimulus,” as one rule and learn, ”If blue sample, followed by orange lower stimulus, then peck white rectangle,” as another rule. Relational learning, on the other hand, is characterized as learning in which relational judgments can account for abstract-concept learning. The gold standard to determine whether subjects are learning the task by memorization or abstraction is a test to examine if performance transfers to novel stimuli. Abstract-concept learning and its standard testing procedure are explained in more detail in the next section.

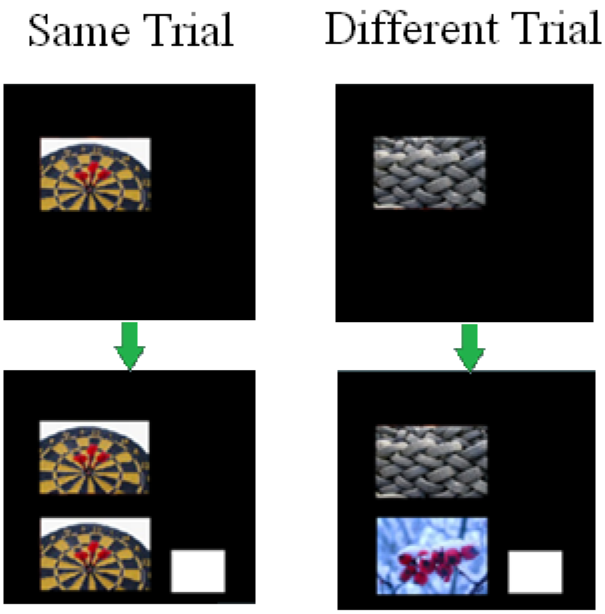
Review of Abstract-Concept Learning

Because the *same/different* task and other tests for relational learning can be learned both *item-specifically* and relationally, these tasks have remained prominent in research. Control of behavior by the absolute properties of individual stimuli or control by relational properties between stimuli has been a recurring debate in the non-human animal literature (e.g., Cumming & Berryman, 1965; Harlow, 1949; Hull, 1930; Kohler, 1918; Premack, 1983; Spence, 1936; Thorndike, 1911; Wright, Cook, Kendrick, 1989; Zentall & Hogan, 1974). Initially, Thorndike's (1911/1998) experimental studies concluded that (with the exception of primates and humans) examinations of learning across species are best explained by instincts and individual acquirement through impulsive trial and error. Thorndike explains impulsive trial and error learning as unique stimulus-response associations mediated by prior outcomes rather than such abilities as relational learning. Kohler's (1918/1939) counter proposal supplied evidence of relational learning in chickens with a brightness comparison task. Such evidence suggested other nonhuman animals besides primates were capable of higher-order learning. Spence (1936) provided accounts of associative learning in which inhibition and excitation tendencies explained mechanisms of response acquisition consistent with trial and error learning in non-human animals. Spence criticized notions of insight and hypothesis-testing by demonstrating the same examinations into animal discriminations in terms of competing processes. Harlow (1949) provided a series of comparative experiments in which he presents his theory of learning sets or learning about learning, which is not consistent with the proposal that non-humans are capable of only trial and error learning. Using the *matching-to-sample* paradigm, some early studies demonstrated that pigeons do not appear to utilize relational rules when performing a matching task. Cumming & Berryman (1965) found failures to transfer to novel stimulus after training in the task. These results were taken to indicate inconclusive evidence of the presence or absence of relational learning in pigeons. Other studies (e.g., Bore & Gollub, 1972; Clark and Sherman, 1978; Nelson 1978) viewed correct matching as simple operants (e.g., interval and ratio schedules of reinforcement) and demonstrated a strong resemblance to performance with known schedules of reinforcement (Ferster & Skinner, 1957). These results were taken to suggest that *matching-to-sample* was arranged procedurally, but the responses made in the task did not suggest that a relational strategy was utilized. Zentall and Hogan (1974), provided evidence which suggested pigeons will demonstrate conceptual behavior provided the test closely resembles training conditions. With this finding, it became conceivable that previous failures to demonstrate relational behavior in non-humans may likely be a function of the inadequate or inappropriate testing methods. Eventually, Premack (1983) stipulated that language trained animals are capable of both types of learning depending on procedural parameters although evidence was tenuous.

Premack's conclusion about the role of language in non-human relational learning has since been challenged by researchers. *Matching-to-sample* and *same/different* tasks have demonstrated evidence supporting abstract-concept learning in a variety of animals including: baboons (Bovet & Vauclair, 2001), capuchin monkeys (Wright, Rivera, Katz, & Bachevalier, 2003), chimpanzees (Thompson, Oden, & Boysen, 1997), dolphins (Herman, Hovancik, Gory, & Bradshaw, 1989), parrots (e.g., Pepperberg,1987), pigeons (e.g., Katz & Wright, 2006; Wright, 1997; Wright, Cook, Rivera, Sands, & Delius, 1988), rats (Peña, Pitts, & Galizio, 2006), rhesus monkeys (Katz, Wright, & Bachelevalier, 2002), and sea lions (Kastak & Schusterman, 1994).

Katz & Wright (2006) provided strong evidence for abstract-concept learning in pigeons using a *same/different* task. In their procedure they systematically increased the training set-size of stimuli (from 8, to 16, to 32, to 64, to 128, to 256, to 512, to 1024) during training. Pigeons were trained to respond to a simultaneously presented two-item *same/different* display. Examples of each trial type can be seen in figure 2. After pecking an upper picture 20 times (Fixed-Ratio 20), they pecked either a lower picture or a white rectangle to designate a *same* or *different* trial which can be seen in the bottom panels of figure 2.

Figure 2

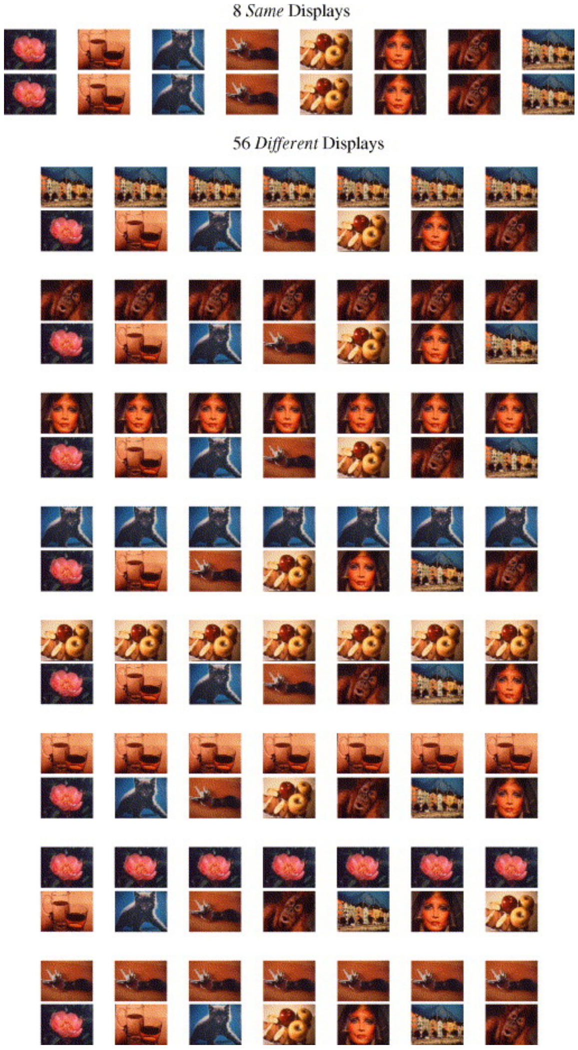


Caption: *Figure 2*. Example of a *same* and *different* trial progression.

If the two items were identical, as seen in the left panel of figure 2, the trial was designated a *same* trial and correct responses were pecks to the lower picture. If the two items were non-identical, seen in the right panel of figure 2, the trial was designated a *different* trial and correct responses were pecks to the white rectangle. Pecks to the incorrect response locations were extinguished and followed by a 15-second time out. A correction procedure (CP) was used in which incorrect trials were repeated until a peck to the correct response area occurred. During training, pigeons were required to complete sessions consisting of 50 *same* and 50 *different* trials. Figure 3 shows the eight *same* trial pairs and 56 *different* trial pairs used in initial acquisitions of the *same/different* task with the 8-item set size.

After reaching a performance criterion in training, subjects were transfer tested to novel stimuli. Transfer testing was conducted for six consecutive sessions. Each testing session contained 100 trials composed of 90 baseline (trained-items) and 10 transfer (novel-items) trials

Figure 3



Caption: *Figure 3.* 8 *same* trial pairs and 56 *different* trial pairs used in initial training for Katz & Wright (2006).

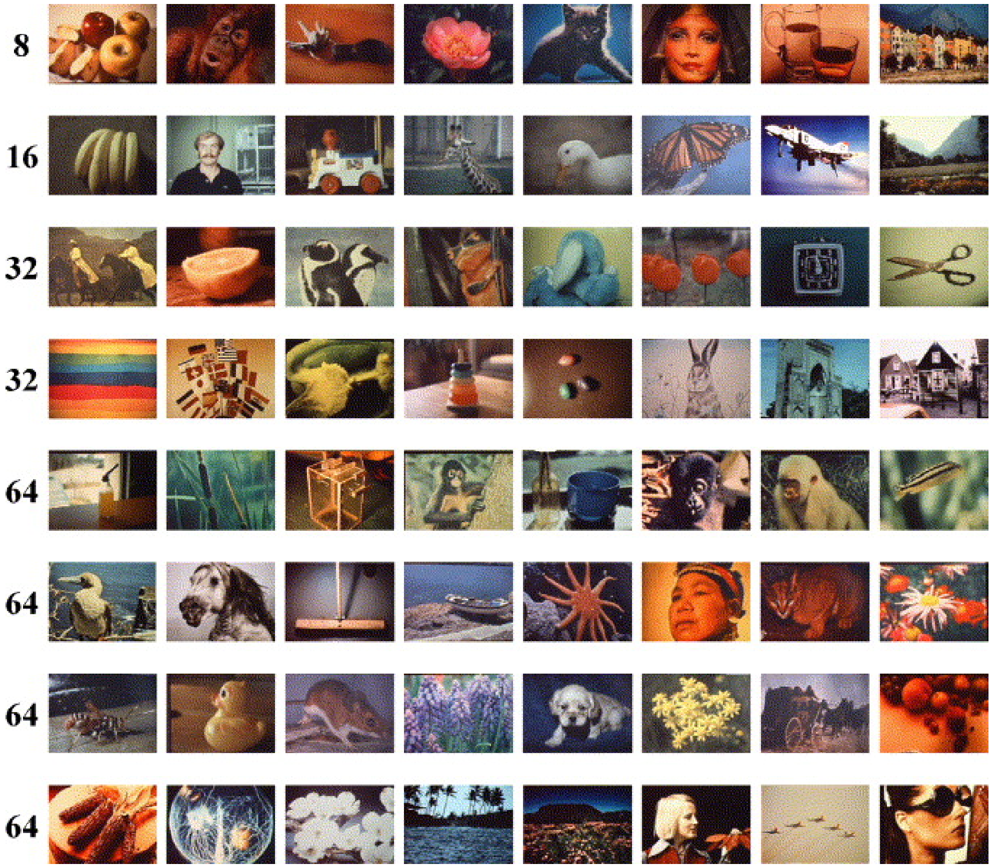
psuedorandomly intermixed. Transfer trials were reinforced in the same way as the baseline trials. There were 5 *same* and 5 *different* transfer trials each session. Figure 4 shows the 60 novel-item displays used for transfer testing.

Figure 4

Caption: *Figure 4.* Transfer test items following 8-item training in Katz & Wright (2006)

Following transfer testing for the 8-item set, the training set was expanded to 16 items by adding 8 new stimuli to the training set and the birds again reached a performance criterion. The training set was again expanded to 32 items by adding 16 new stimuli to the training set. After pigeons again reached a performance criterion, they were then tested for novel-item performance at training set size 32. The set-size was increased from 32 to 64, to 128, to 256, to 512, to 1024. The items for the first three set-size expansions can be seen in Figure 5. Although there was no transfer test conducted at set-size 16, each of the subsequent expansions included transfer testing upon reaching a performance criterion.

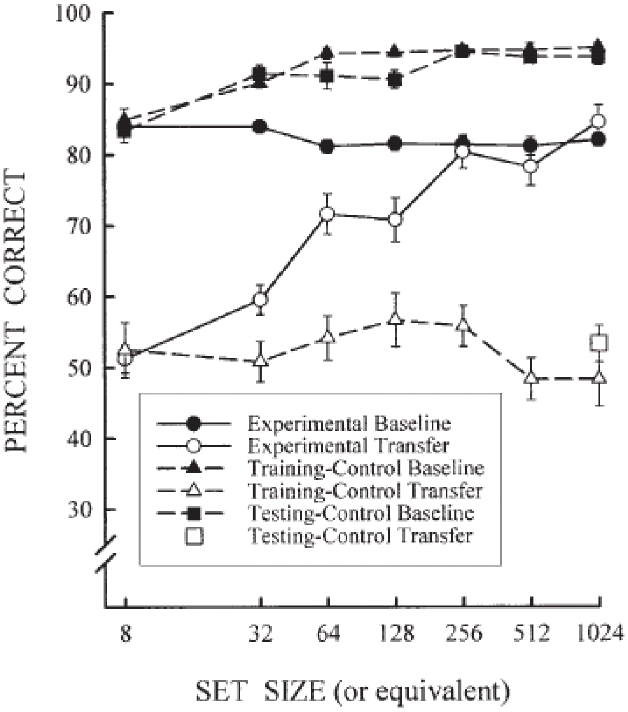
Figure 5



Caption: *Figure 5*. Stimuli used for set-size expansions from 8, to 16, to 32, to 64 in Katz & Wright (2006).

Analysis of the results of these transfer tests was then used to determine if pigeons were responding significantly different for the novel stimuli to that of the baseline stimuli. If responding to novel stimulus trials resembled that of the baseline trials, then it can be argued that the pigeon's behavior is under control by the relational rule. In contrast, if responding differs between these two trial types, responding is assumed to be under some other form of control such as item-specific learning (see Wright and Katz, 2009). Across the expansion of training item set-size, performance for novel item trials gradually increased to where it was equal to baseline trials (see figure 6).

Figure 6

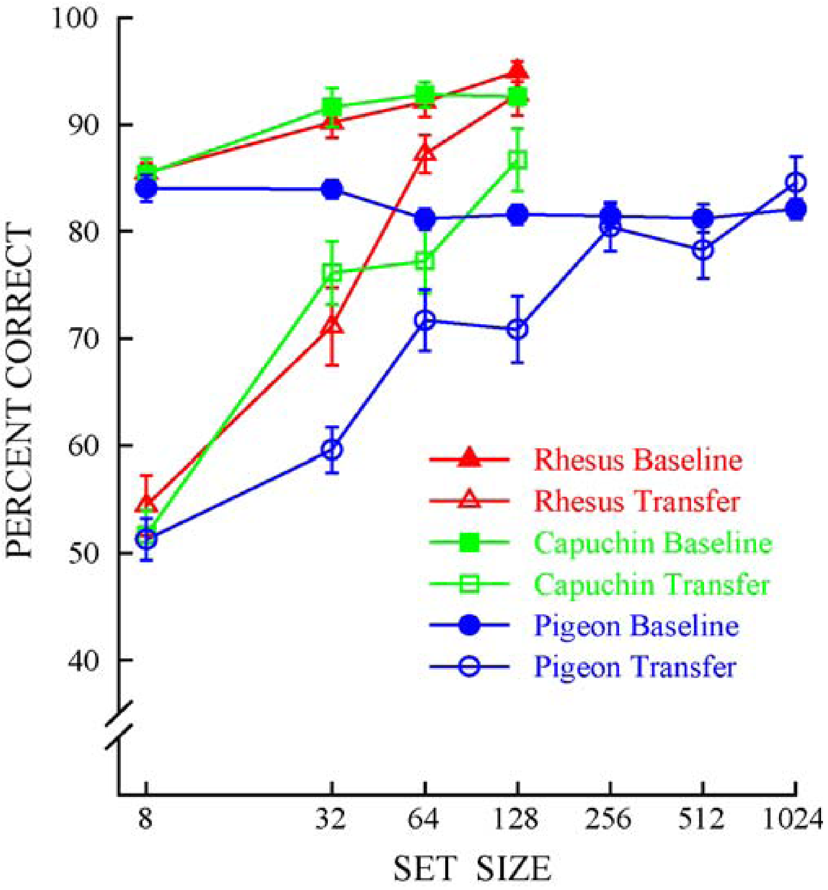


Caption: *Figure 6.*Performance meaned across subjects for transfer (test-items) and baseline (trained-items) for experimental and control groups from Katz and Wright (2006). See text for distinctions of experimental and control groups.

The significant difference for transfer and baseline performance, or *no transfer*, indicated item-specific learning at smaller set-sizes tests (e.g., 8, 32). Performance on novel-item trials for the intermediate training set-size (e.g., 64, 128) demonstrated a *partial transfer*, in which accuracy of responding is significantly above chance but below baseline performance. This suggests the subject behavior is under control of competing strategies (e.g., relational learning, item-specific learning). In this case, neither strategy appears to be predominating or account for all responding in the task. The larger training set-size tests (e.g., 256, 512, 1024), demonstrated a *full transfer*, in which performance on novel-items was equivalent to that of baseline trials and was taken to indicate the use of relational rules. Katz and Wright controlled for the effects of repeated transfer testing and the effects of training as sources of increasing transfer test results by designating a testing-control group and a training-control group. The testing-control group received training with a fixed 8-item set, but transfer was tested only at the completion of the entire procedure. The training-control group received training with a fixed 8-item set, identical to the testing-control group, however throughout training subjects were tested for novel-stimulus transfer at the mean times during training when the experimental group was tested. These control groups, seen in figure 6, provided evidence that the experimental condition of an expanding set-size demonstrated unique effects from that of the control groups and that transfer test performance did not increase as a result of training or repeated testing in the task. The results of the experimental and control groups in this study indicated strong evidence that the size of stimulus training sets can be directly manipulated to demonstrate control of item-specific and relational rule use (Katz & Wright, 2006)

Katz and Wright (2006) provided evidence indicating that pigeons possess the ability to form abstract-concepts and that this ability is mediated by the number of items used during training in their task. By comparing rhesus monkeys, capuchin monkeys, and pigeons in the identical *same/different* task from Katz and Wright (2006), Wright & Katz (2006) observed quantitative differences in set-size functions across species seen in figure 7.

Figure 7



Caption: *Figure 7.* Mean performance in the *same/different* task for baseline and transfer trials at each set size for rhesus monkeys, capuchin monkeys, and pigeons in Wright & Katz (2006). Error bars represent SEMs.

Wright and Katz noted for these three species, the emergence of *full concept* learning at 128 items for monkeys and even later at 256 items for pigeons. While this difference in set size is a quantitative difference, all species show qualitative similarity in their ability to solve the *same/different* tasks relationally. These findings suggested the effect of set-size on transfer performance is a general phenomenon common to very different species of vertebrates.

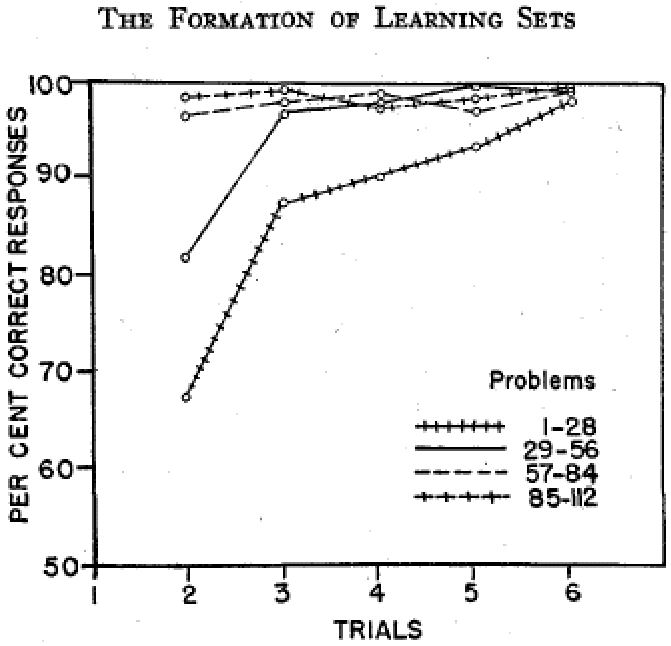
Taken together, the results from these studies suggest how a *same/different* task is learned (item-specifically versus relational learning) is controlled by the number of items appearing in the training set-size. To strengthen the conclusions even further, converging operations can be explored. A converging operations method of analysis involves exploring a single phenomenon with multiple procedures and provides a valuable scientific resource to confirm or dispute such conclusions. In utilizing this approach, an alternative measure beyond the traditional transfer test can serve to further strengthen this conclusion. Further manipulation on the s*ame/different* task could provide an additional measure of abstract-concept learning in pigeons, supplementing the existing evidence. One such manipulation lies in the reversal design.

Discrimination Reversal Learning

A common procedure in discrimination learning is the reversal design, which has been utilized in a variety of species including goldfish (Woodward, Schoel, & Bitterman, 1971), pigeons (Vaughan, 1988), pinyon jays, clark's nutcrackers, western scrub jays (Bond, Kamil, & Balda, 2007), rats (Mackintosh, Mcgongle, Holgate, & Vanderver, 1968), rhesus monkeys (Harlow, 1949), & tufted capuchins (Lillo & Visalberghi, 1994). In this design, contingencies of a trained response are reversed such that the stimulus previously associated with non-reinforcement (S-) becomes the stimulus associated with reinforcement (S+) and vice versa.

One of the first discrimination reversals was conducted by Harlow (1949). He examined the ability of rhesus monkeys to learn a reversal task in which one stimulus was always the correct choice and rewarded (e.g. selecting a red bowl was rewarded whereas selecting a green bowl was not). After successfully learning this discrimination, the contingency was then reversed, and choosing the other stimulus was rewarded. In Figure 8, we see that Harlow's

Figure 8



Caption: *Figure 8.*Mean Performance of rhesus monkeys averaged across successive groups of 27 repeated contingency reversals for the trials subsequent to a reversal in Harlow (1949).

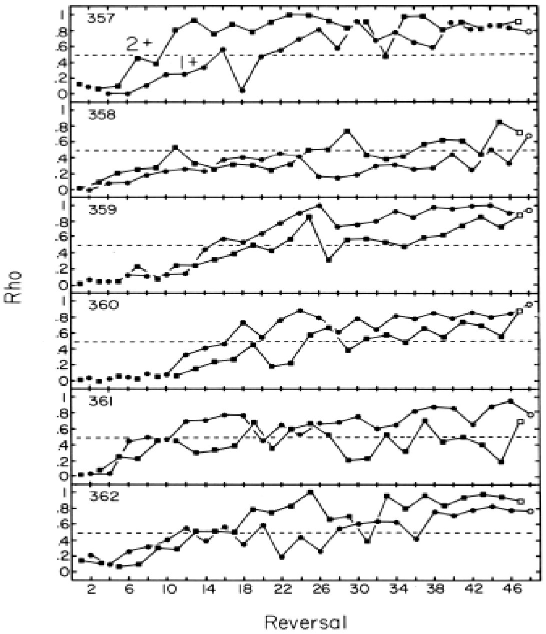
analysis designated each successive problem as a contingency reversal.

Performance on the 1st trial of each problem did not figure into the analysis, as this was designated the informing trial. Each trial number indicates the mean accuracy for that trial within the given range of successive problems. Harlow found that after several of these successive reversals, the Rhesus monkeys made virtually no errors after the initial informing trial for each reversal and showed much more rapid acquisition as a function of repeated successive reversals. Harlow outlined in his theory of learning sets that evidence indicates that non-human animals do not solely respond to rewards and punishment and exerted his subjects were capable of learning about learning (i.e., a rule; Harlow, 1949). Through his procedure, Harlow demonstrated rule learning in Rhesus monkeys by utilizing a reversal design in a simple discrimination task in which responding to stimuli was based on outcomes of other stimuli.

Evidence of such patterns have been repeated with consistent results implicating that simple stimulus and response relationships could not fully account for behavioral data. Pigeon's ability to acquire stable and accurate performance levels across repeated reversals was extensively studied by Vaughan (1988). Vaughan examined stimulus equivalence in the pigeon using a reversal learning procedure. Pigeons were rewarded for responding to a set of 20 out of 40 slides under an initial contingency. After a number of sessions, the contingency was reversed and choices to the other 20 slides were now the only responses that were reinforced. After several more sessions the contingency was then reversed back to the initial conditions. Figure 9 demonstrates individual subject data for both contingencies 1+ (20 out of the 40 total slides) and 2+ (other 20 out of the 40 total slides) for the 1st 40 trials of a reversal session. Vaughan noted initial low performance accuracy for the early reversals and a gradual increase in accuracy as a function of successive reversals for both of the contingencies. Thus, he demonstrated that in a more complex procedure in which the discrimination task involved more than two stimuli, repeated reversals seemed to gradually lead to accurate and stable performance across many reversals (Vaughan, 1988). What is consistent between Harlow (1949) and Vaughan's (1988) findings, as seen in figures 8 and 9, are the positive relationships of repeated reversals and accuracy in the task.

The reversal procedure manipulation has yet to be utilized in studying the pigeon's ability to use abstract-concepts. Such a manipulation will provide valuable information through a converging operations approach to answer questions about the ability of relational judgments in pigeons and potentially other non-humans. This procedure will also reveal evidence characterizing performance for a relatively large set-size in a simultaneous two-item *same/different* task. The first step in utilizing this procedural design for further examinations into abstract-concept formation and the purpose of the first experiment is to establish the pigeon's ability to acquire consistent high rates of accuracy in the *same/different* discrimination task with repeated successive contingency reversals.

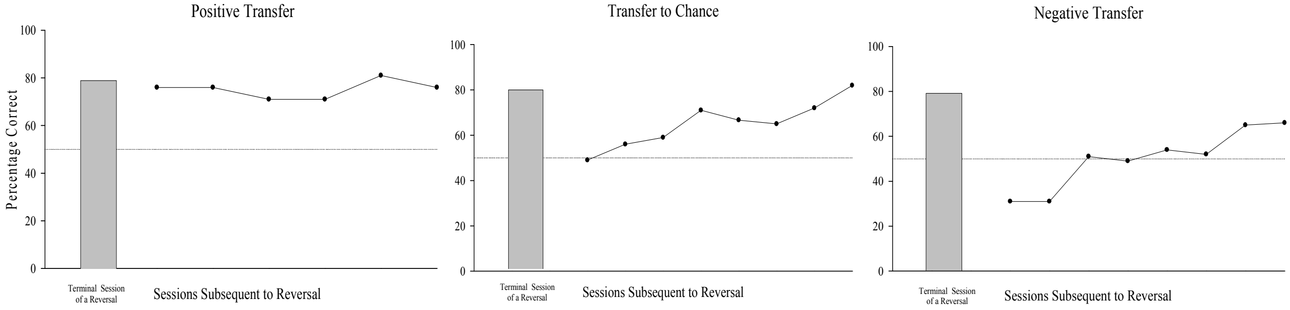
Figure 9



Caption: *Figure 9.* Individual subject Rho (probability of making a correct response) values for both contingencies 1+ (20 out of the 40 total slides) and 2+ (other 20 out of the 40 total slides) for the 1st 40 trials of a reversal session across successive reversals in Vaughan (1988).

The ability of non-human animal subjects to learn the *same/different* task with a large set-size and repeated contingency reversals has yet to be examined. The purpose of Experiment 1 is to assess same/different performance in a discrimination reversal design by examining the ability of pigeons to flexibly learn the reversal task with repeated reversals under conditions known to promote relational learning. Four pigeons were trained and tested in a simultaneous two-item *same/different* task. Under the first contingency, subjects were required to peck the lower of two pictures if the items were the same or a white box if the items were different. Once steady-state performance was reached, the contingency was reversed, such that the subject was required to peck the white box to indicate same and the lower picture to indicate different. Three possible outcomes, seen in figure 10, are feasible for a reversal.

Figure 10



Caption: *Figure 10.*Three hypothetical outcomes subsequent to a reversal. Grey bars represent the mean performance for a subject for the last three sessions of acquisition for a given contingency. The plots represent performance for a subject in the sessions subsequent to a reversal.

One possibility is positive transfer as shown in the left panel of figure 10. Subjects demonstrate no decrement in performance despite the reversal in correct peck locations for same and different trials implying that for any potential strategy the pigeons are using (e.g. relational rule use, *item-specific* learning), subjects demonstrate the cognitive capacity to detect a reversal of contingencies and shift responding accordingly. Another possibility, seen in the middle panel, is a transfer to chance performance (50%) in which a subjects responding is not predominately controlled by either contingency suggesting subjects cognitive capacity to detect a reversal of contingencies exists, however, they do not appear to shift responding accordingly . The final possible outcome is seen in the right panel. A negative transfer is designated as the possible outcome where subject's performance is well below chance and they are responding based on what had been previously learned suggesting subjects do not immediately demonstrate the cognitive capacity to detect a reversal of contingencies and shift responding accordingly.

In the current study, regardless of the type of transfer, once a subject reached the steady-state performance requirement, the contingency was again switched. Alternations between the contingencies were performed until 9 reversals were completed. Repeating reversals allows one to assess whether the form of transfer changes over reversals to characterize subjects' performance under the current experimental conditions. The form of transfer cannot be used alone to establish the use of relational or item-specific strategies in the task, therefore, an assessment of performance for trials containing novel stimuli was required to establish the type of rule use which was controlling behavior.

After the 9 reversals were completed, Experiment 2 commenced. Pigeons were tested on a reversed contingency containing novel-item trials within sessions containing trained-item trials. This test was conducted to ensure that choice behavior was still under control of relational rules.

Experiment 1

The purpose of Experiment 1 was to assess and characterize performance in a same/different task with reversals under conditions previously demonstrated to facilitate abstract-concept learning.

Method

Subjects

Four White Carneaux Pigeons with extensive experience in the *same/different* task (Schmikde, Katz, &Wright, 2010) served as subjects. All pigeons had previously shown full concept learning. They were maintained at 80-85% of their free feeding weight.

Apparatus

Pigeons were tested in two similar (35.9-cm wide x 45.7-cm deep x 51.4-cm high) custom wood test chambers. A fan (Dayton 5C115A, Niles, IL) located in the back wall of each chamber provided ventilation and white noise. Pecks to the computer monitor were detected by an infrared touch screen (17” Unitouch, Carroll Touch, Round Rock, TX). The touch screen was pressure fitted within a 40.6 x 32.1-cm cutout in the front panel that was centered 7.7 cm from the top of an operant chamber. A 28-V (No. 1829, Chicago Miniature, Hackensack, NJ) houselight was located in the center of the ceiling and was illuminated continuously throughout the procedure, except during a timeout. A custom food hopper containing mixed grain was accessed through an (5.1 x 5.7 cm) opening centered in the front panel 3.8 cm above the chamber floor. The hopper allowed 3-second (s) access to mixed grain to reinforce correct responses. A tone was presented as a paired reinforcer with the 3 s access to mixed grain using desktop speakers (Dell, Round rock, TX) located beneath the monitor.

Stimuli. Travel-slide color pictures were digitized with a Howtek Photomaster (No. 87RU, Hudson, NH) camera and a Truevision TARGA-16 processing card (Indianapolis, IN) in a 256 x 256 resolution. Stimuli were presented on a 40.3-cm color monitor (Eizo T550, Ishikawa, Japan; 800 x 600 pixel resolution). Stimulus displays consisted of two travel-slide color pictures (each 5.7 x 3.8 cm) and a white rectangle (2.5 x 2.4 cm) on a black background. The pictures were vertically aligned with a 1.28-cm gap between them. The top picture was centered 20.63 cm from the left edge and 18.75 cm from the top of the cutout in the front panel. The bottom of the white rectangle was horizontally aligned with the bottom of the lower picture with a 1.4-cm gap between them. The white rectangle will always occur on the right side of the lower picture. *Same* and *different* trials were constructed by a custom Microsoft Visual Basic program that pseudorandomly selected pictures from a 1,024-item set used during their previous exposure to the task. There was a total of 1,048,576 different displays (1,024 *same* and 1,047,552 *different*). The size of the display was 68.7° (vertical) and 72.9° (horizontal) as viewed from 6.5 cm (average beak length plus 3-cm distance from the screen).

Experimental control. Experimental events were controlled and recorded with custom software written in Visual Basic on a personal computer. A video card (ATI 3D Rage Pro AGP 2X, Ontario, Canada) controlled the monitor. A computer-controlled relay interface (Metabyte, Freemont, CA) operated the food hopper and houselight.

Procedure

Reacquisition training. Subjects were reintroduced to the *same/different* task under the same contingency of the initial experiment (Kelly et al., 2010), as they had several months without training or testing in the task. Retraining in the *same/different* task began with the presentation of the upper picture alone. Following a single peck to the upper picture, the lower picture and the white rectangle were simultaneously presented along with the upper picture. If the two pictures were the same, a peck to the lower picture was correct and was rewarded. If the two pictures were different, a peck to the white rectangle was correct and was rewarded. This contingency was labeled *contingency A* and was implemented on all even numbered successive reversals. After the choice response, the display was immediately extinguished. A correct choice resulted in the tone and reinforcement. An incorrect choice resulted in no reinforcement. A correct or incorrect choice was followed by a 15-second (s) inter-trial interval (ITI). Starting on the seventh session of the reacquisition phase, incorrect choices were also followed by a repetition of the incorrect trial, a correction procedure (CP). On correction trials, a darkened 15-s timeout preceded the ITI. An incorrect trial was repeated until it was resolved correctly. Accuracy was based on first-trial performance only. Performance on correction trials (although it was recorded) was not included in the analyses. Over the first 15 reacquisition sessions, the number of responses to the upper picture was gradually increased to 14 pecks (FR 14). This FR was selected based on previous unpublished findings (J. S. Katz, personal communication, November 15, 2009). Sessions consisted of 100 trials (50 *same*, 50 *different*). The sequence of *same* and *different* trials were randomly constructed and varied from day to day. The items used to construct the displays were selected with replacement from the 1024-item set. If a session was not completed within 2.5 hrs, then it was resumed the next day. Training continued until performance was 80% or better for three non-consecutive sessions, with a minimum of 20 sessions. There was no limit to the number of intervening sessions between the sessions in which subjects performed at 80% or better. Each pigeon was trained to criterion, and then reversal training began.

Reversal training phase. The session immediately following each subject reaching the performance criteria began the first reversal of contingencies in the *same/different* task or Reversal Phase 1. The first phase of the reversal was identical to the terminal sessions of the requisition phase except for the reversed contingencies. In Reversal Phase 1, if the two pictures were the same, a peck to the white rectangle was correct and was rewarded. If the two pictures were different, a peck to the lower picture was correct and was rewarded. This contingency was labeled *contingency B* and was implemented on all odd numbered successive reversals. Upon reaching a criterion of 40 sessions in Reversal Phase 1or 80% or greater for at least one session, a reversal back to the initial reacquisition phase *contingency A* (Reversal Phase 2) was implemented. Upon reaching criterion of 80% or greater for at least one session with a minimum of 20 sessions in Reversal Phase 2, a reversal back to the contingency from Reversal Phase 1 (*contingency B*) was implemented and subjects began Reversal Phase 3. Training continued until the 80% criterion was met again with a minimum of 8 training sessions. Subsequent repeated contingency reversals were implemented until the identical criteria of phase 3 (80% with a minimum of 8 sessions) was reached for each successive phase (4, 5, 6, 7, 8, 9). This progression can be seen with each reversal's corresponding specifications in table 1. The correction procedure was occasionally removed when learning appeared to asymptote prior to reaching criteria to see if this would help the pigeons reach criterion. An asymptote in learning was defined as 30 or more consecutive sessions where subjects performed above chance but below criterion (80%). Reversals of contingencies continued until the criterion was reached for Reversal Phase 9. The entire progression and details of Reacquisition and Reversal Training are summarized in Table 1.

Results

Acquisition

Initial reacquisition The subjects reached the 80% criterion in the two-item simultaneous S/D task in about 8 sessions (*M* = 825 trials, range = 800–900 trials). These findings, not surprisingly, reveal substantially fewer trials to acquisition at set-size 1,024 than with naïve birds (e.g., *M* = 7250 trials; Nakamura, Wright, Katz, Bodily, & Sturz 2009) because the current pigeons had previous training in the task.

Table 1

Sequence for Training

Phase	Contingency	Correction Procedure	Criterion*
Reacquisition	A	Yes	3 sessions ≥ 80% accuracy ≥ 20 Sessions
Reversal 1	B	Yes	≥ 40 Sessions
Reversal 2	A	Yes	≥ 20 Sessions
Reversal 3	B	Yes	≥ 8 Sessions
Reversal 4	A	Yes	≥ 8 Sessions
Reversal 5	B	Yes	≥ 8 Sessions
Reversal 6	A	Yes	≥ 8 Sessions
Reversal 7	B	Yes	≥ 8 Sessions
Reversal 8	A	Yes	≥ 8 Sessions
Reversal 9	B	Yes	≥ 8 Sessions

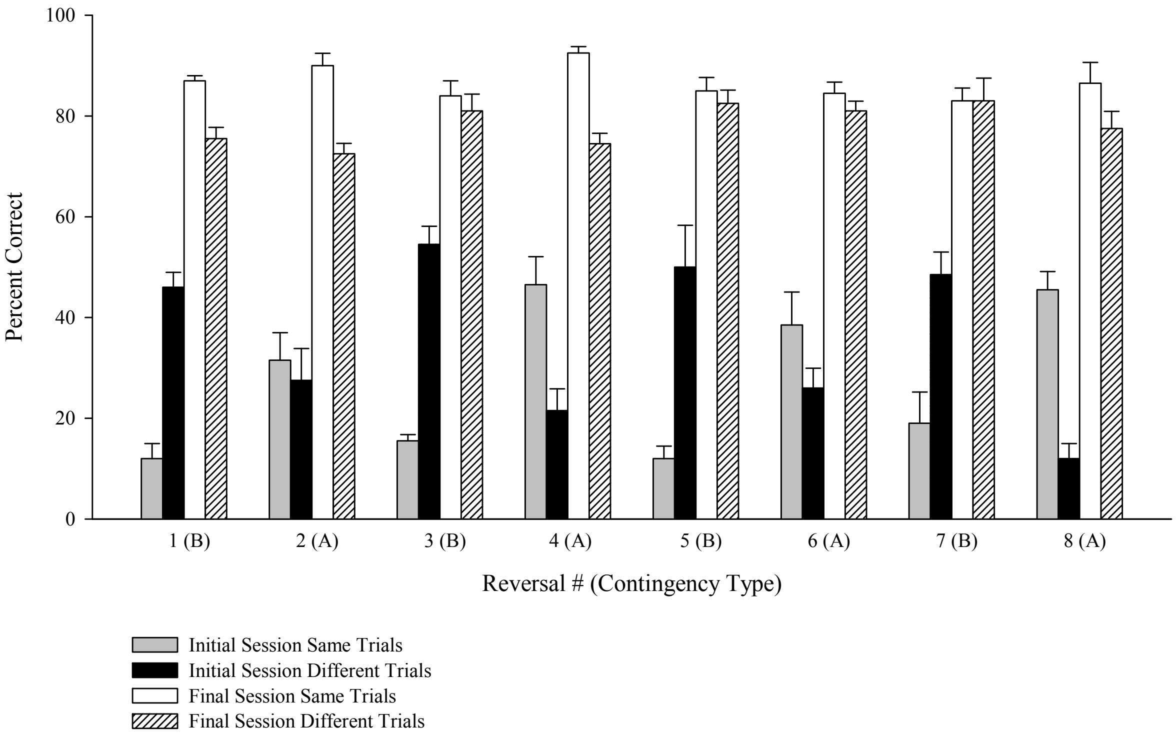
NOTE. * Each phase's criterion also requires at least 1 session ≥ 80% performance accuracy

Reversal training Figure 11 shows mean performance on the initial and last session of reversal training for the first eight successive reversals. Reversal 9 was left out of this analysis in order to provide an equal number of reversals to *contingency A* and *contingency B.* Figure 11 clearly demonstrates negative transfer, as performance for the initial sessions of both same (M =

27.56%) and different (M = 32.94%) trials was below chance. This result was confirmed by a single sample t-test (50%), *t* (31) = -20.866, *p* < .01. Furthermore, the relatively large negative *t* (-20.866) confirms that scores were well below chance performance. Mean percent correct for both same and different trials during initial session (31.66 %) and final session (82.06 %) was significantly different and stable across reversals. These results were confirmed by a three-way

Figure 11

Mean Performance on Initial and Final Session for Same and Different Trials

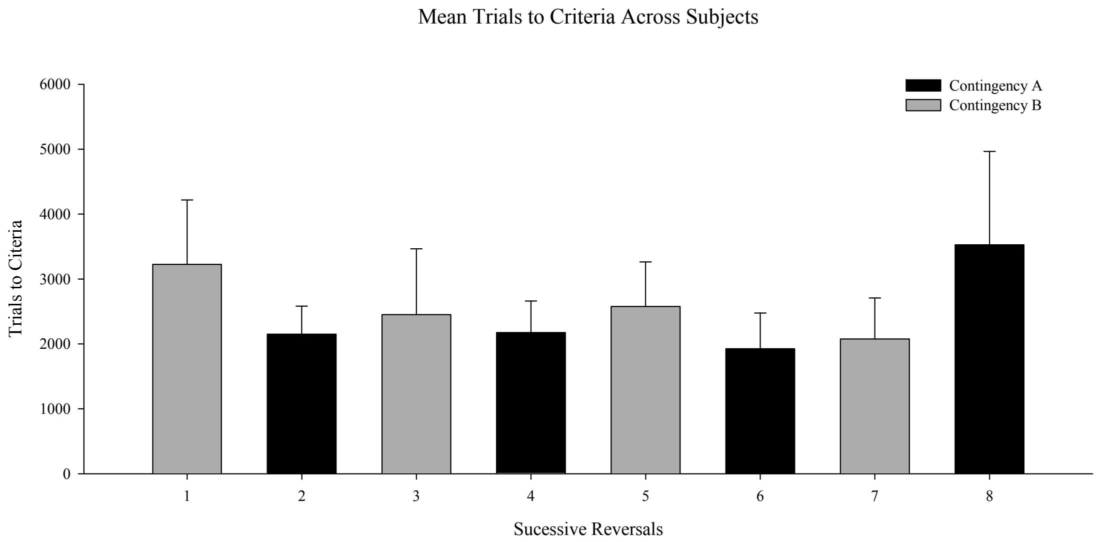


Caption: *Figure 11.* Mean percentage correct for initial and final session same and different trial performance averaged over the 4 Subjects sessions grouped by each reversal of contingencies. The Contingency Type for each successive reversal is denoted in parenthesis for each reversal. Error bars represent SEMs.

repeated measures analysis of variance (ANOVA) of Session Type (first, final) × Trial Type (same, different) × Successive Reversal (1, 2, 3, 4, 5, 6, 7, 8) on accuracy, yielding a significant main effect of Session Type, $F(1, 3) = 1523.966$, $p < .01$, no Successive Reversal effect, $F(7, 21) = 1.476$, $p = .229$, or interaction between Session Type and Successive Reversal $F(1, 3) = .486$, $p = .834$. A significant three-way interaction, $F(7, 21) = 11.863$, $p < .01$, reveals that that for initial sessions, subjects perform significantly different for same and different trials across reversals. However, for final sessions, subjects do not perform significantly different for same and different trials across reversals consistently. A significant interaction between Trial Type and Successive Reversal, $F(1, 3) = 9.350$, $p < .01$, reveals a significant difference between same and different trial performance which varies across reversals. Also seen in Figure 11, subjects appear to perform significantly different for Trial Type during initial sessions but not during final sessions. This result is confirmed by a significant interaction between Trial Type and Session Type, $F(1, 3) = 31.484$, $p < .05$. These interactions were due to the pigeons pecking the lower picture position which diminishes by the end of reversal training and suggests a potential default location response or picture preference which emerges during sessions immediately following a reversal of contingencies. Because the pigeons had previous training in the task with Contingency A, an important question about transfer for initial sessions was the effect of Contingency Type. Contingency Type (A, B) was not truly a nested factor in Successive Reversals (e.g., Reversal 1 was contingency B, Reversal 2 was Contingency A, …, Reversal 8 was Contingency A) and therefore could not be added as a factor in the repeated measures ANOVA. Since the omnibus *F* was significant, determining whether session performance varied based on Contingency Type was critical. A planned contrast to directly compare Contingency Type for Initial session performance was conducted and confirmed that the effect was non-significant, *F*(1, 3) = .663, p = .475. This finding suggests that the negative transfer seen in figure 11 was not differentially affected by prior experience and was equal for both Contingency Types.

Figure 12 shows the mean number of trials to reach 80% performance criteria for Contingency A and Contingency B averaged across subjects for each successive reversal. Rates of acquisition were stable, as revealed by a one-way repeated measures analysis of variance (ANOVA) of Reversal (1, 2, 3, 4, 5, 6, 7, 8), yielding a non-significant main effect of Reversal, *F*(7, 21)= 1.61, p= .187. The pigeons previous training in the task did not have a differential effect on rate of acquisition for either Contingency type A or B, as confirmed by planned contrast, *F*(1, 3) = .263, *p* = .643. Overall, with a relatively large (1024) training set-size, the repeated acquisition procedure in reversal training is characterized by stable performance with a

Figure 12

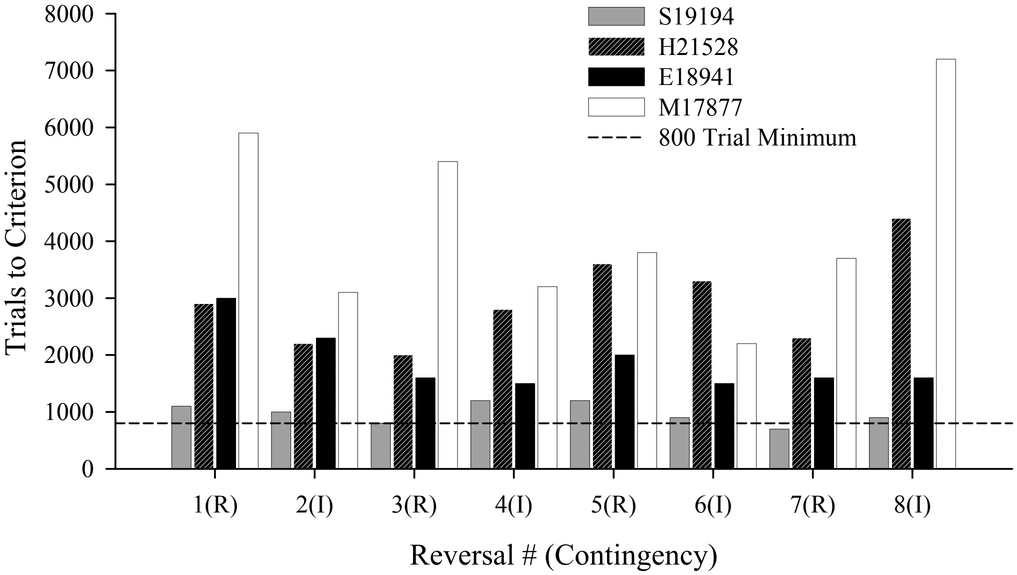


Caption: *Figure 12.* Mean number of trials until 80% performance criterion component was reached averaged over the 4 Subjects for each reversal of contingencies. Error bars represent SEMs.

large amount of between subject variability *F*(1, 3) = 11.890, *p* <.05. This between subject variability can be seen in figure 13

In summary, Experiment 1 found that subjects flexibly learned the *same/different* task with reversals under conditions known to promote abstract-concept learning. This performance was characterized by consistent negative transfer of performance across successive reversals. Acquisition did not appear to become more rapid for each reversal throughout training in the task. Furthermore, each subject began the successive reversals with a relatively large difference in performance depending on correct response location of the trial. This discrepancy was greatly reduced for sessions in which criterion was reached.

Figure 13



Caption: *Figure 13.* Individual subjects' number of trials until 80% performance criterion component was reached for each reversal of contingencies. The Contingency Type for each successive reversal is denoted in parenthesis for each reversal.

Experiment 2

The purpose of Experiment 2 was to determine if relational rules were still controlling subjects responding with the added manipulation of contingency reversals to a simultaneous two-item *same/different* task. It is unknown whether pigeons would have switched from a relational to an item-specific strategy with stimulus reversals. Transfer testing with novel stimuli is the gold standard for relational learning, and was utilized to ensure the pigeons were responding based on relational properties of the stimuli. Hence, in Experiment 2, pigeons were tested with novel stimuli. A comparison of performance on trained (baseline) stimuli trials to novel (transfer) stimuli trials was tested during a reversal to Contingency B. The results will indicate whether subjects were responding to novel stimuli based on their relational properties

Method

Subjects & Apparatus

Two pigeons from experiment 1 served as subjects and the same apparatus was used.

Procedure

Training To acclimate subjects into conditions which were necessary for transfer testing, pigeons were exposed to the reversal task with the removal of the correction procedure (CP). A correction procedure could provide additional exposure to novel stimuli during transfer testing which may change how the subjects discriminate the novel items.

Experiment 1 was comprised of Reversal Phases 1 through 9. Experiment 2 began with the Reversal Phase 10, training was identical to the previous experiment except the correction procedure was removed after the initial 5 sessions of this phase. Reversal Phases 11 and 12 were identical to Reversal Phase 10 except they were programmed with an alternating CP. That is, for one session the CP was implanted and then the next session it was not. Alternation was used to ensure that the subjects would show some acquisition at the start of a reversal in preparation for transfer testing. Progression and details of transfer testing are summarized in Table 2.

Reversal transfer testing. Immediately after the 12th reversal, transfer testing to novel stimuli began with the first session of the 13th reversal. Reversal transfer testing was identical to the 12th reversal except for the insertion of novel stimuli in every other session (e.g. transfer sessions) in which the correction procedure was not used. Beyond the contingency reversal, transfer tests were conducted identically to Katz & Wright (2006). The novel stimuli trials were pseudorandomly inserted into sessions after the 7th trial of the 100 trial sessions. Transfer stimuli were selected randomly from the database with 5 *same* trials and 5 *different* trials for each transfer session (e.g., 15 novel stimuli for each transfer session). Correct and incorrect responses for transfer trials were reinforced just like baseline trials.

Table 2

Sequence for Transfer Testing

Phase	Contingency	Correction Procedure	Criterion*
Reversal 10	A	No	≥ 8 Sessions
Reversal 11	B	No	≥ 8 Sessions
Reversal 12	A	Alternating	≥ 8 Sessions
Transfer Test	B	Alternating	N/A

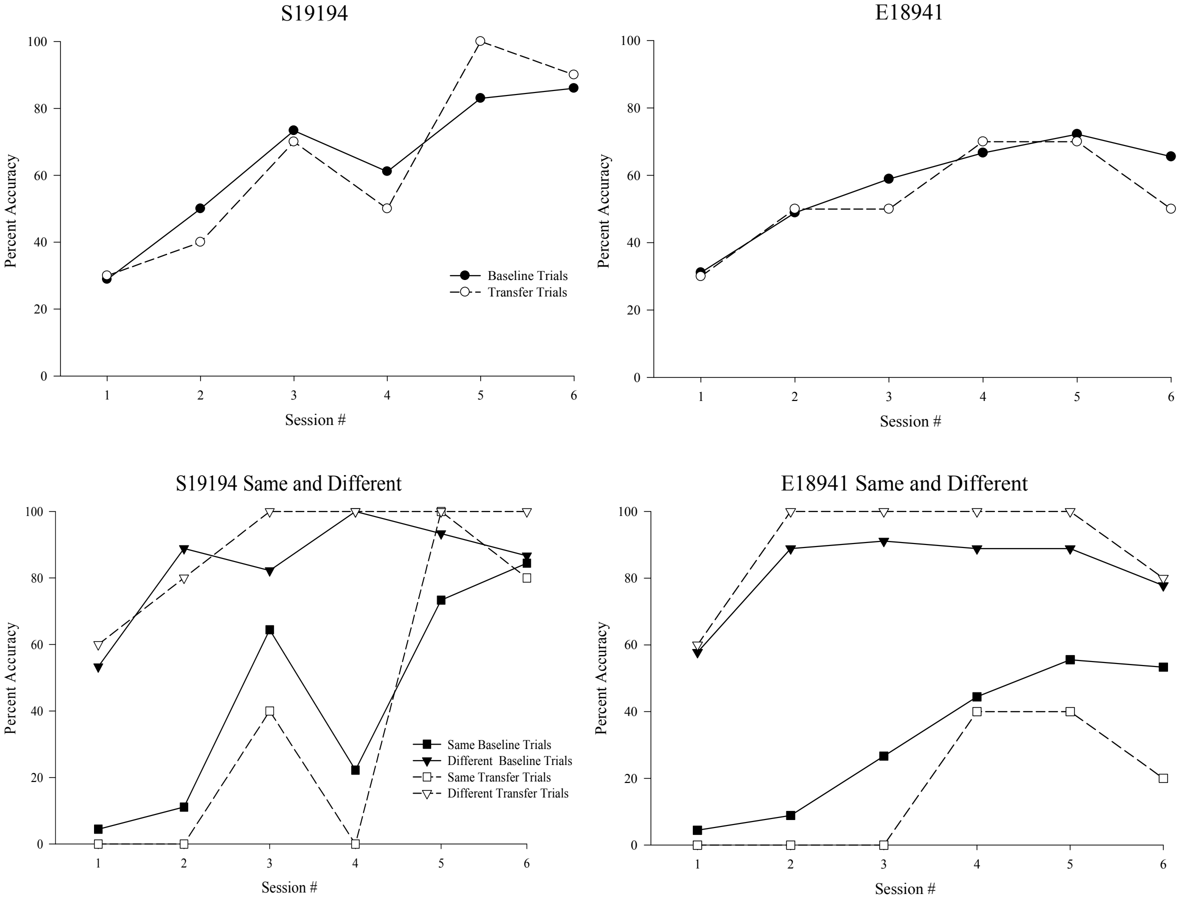
NOTE. * Each phase's criterion also requires at least 1 session ≥ 80% performance accuracy

Results

Novel Transfer

Figure 14 shows percent correct for both subjects across the 6 transfer testing sessions for baseline and transfer trials separated for *same* and *different* trials. Test-Trial Type (baseline, transfer) performance appears similar for same and different trials for both subjects. Differences between accuracy for Test-Trial Type did not appear to vary across Session (1, 2, 3, 4, 5, 6) indicating that baseline and transfer performance were equivalent over all of the test sessions. The data seen in Figure 14 suggests a change in significant difference for s*ame/different* Trial-Type across Session for both subjects. Consistent for both Test-Trial Types,

Figure 14



S19194

E18941

S19194 Same and Different

E18941 Same and Different

Caption: *Figure 14* . Performance for baseline and transfer performance by two subjects for each session subsequent to a reversal to Contingency B is shown in the top panel. *Same* trial and *Different* trial performance by subjects for each session subsequent to a reversal to Contingency B is shown in the bottom panel.

different trial performance appears to be greater than *same* trial performance for initial sessions but to a lesser extent for the final sessions. This finding, which is consistent with training for both contingencies, indicates an initial bias to select the lower picture position which diminishes in the sessions subsequent to a reversal for both baseline and transfer trials.

Performance for each *Same/different* Trial-Type did not appear to differ based on Test-trial type, indicating that there was no discrepancy for same and different trial performance based on whether subjects were performing a transfer or baseline trial. There was an apparent effect for Session, and for Trial Type, indicating that, overall, subjects' performance changes across sessions and that they perform differently on *same* and *different* trials.

In summary, given the fact that only two subjects have completed Experiment 2, the statistical analysis appropriate for our total *n*=4 was not used. Upon the remaining subjects completion of Experiment 2,a three-way repeated measures ANOVA of Session (1, 2, 3, 4, 5, 6) × *Same/different* Trial Type (same, different) × Test-Trial Type (baseline, transfer) on percent correct will be used to assess these factors and their interactions.

General Discussion

In Experiment 1, subjects flexibly learned the *same/different* task with reversals. Performance was characterized by negative transfer across successive reversals and acquisition rates which appeared stable throughout training in the task. Performance during each reversal began with a large difference in accuracy for *same* and *different* trials. This difference disappeared once the performance criterion was obtained at the end of each reversal training period. In Experiment 2, the subjects performed equivalent on baseline and transfer trials. In both baseline and transfer trials, subjects accuracies appeared different for *same* and *different* trials for the initial session but this difference appears to have be reduced as a function of training. Given the full transfer to novel stimuli for subjects when trained on the 1024-item set, it can be concluded, thus far (*n*=2), that subjects are solving the task based on the relational properties of the stimuli with the added manipulation of a reversal procedure to the traditional *same/different* task.

Taken together the results from Experiment 1 and 2 suggest that subjects were using relational rules to reach high levels of accuracy for the task, although a lower picture location preference is likely controlling initial performance at the start of each reversal. Furthermore, with the establishment of relational rule used in the task via the transfer test, all other features of the subjects' performance during training can be presumed to pertain to acquisition of control by relational properties of the stimulus configurations. Regardless of the contingency, performance under conditions demonstrated to facilitate relational rule use was characterized by negative transfer with an initial preference or bias to peck the lower picture stimulus, which declined through acquisition. Subjects did not show evidence of reductions in negative transfer or increased speed of acquisition when relational rules were used to solve the task.

Other studies of reversal learning (e.g., Harlow, 1949; Vaughan, 1988) showed variable reductions in negative transfer. Harlow (1949) began to record accuracies above chance sometime between the 1st and 28th reversal. Vaughan (1988) also noted such decreases in negative transfer. The current study, in some sense, reveals consistent findings to that of Vaughan and Harlow in that negative transfer is stable across reversals for the first 8 successive reversals of training. This analysis provides quantitative features shared during initial successive reversals for each of the studies suggesting that, with only eight successive reversals, subjects were not demonstrating variance in negative transfer as a function of successive reversals. Furthermore, it is possible that in an abstract-concept learning task with reversals, subjects require differential amounts of reversal training, than in the prior studies which utilize *item-specific* strategies. Additional experimentation could be utilized to assess the possibility that mean acquisitions and negative transfer would vary with extensive training in an abstract-concept learning task; however, transfer testing in the task provides an assessment of the strategy utilized by subjects. By establishing the strategy utilized, performance for less extensive training may be examined for aspects which are discussed in the current study (e.g., acquisition, form of transfer)

In addition to Katz and Wright(2006), Wright and Katz (2006), Bodily et al. (2008), Nakamura et al. (2009), Schmidtke et al. (2010), and Katz et al. (2010), this study provides further evidence from an alternative approach that pigeons can solve the *same/different* task relationally if trained with a relatively large stimulus set. This relational strategy is established via the transfer test sessions in which subjects demonstrated equivalent performance for baseline and transfer trials through acquisition in the sessions subsequent to a reversal of contingenies. The current study can serve to provide a comparison for future examination of the *same/different* task with reversals under conditions known to facilitate *item-specific* learning (i.e. small training set-size). Based on the findings of Katz and Wright (2006), this relatively small training set-size should promote an item-specific strategy as would be evidenced by quantitative differences in transfer trial performance and baseline trial performance in the sessions subsequent to a reversal of contingencies. Performance in such a task would reveal an acquisition consistent to transfer for that of trained stimulus trials, however, because subjects are using rote memorization of the limited total number of stimulus configurations, performance for novel-item trials should remain at chance (50%). The topography of performance in training should additionally appear distinct to that of the current study. Based on the far fewer number of configurations to memorize with a small training set-size, subjects should demonstrate more rapid rates of acquisitions for each reversal. Furthermore, those rates should likely increase as evidenced by a fewer number of trials to reach criterion for each successive reversal. The form of transfer should also demonstrate quantitative differences to that of the current study given the vast reduction in number of items used in training. Although logically these differences in performance should emerge given the evidence on the effects of relative training set-size in the *same/different* task, only a test for transfer of performance to that of novel-item trials can establish the strategy utilized by subjects in the task. The quantitative differences in aspect of performance through training which were examined in the current study (e.g., acquisition, form of transfer) could provide further alterative assessments for the effects of relative training set-size in abstract-concept learning tasks and uncover much about the mechanisms meditating the learning of the task.

Through a better understanding of conditions which influence the use of item-specific and relational strategies, research and applications on conditions which mediate either strategy could prove useful in a variety of areas. Regardless of species, one could utilize this understanding as a guide for facilitating conditions in which either strategy is appropriate. Because the task is nonverbal, it can be utilized in a variety of species. For example, further comparative work on the effects of pharmaceuticals or environmental toxicants on relational and item-specific learning could provide assessments of selective disruption of these cognitive functions. Such analysis could enhance the understanding of specific structures, pathways and neurotransmitters involved in either strategy as well as increase the knowledge of drug-effects for specific or classes of pharmaceuticals.

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