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An investigation of the concept of cube in the pigeon

Stevens, Ronald, Ph.D.

City University of New York, 1992

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AN INVESTIGATION OF THE CONCEPT OF CUBE IN THE PIGEON

by

RONALD STEVENS

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

1992

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.

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Chair of Examining Committee

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Date

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Abstract

AN INVESTIGATION OF THE CONCEPT OF CUBE IN THE PIGEON

by

Ronald Stevens

Adviser: Professor Eric G. Heinemann

The categorization process was investigated using computer generated projections of two three dimensional objects, a cube and a distorted cube. Sixteen pigeons were randomly assigned to one of four groups. Each group was presented with different sets of training stimuli comprised of Cube-Distortion pairs. These pairs were created by rotating the individual Cube and Distortion stimuli in 10 degree increments, simultaneously about the X, Y, and Z axes. Group 1 was trained using one pair, Group 2 was trained using two pairs, Group 3 was trained using four pairs, and Group 4 was trained using eight pairs. Using a choice procedure, the pigeons were trained to discriminate between the Cube and Distortion stimuli.

Generalization tests were performed to determine whether the pigeons had successfully learned to categorized both the Cube and Distortion stimuli. In addition, the underlying nature of the categorization process was investigated by comparing the generalization gradients, produced by the pigeons, to simulated generalization gradients, derived from the Heinemann and Chase (1990) model.

Results show that the pigeons categorize both Cubes and Distortion significantly better than chance. The results were also consistent with the simulations produced by the model.

Acknowledgements

First, I would like to thank my parents for giving me the support and confidence which enabled me to begin this undertaking; without them none of this would have been possible. Second, I would like to thank my wife, Gloria, for believing in me, and giving me the strength to continue on. Even when I am impossible to live with, she is there for me. She was the calming influence in the latter portion of this endeavor; she alone is responsible for encouraging me to continue on, when felonious assault and an inescapable prison sentence seemed a preferable alternative. And third, I especially would like to thank the pigeons for the hundreds of hours they spent providing data for this experiment.

Finally, I would like to thank the members of my committee. I am grateful to my outside readers, Dr. Chodorov and Dr. Lee, for their time, energy, and understanding in facilitating the completion of this thesis. To Dr. Chase and Dr. Sclafani, who served as members of my thesis committee, your guidance and comments were essential in shaping this final product. And to my mentor, Dr. Eric Heinemann; thank you for the years of advice and guidance, and the opportunity to learn and experience what Experimental Psychology is all about.

Table of Contents

List of Tables

List of Figures

INTRODUCTION

The experimental procedures used in the research that will be described require pigeons to categorize unusual stimuli. In general subjects are said to categorize if they consistently make a common response to a set of diverse stimuli.

Previous researchers in this area have sometimes distinguished between natural categories and man-made categories. In principle, the difference between natural and man-made categories is that the stimuli that compose the two types of categories are either of natural origin or man-made. Natural categories are groupings which are composed of objects that are found in nature (e.g. trees, fish, lakes). Similarly, manmade categories are groupings that are composed of objects that are created by humans (e.g. cube projections, cartoon characters).

There is evidence (Herrnstein, 1964, Cerella, 1980) that categorization of stimuli from natural categories (e.g. photographs that include images of humans vs. photographs that do not) is learned more easily than categorization of stimuli from man-made categories (e.g. line drawings of cartoon characters). However, in the work of Herrnstein the natural man-made distinction is confounded with the complexity and dimensionality of the stimuli. Thus the stimuli from natural categories are usually color photographs of natural scenes; however, the man-made stimuli are typically line drawings in black and white. And there is evidence, Herrnstein (1964), to indicate that black and white slides will cause a slight deterioration in performance when compared to the same discrimination using color slides.

In 1964 Herrnstein and Loveland published an article entitles "Complex Visual Concepts in the Pigeon" which showed that pigeons could learn a complex discrimination quickly, and almost to the point of perfection. In this experiment the discriminative stimuli were a set of 1200 colored slides of scenes with or without humans.

Herrnstein investigated the ability of pigeons to categorize pictures of other items as well (e.g. trees and water, Herrnstein, Loveland, and Cable, 1976). The procedure was similar to that used in the first experiment, except that 800 slides were reserved, and used to test the ability of the pigeons to conceptualize. Results indicated that the pigeons responded more to the positive slides (trees, people, or water), on average, than they did to the negative slides. By using a variety of techniques, Herrnstein showed that all groups classified new instances of the categories, at better than chance levels, as belonging to the categories under examination.

He continued his exploration of the properties of the categorization process, by testing to see if a category is as good a negative stimulus as it is a positive stimulus (Herrnstein, 1979). Slides of trees were used as the negative stimuli, and non-trees were the positive stimuli. Seven of the eight generalization tests were significant, with the pigeons responding appropriately to the stimuli.

He further examined the categorization process to determine whether unfamiliar objects (fish) could be categorized as easily as the more familiar objects (Herrnstein, and De Villiers, 1980). Results indicated that when pigeons were taught to discriminate between fish and non-fish slides, the discrimination was acquired rapidly as it was with previous discriminations.

All of Herrnstein's stimuli were pictures of natural objects that were divided into positive and negative instances of a category by human discretion, usually by the photographer himself. These experiments showed that pigeons could rapidly acquire the discrimination and could identify new exemplars of the categories during a generalization test.

It is not clear what Herrnstein means by the term "concept". On an empirical, operational level, there is no difficulty; "concept" is simply equivalent to "category."

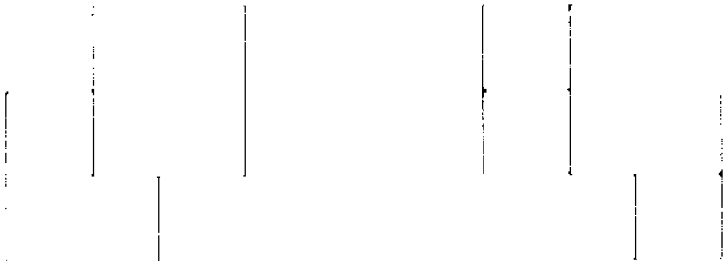
Some other investigators (e.g. Blough, 1984, Cerella, 1977) have concerned themselves with the question of whether the pigeons can detect the three dimensional aspects of objects pictured in two dimensions.

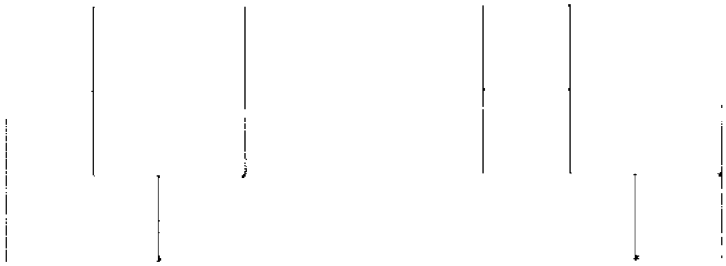
Blough (1984) addresses the question "Do pigeons see the two dimensional pictures and projections that we show them as representing three dimensional objects?", by investigating the "object superiority effect".

An object superiority effect occurs, when forms that can be seen by humans as three dimensional objects are discriminated from each other faster than forms that can only be seen as two dimensional patterns. The subjects are presented with different pairs of stimuli. These stimuli differ in a common characteristic (e.g. their orientation of a single line). The sets of stimuli differ; however, in that one set can be perceived as a two dimensional projection of a three dimensional object, while the other set can only be perceived as a two dimensional pattern. The appearance of an object superiority effect in pigeons would lend credence to the assumption that pigeons have the ability to extract the three dimensional properties from two dimensional projections. Using stimuli that had produced this effect in humans (Weisstein, and Harris, 1974), (See Figure 1) Blough found that it was difficult to train the pigeons. The pigeons hardly showed significant learning, and only one pigeon showed a significant difference between the two sets of stimuli. "This outcome suggests a failure to see the 'simple' forms in depth ... (p. 9)" (Blough, 1984).

Figure 1

Object Superiority Effect Stimuli Similar to those used by Blough (1984).





To date, one of the most thorough and systematic investigations into the categorization process in pigeons has been done by Cerella.

Cerella (1977) attempted to teach a pair of pigeons the category of a cube by training them on a single orientation of a cube. They were presented with a square as the positive stimulus and random quadrilaterals as the negative stimuli. Within several months the discrimination ratio for these stimuli rose to over 0.75. As a test to see if the pigeons had formed the category of "cube", they were then presented with random polar projections of a cube as the positive stimuli. The vertices of the random projections of a cube were varied, a small random amount, to produce the negative (distorted) stimuli. These stimuli no longer had the defining characteristics of "cubeness" (angular and line relationships) but they still had the same number and type of elements (number of lines, number of vertices, and number of surfaces) as the original cubes.

During the entire test phase, which lasted for 150 sessions, the discrimination ratio of the pigeons dropped to chance. Upon return to the original stimuli, the discrimination ratio returned to it's previous level.

Expanding on this experiment, Cerella (1977) trained four pigeons to discriminate a cube that was rotated 46 degrees about the X, Y, and Z axes, so that one corner pointed at the viewer, from the random quadralterals, with the purpose of adding more and more positive stimuli to their training set. The positive training set consisted of all the possible projections that could be produced by rotating a cube through 21 discrete magnitudes of rotation. The number of rotations increased so that the first set had one cube, the second set eight (2x2x2), the third 64 (4x4x4), and so on, to the twelfth set that had (21x21x21) 9261 cubes. Sets were introduced in sequence until a discrimination ratio of 0.70, over three consecutive sessions was reached. At this point the next set was introduced. If the criterion was not met within 30 sessions, the pigeon was removed from the experiment. All of the pigeons learned the first seven sets (1728 stimuli), and all pigeons failed to learn the entire 12 sets, thus indicating that the pigeons did not treat the object as a single three dimensional object. Had the pigeons treated the stimuli as a single three dimensional object, it was expected that generalization would be shown by the pigeons correctly categorizing the additional stimuli.

Cerella then created sets of abstract stimuli by rotating each line segment of the cube and quadrilateral projections ninety degrees about its midpoint. In this way, these stimuli contained the same amount of structural information, i.e. number of lines, as the original stimuli. Using these sets of abstract stimuli, Cerella repeated his experiment and obtained the same pattern of learning that he obtained for the cube stimuli. He thereby added evidence for the contention that pigeons don't sense the three dimensionality of the cubes, and that abstract patterns and cubes do not differ in their complexity for pigeons.

Similar results were found with cartoon drawings (Cerella, 1980). Pigeons were trained to discriminate pictures of Charlie Brown from other characters of the Peanuts cartoon series. The pigeons found the discrimination difficult to learn, but once learned, they would recognize Charlie Brown even if his body was rearranged and turned upside down. The pigeons seem to have treated the figures as if they were a set of two dimensional lines, that could be rearranged at will.

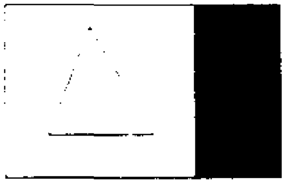
Using geometric forms, Cerella (1980) first trained pigeons to discriminate triangles from other figures (stars, circles and diamonds) on a ½ black ½ white field. By shifting the triangle on the field, he created obstructed triangles. Partial triangles, of the same degree as the obstructions, were also tested for generalization (See Figure 2).

Results showed that partial triangles elicited greater responding than obstructed triangles. Once again, pigeons responded as if they were only aware of the two dimensional characteristics of the stimuli since the obstructed triangles retain more of the Gestalt of the triangular form for humans. The truncated forms, however, match the original triangles better in terms of their location. The obstructed triangles were made by shifting the image of the triangle to the right, so that the image seemed to be blocked by an opaque screen.

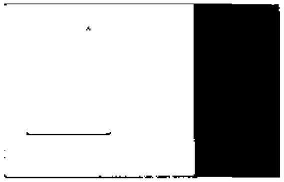
In order to investigate the effects of transformations further, Cerella (1984) split the types of transformations applied to the stimuli into dilations, shifts, X axis rotations, Y axis rotations, and Z axis rotations.

Figure 2

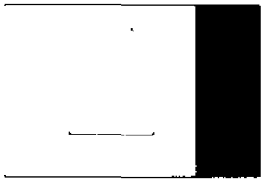
Examples of Triangle Stimuli Similar to those used by Cerella (1980).



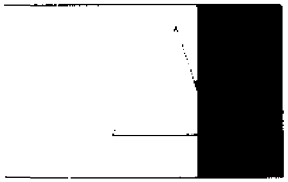
Complete Triangle



Partial Triangle



Partial Triangle



Obstructed Triangle

Cerella progressed onto smaller and more specific transformations of objects. He investigated the effects of small X, Y, or Z rotations, expansions and contractions, and shifts on recognition of chevrons and trapezoids. Using the technique of establishing a positive-negative discrimination between a figure and randomly generated distortions of that figure, he then tested with novel stimuli (translations). Five magnitudes of each type of translation (rotation, size or shift) were employed in order to present increasing amounts of distortions.

Results indicate that small shifts in location have little effect on the pigeons' discrimination of the projections. Expansions and contractions have a slight effect on the discriminability of the projections. Rotations, however, cause a major disturbance in the recognition of the forms. First magnitude rotations cause a drop in the confusion ratios (the response rate to the transformation divided by the response to the untransformed prototype) to approximately .90. And by the second magnitude of the rotations, the pigeons' confusions ratios dropped to .50. By the final magnitude of the distortions, the confusion ratios for all rotations are below .10.

Today there is little argument that pigeons can correctly categorize by identifying stimuli as belonging to one group or another. The question is not whether pigeons form concepts, but what is the underlying mechanism of categorization.

One such mechanism has been suggested by Heinemann and his colleagues. The present research is based on a model of pattern recognition in pigeons developed by Heinemann and Chase (1990).

According to Heinemann and Chase, during the initial stages of training, during the presolution period (PSP), the pigeon simply detects the statistical relationships between the discriminative stimuli, its own behaviors and its associated stimuli and feedback, and the outcomes that follow these behaviors. During this stage of learning, nothing is actually learned about the training stimuli. At this point, the pigeon is searching for the "sensory channels" that carry information relevant to the particular situation. Once the relevant sensory channels have been identified, learning about the relationships between the information arriving over these channels and reward-producing behaviors may begin. During the learning phases that follow the PSP, the only sensory stimuli that are stored in long term memory (LTM), are those that have been shown to be relevant during the PSP.

Visual stimuli are internally represented by the myriad of visual sensations that are distributed continuously across the visual field. As a convenient way of dealing with sampling this field of sensations, the computer-vision practice of treating the visual field as a set of small cells, called pixels, is employed. In this way, stimuli can be represented in memory by the X-Y coordinates of the pixels, along with information about the brightness, hue, and saturation of each pixel that constitutes the figures.

During the presolution period, each pixel in the visual field is undergoing its own presolution period. Therefore, only those pixels that have been shown during the PSP to be relevant to the outcome of the behavior contribute to the memory records. Only information arriving over these channels is stored in LTM. Only these pixels contribute to the decisions that the pigeons make.

Heinemann and Chase characterize the pigeon's LTM as limited in capacity, and divided into discrete memory locations, each holding a record. Beginning at the end of the PSP, and continuing throughout the course of learning, information experienced on each trial is stored in one of the memory locations. While the number of memory locations is limited, each particular location is not limited with respect to the type of information that can be stored in it. For a given trial, a memory record may contain the sensory information concerning the discriminative stimuli of the experiment. The behaviors of the pigeon, such as responses directed at the stimuli, and preparatory responses, will also be stored in the record, along with information regarding the consequences of the pigeon's reaction, such as the presentation of reward, and the sensations associated with it's ingestion. After sufficient learning has occurred, the LTM will be filled with records, acquired during the training stage, containing information that is predictive of the outcomes of behavior. One further characteristic of the LTM is that, while a stimulus resides in LTM, Gaussian noise is added to the values of the vertical and horizontal coordinates of each pixel as well as its non-spatial dimensions.

The process by which the pigeons categorize training or generalization stimuli is as follows. When a stimulus is presented to the pigeon, the current input is compared to a small, randomly selected, sample of records of positive stimuli drawn from memory. The sensory perceptions of the memory stimuli are considered to fluctuate rapidly over time. For each pixel on the memory record, this fluctuation can be described as a bivariate truncated normal distribution whose mean is the value of the sensory effect experienced when the record was originally retrieved. The input is compared to each memory record in the retrieved sample, and differences in probability densities associated with the various remembered responses are computed for each input/memory comparison. The densities are then summed for each response, and the response with the largest total probability density is selected as the response to be produced. The current input, the response made to it, and the subsequent result will then be randomly placed in one of the locations of the LTM.

One further requirement of the Heinemann and Chase model is that the pigeons must possess a rather large memory in which to store records. Current evidence shows that they do have the capacity to memorize large numbers of stimuli. Vaughan and Greene (1984), using a rate procedure, trained pigeons to rote-memorize 320 slides of various scenes. They performed numerous tests to support the conclusion that the birds had actually memorized the individual stimuli, and that some artifact wasn't causing them to perform well. Evidence showed that the pigeons actually memorized the slides. Vaughan and Greene stopped the experiment at 320 slides.

In a similar experiment, using a rote learning procedure in which the pigeons were required to peck several times at a picture, and then choose either one of two side keys, Heinemann, Stevens, Ionescu, and Neiderbach (in preparation) were able to train pigeons to recognize 640 slides. Scenes taken at varied locations, half with and half without people, were randomly assigned to either the left or the right side key. By the end of the experiment, the pigeons were performing at 85% correct on the 640 slides.

These experiments demonstrate that pigeons do have the capability to memorize hundreds of slides, and have the ability to memorize enough stimuli to be compatible with the memory requirements of Heinemann and Chase's model.

The model has successfully simulated results from a variety of paradigms and discrimination tasks; probability learning, fixed ratio schedules, retroactive interference, and letter recognition.

According to the assumptions of the Heinemann and Chase model, "concept formation" is defined in terms of stimulus generalization. If one assumes that only simple stimulus generalization is occurring, a peaked generalization gradient should occur for each training stimulus. The more training stimuli there are, the more likely each generalization gradient will overlap with another. Given a sufficient number of training stimuli, generalization testing will yield a flat generalization gradient. Therefore, the appearance of a concept during testing would be evidenced by a flat generalization gradient for new instances across the continuum being varied (i.e. Luminance, displacement). This gradient would be the result of an overlap of the generalization gradients produced by the training stimuli. If enough training stimuli were presented to cover the entire continuum of instances, new instances would be correctly identified due to generalization from old stimuli.

The purpose of the present experiment is to investigate these predictions by presenting various projections of three dimensional objects as stimuli. A regular three dimensional object (cube) is used as well as an irregular distorted shape. Rotations of equal degrees about the X, Y, and Z axes enable the pigeons to be presented with different projections of the shapes. Using these objects, one would expect to see the effect of the number of training stimuli on generalization gradients.

Since the rotations for both the cube and distorted stimuli are at regular and equal intervals, it is expected that by using a continuum of rotation, generalization testing will yield generalization gradients about each training stimulus. A cube-distortion training set consisting of one cube and one distortion should exhibit a generalization gradient about both the cube and the distortion stimulus, while a cube-distortion training set consisting of two cubes and two distortions should exhibit a generalization gradient about each of the four training stimuli. It is hypothesized that all groups should exhibit these generalization gradients about their training stimuli, and that a flattening of generalization gradients should be observed as the training sets become larger.

The underlying nature of the categorization process will also be investigated by comparing the generalization gradients, produced by the pigeons, to simulated generalization gradients, derived from the Heinemann and Chase model.

The expected generalization gradients are based on the assumption that the underlying continuum for generalization is based on rotation about the X-Y-Z axes. However, while intuitively this should be the situation, these outcomes are not necessarily predicted by the Heinemann and Chase model. There are no parameters in the model for, nor does the model assume, any continuum for generalization. Therefore, it is expected that the simulated generalization gradient data (proportion cube response for each stimulus) should correlate with actual generalization gradients data. The magnitude of the correlations are expected to be no greater than the correlations between the individual pigeons, within each groups.

METHOD

Subjects

The subjects were 16 experimentally naive white Carneaux pigeons. They were maintained at 80 percent of their free feeding weight throughout the experiment.

Apparatus

The pigeons worked in a standard LVE operant chamber (30 cm by 33 cm x 36 cm), the front panel of which was modified to accommodate a small (7.5 cm by 5.5 cm) black and white Sony monitor (Model PVM-400(S)) positioned 1 cm behind a clear plexiglass 8 cm^2 display key. Five cm to either side were round response keys (2.5 cm in diameter). In addition, a clear piece of plexiglass was placed in front of the display key with a round hole measuring 4 cm in diameter, in order to limit the pigeons pecks to the central region of the display key. A standard grain feeder was mounted 7 cm below the center key. A Tandy 1000 computer controlled all aspects of the experiment: presentation of stimuli, reinforcement, and recording of responses. Interfacing of the computer to the operant chamber was accomplished via an Alpha products A-Bus (Model AR-133), Digital

Input Card (Model IN-141) and a Relay card (Model RE-140).

The stimuli were 69 white dot matrix figures on a dark background, displayed within an area approximately .5 cm wide and .5 cm high. The forms were positioned at the center of the display key.

Stimuli

The forms were generated by rotating an imaginary wire cube or distorted cube in 10 degree increments simultaneously about the X, Y, and Z axes. Cube stimuli were produced by rotating the wire cube from it's original position (position zero, in which one side faced the subject so that the cube appeared like a two dimensional square). This technique produces 36 orthographic projections of the cube, 33 of these being distinct projections of the cube. Four of the projections; 0, 90, 180, and 270 degrees of rotation, were the identical 4 sided square.

The distorted cube was produced by randomly displacing the vertices of the square (cube at 0 degrees rotation), no more than half the length of a side in either the X, Y, or Z planes, under the constraint that the mean displacement of the eight vertices would be zero. This produced an irregular three dimensional figure which was then rotated by 10 degree increments simultaneously about the X, Y and Z axes thru 360 degrees. This technique produces 36 distinct distortions that are related to each other in the same fashion that the cube rotations are: 36 different views of a three dimensional object. In this way, all 36 views of the cube can be paired with a comparable distortion (i.e. the 40 degrees of rotation cube is paired with the 40 degrees of rotation distortion).

The sixteen training stimuli were chosen from among the 36 pairs, each representing a different degree of distortion, so that the training set of Group 4 projections (Forms 1, 6, 12, 17, 19, 24, 30, 35, 37, 42, 48, 53, 55, 60, 66, and 71) were representative of the entire set of projections. The remaining three groups were each a subset of the next higher group in the continuum. Half the stimuli seen by Group 4 were seen by Group 3 (Forms 1, 12, 19, 30, 37, 48, 55, and 66), half the stimuli seen by Group 3 were seen by Group 2 (Forms 19, 30, 55, and 66) and finally half the stimuli seen by Group 2 were seen by Group 1 (Forms 30 and 66).

Procedure

Four pigeons were randomly assigned to each group. Each session consisted of 80 reinforced trials, cubes were shown on 40 trials, and distortions were shown on the other 40 trials. The order of presentation of the stimuli were predetermined prior to the session and were the same for all the pigeons in a given group. The beginning of a trial was indicated by a pair of bracket-like figures (5.5 cm high and 1.5 cm from center) displayed on the screen. A peck to the display key caused the figures to disappear, and the stimulus, a cube or a distortion, to appear at the center of the screen. After 20 pecks to the display key, the side keys lit up white. For half the pigeons a peck to the left side key was considered a correct response to a cube stimulus, while for the remaining pigeons a peck to the left side key was considered a correct response to a distorted stimulus. A peck to the correct side key would give the pigeon 2 sec. access to grain (reinforcement), and the screen and side keys to darken for 10 sec. An incorrect response would cause the screen and keys darken for 10 sec., and the trial to repeat until a correct response was given (rerun-correction method). Only the first presentation of the stimulus on each trial were used in data analysis.

Generalization Tests

In order to minimize the disruption associated with the transition from continuous reinforcement during the acquisition phase, to partially reinforced trials during the generalization phase, the reinforcement probability for the original training stimuli was gradually reduced from a reinforcement for every correct response, to a reinforcement, on average, for every fourth correct responses. This phase of the experiment began 125 days from the beginning of the experiment. Over a period of 5 to 6 days the reinforcement probability was reduced to the partial schedule, and the number of trials per session was increased to 192. The pigeons were then kept on the partial schedule at 192 trials for an additional 5 days to insure stable performance before the generalization test took place.

As previously stated, the generalization stimuli consisted of all 69 unique stimuli that comprise the set of cubes and distortions. The total number of stimuli presented during each session varied from group to group under the following constraints. Reinforcement for correct responding was available for 48 of the trials presented to each group. These were trials on which the original training stimuli were shown. The standard rerun-correction method was used after incorrect responses to these stimuli, but not for the generalization test stimuli. Each of the generalization stimuli were each presented twice without reinforcement. This final phase lasted for 30 sessions.

RESULTS

In order to simplify the identification of the various pigeons, the following convention has been adopted: Bird numbers indicate the group membership and the individual pigeons' number. For example, Bird13 identifies the third pigeon in the first group, while Bird21 identifies the pigeon as belonging to Group 2, pigeon number 1.

Figure 3 presents the learning curves for the six pigeons in the experiment that continued on to the generalization phase. Their data is plotted as the mean proportion correct for each session. As can be seen, all of the pigeons show performance considerably above the chance level (0.5). Two of the pigeons in Group 2, Bird22 and Bird24, rapidly acquired their discriminations and performed nearly perfectly during the last sessions before generalization. As for the other pigeons, they all slowly acquired their discriminations and leveled off at asymptotes well below 1.0. Overall, all six pigeons were judged to have reached asymptotic performance by session 120. These judgements were made by visual inspection of the learning curves.

Figure 3

Acquisition Curves for Pigeons that Continued onto the Generalization Phase.

Figure 3 (continued)
Bird11

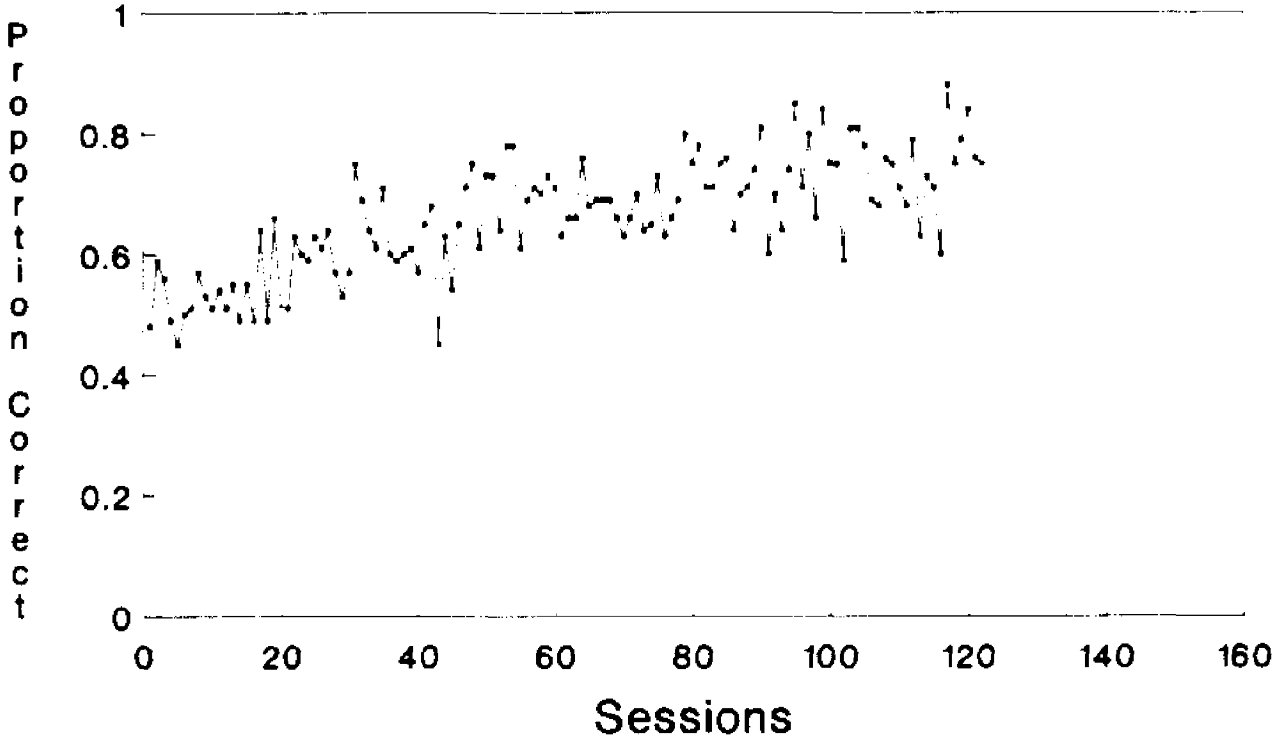


Figure 3 (continued)
Bird13

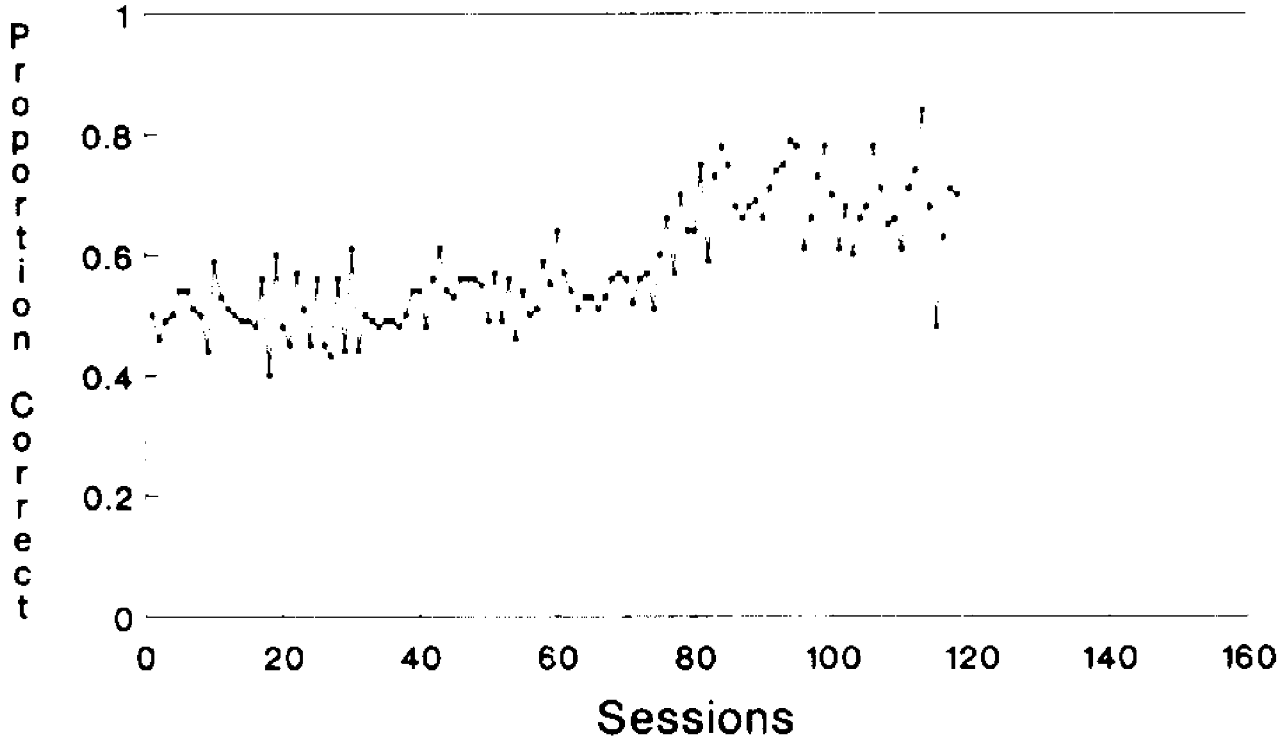


Figure 3 (continued)
Bird21

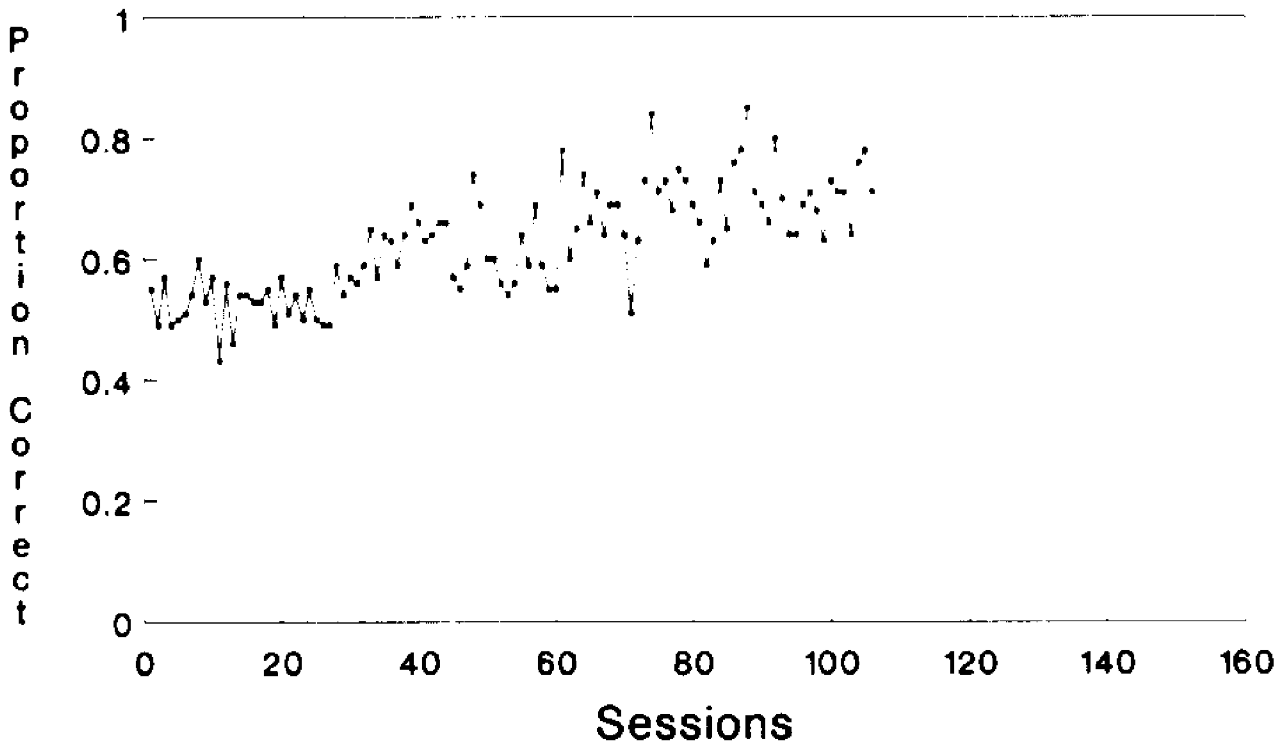


Figure 3 (continued)
Bird22

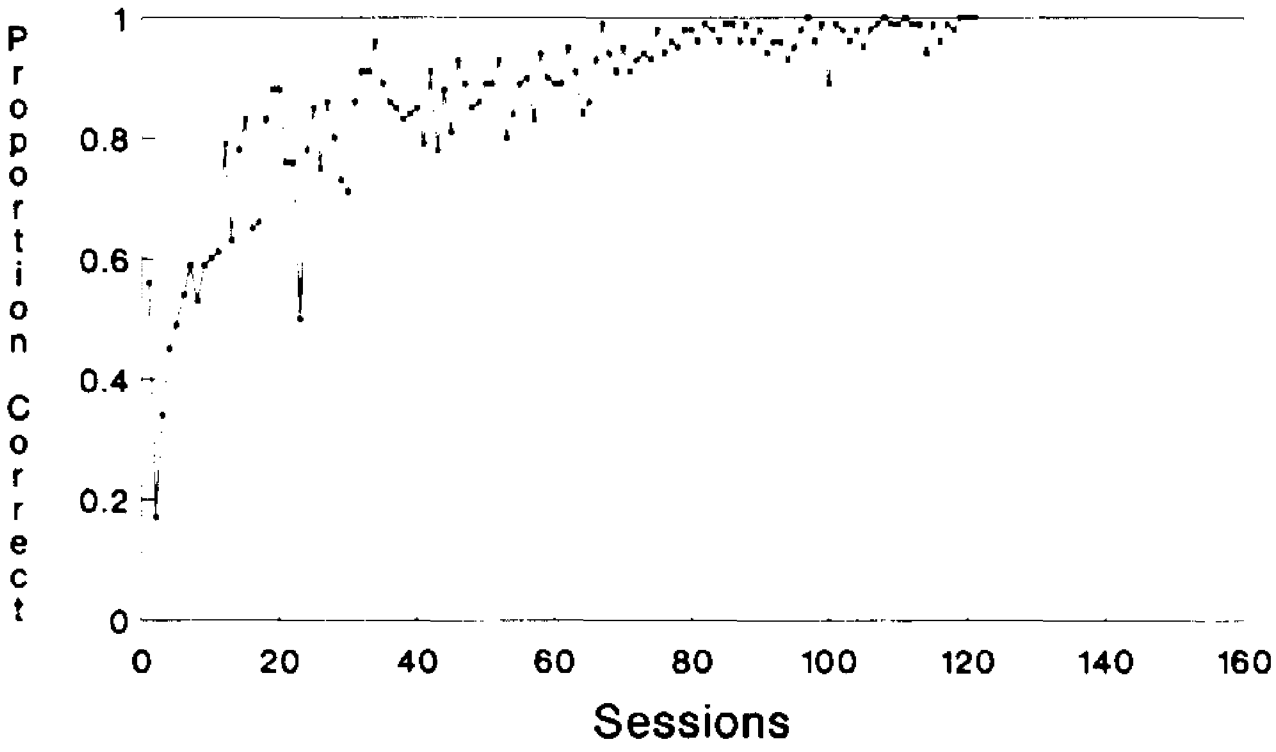


Figure 3 (continued)
Bird24

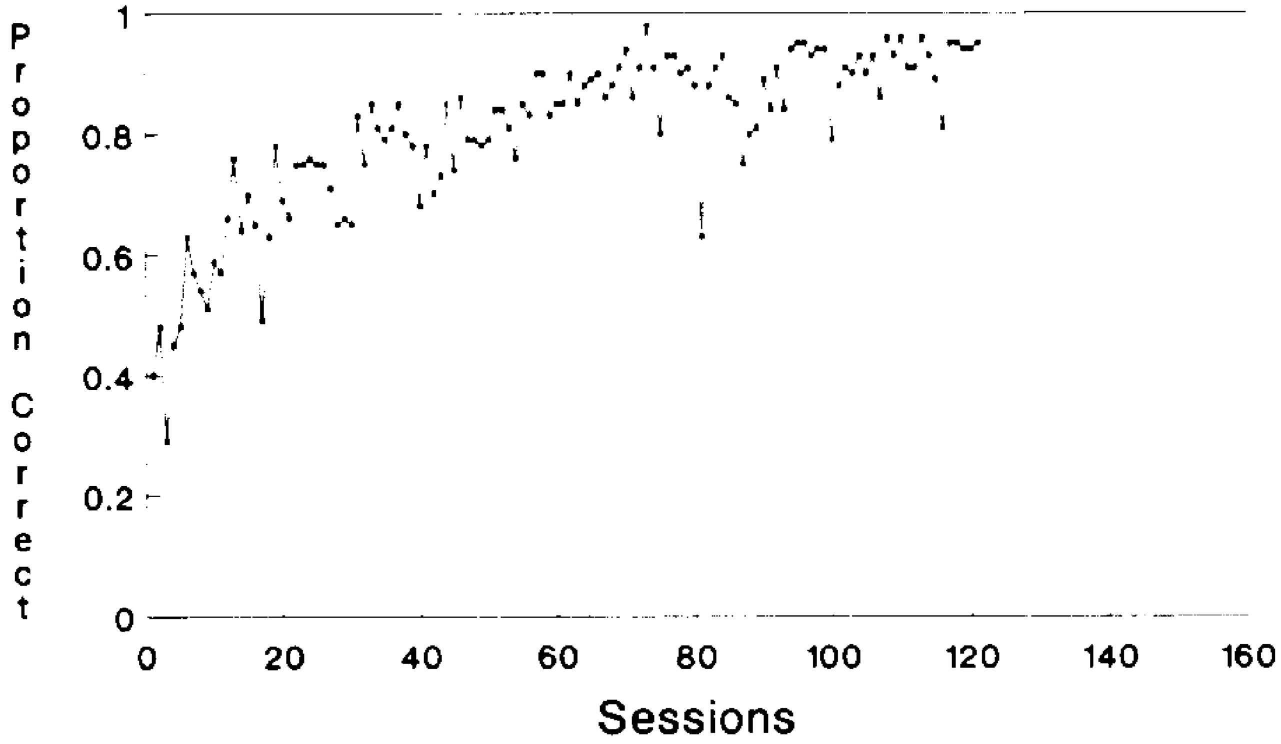
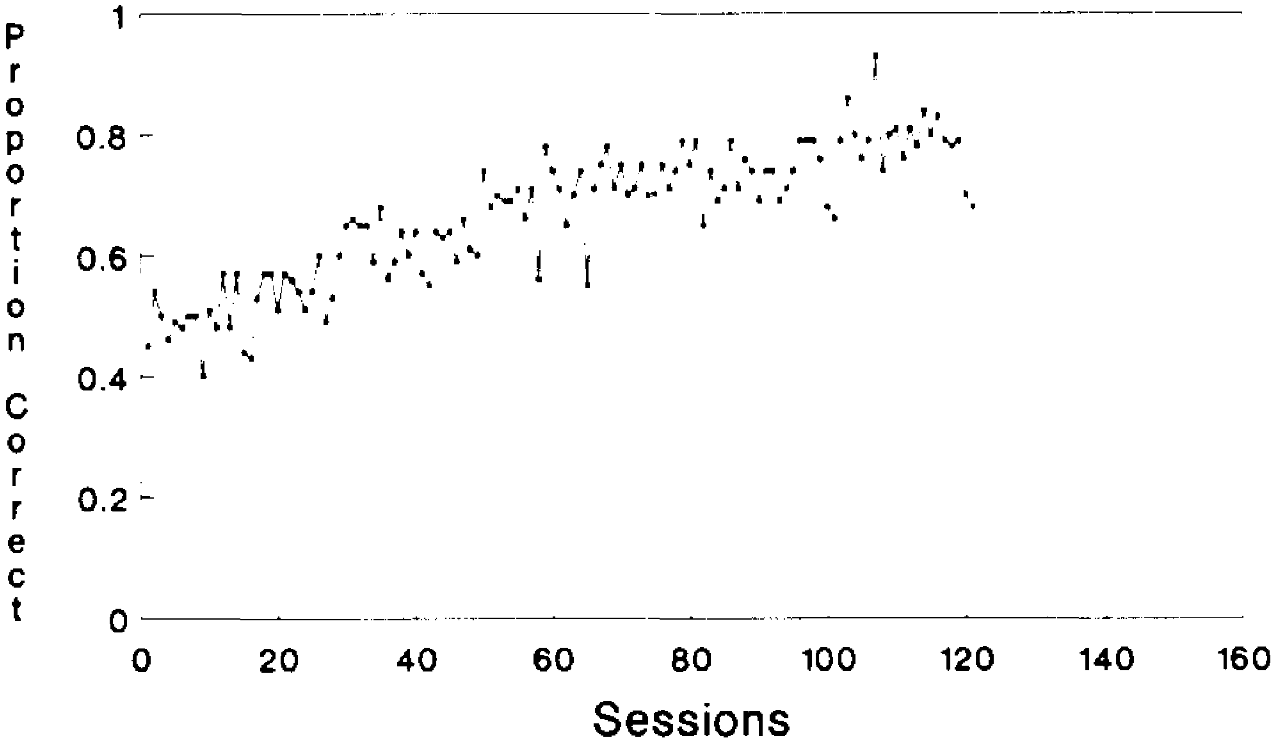


Figure 3
Bird34



The acquisition phase for the ten pigeons who were not given the generalization (Bird12 and Bird14 from Group 1, Bird23 from Group 2, Bird31, Bird32 and Bird33 from Group 3, and Bird41, Bird42, Bird43, and Bird44 from Group 4) was continued for forty days; until the other six pigeons completed the generalization test (See Figure 4). Examination of their learning curves gave no indication of an increase of performance above chance levels. At this point the pigeons were withdrawn from the experiment.

Figure 5 presents the generalization curves for the six pigeons who were tested. These curves represent the average proportion of trials, over the generalization phase, on which the pigeon gave a cube response, pecked at the key defined as correct for the cubes during training, to each form. Forms 0 through 35 represent Cube stimuli, and forms 36 through 71 are Distortion stimuli. At first glance all the curves have a random appearance; there does not seem to be any regularity to their form. However, careful comparison among the curves shows they have a remarkably similar shapes. All curves exhibit a sawtooth like pattern for the Cube stimuli, and show a tendency to slope upward. For the Distortions, the pigeons all show the same smooth drop in performance

Figure 4

Acquisition Curves for Pigeons that Did Not Continue onto the Generalization Phase.

Figure 4 (continued)
Bird12

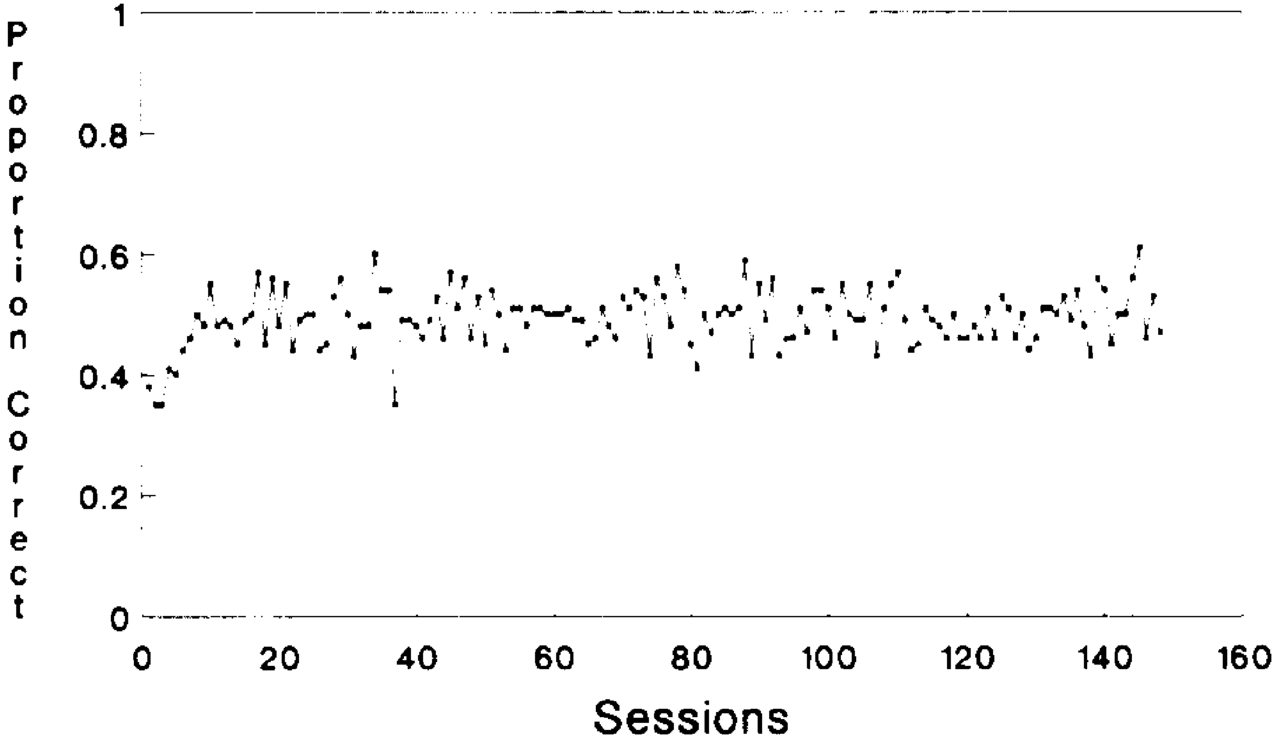


Figure 4 (continued)

Bird14

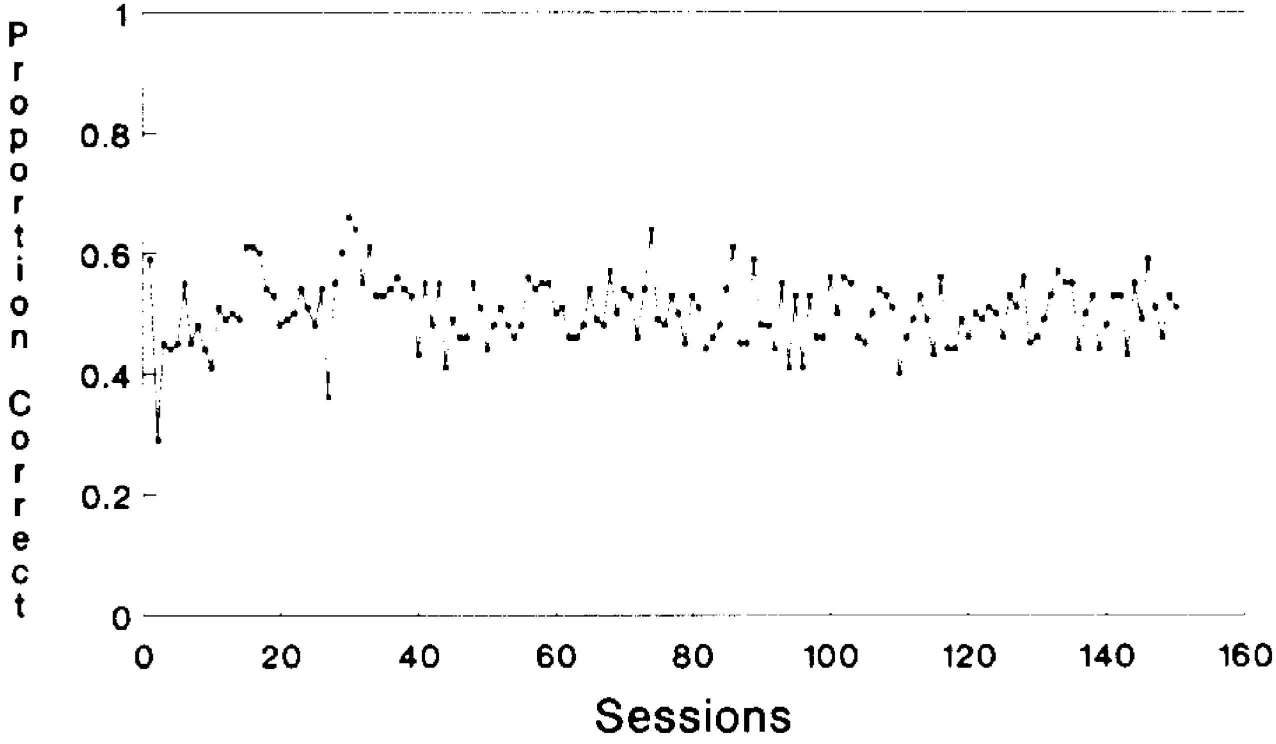


Figure 4 (continued)
Bird23

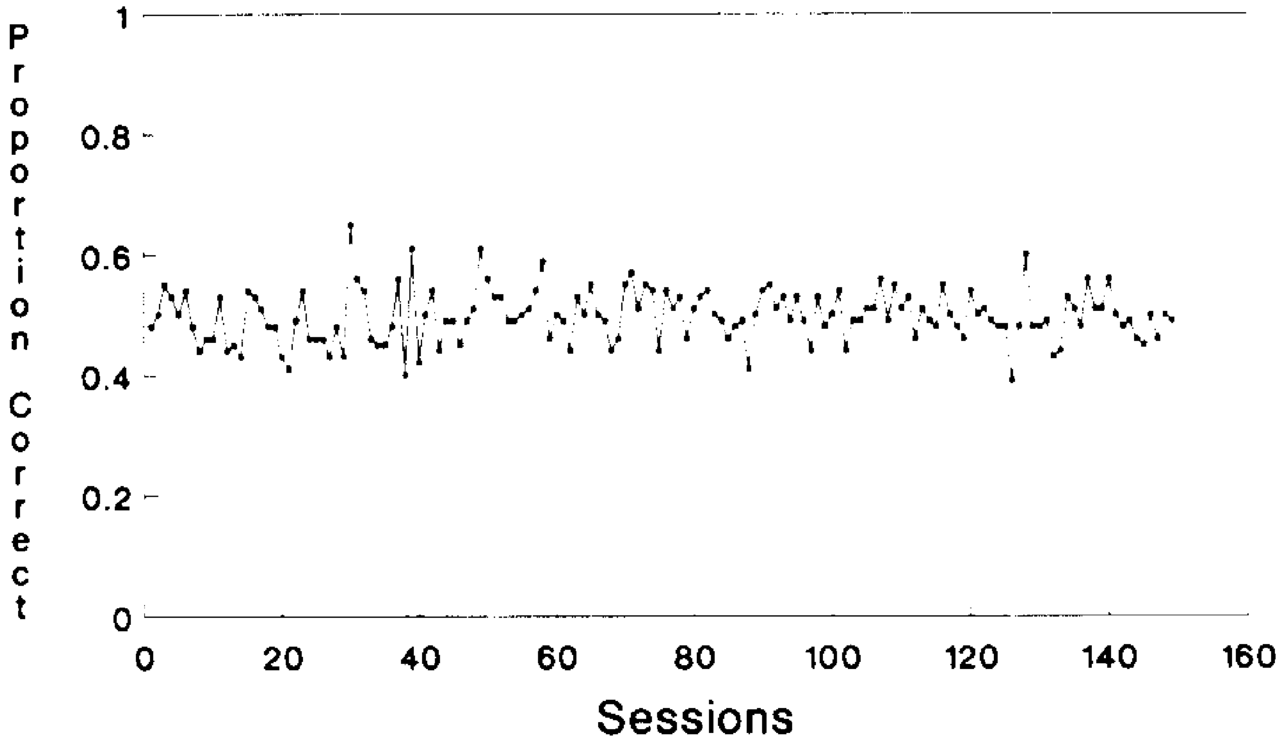


Figure 4 (continued)
Bird31

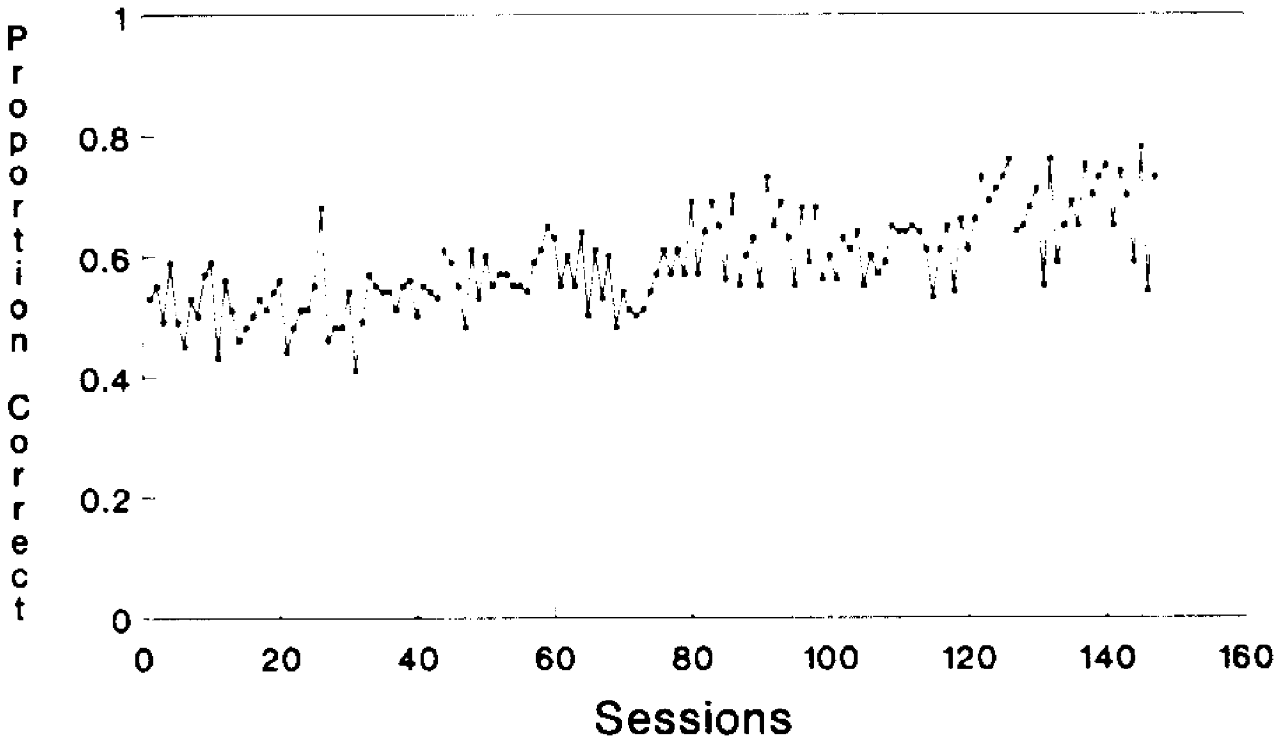


Figure 4 (continued)
Bird32

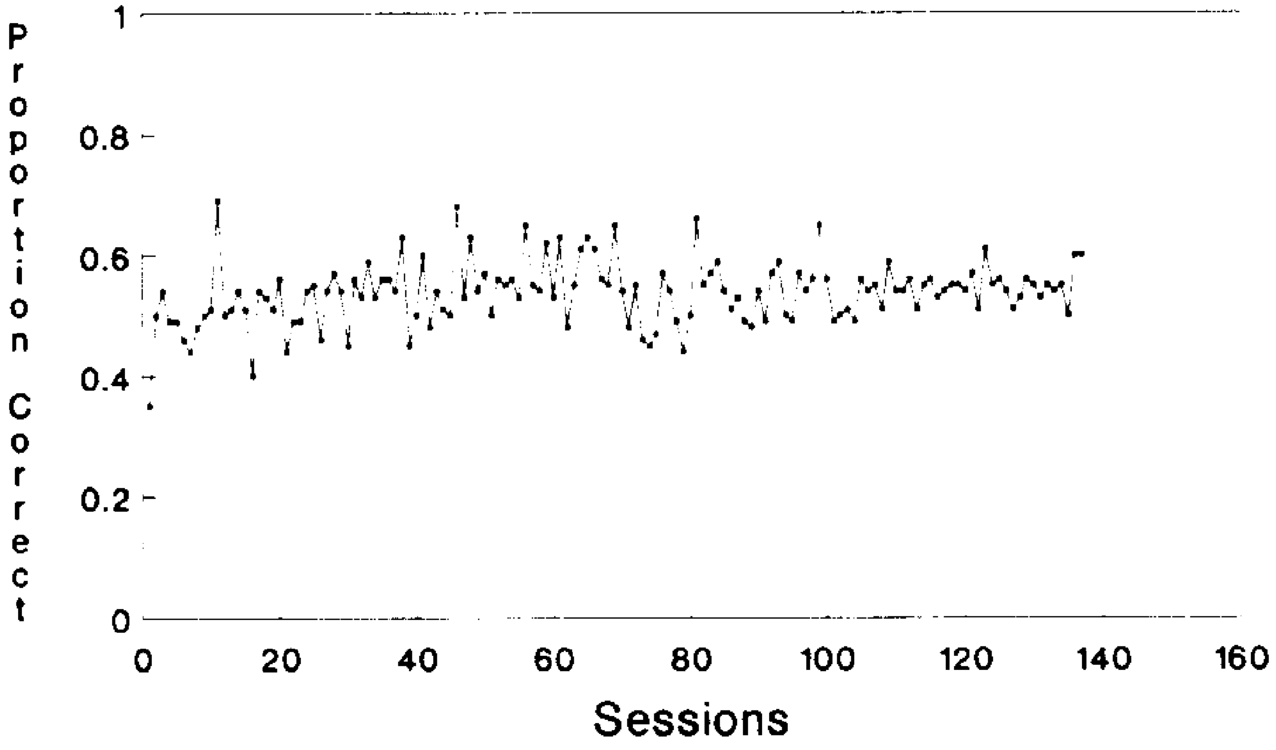


Figure 4 (continued)
Bird33

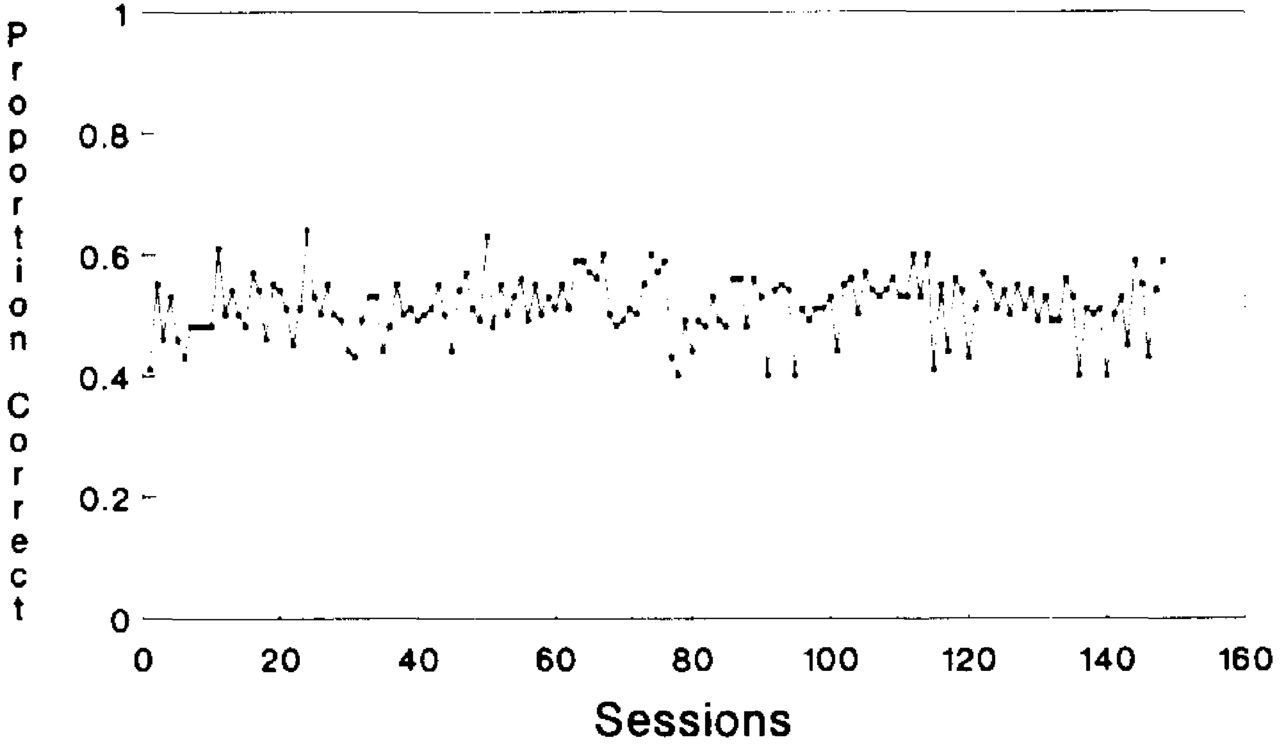


Figure 4 (continued)
Bird41

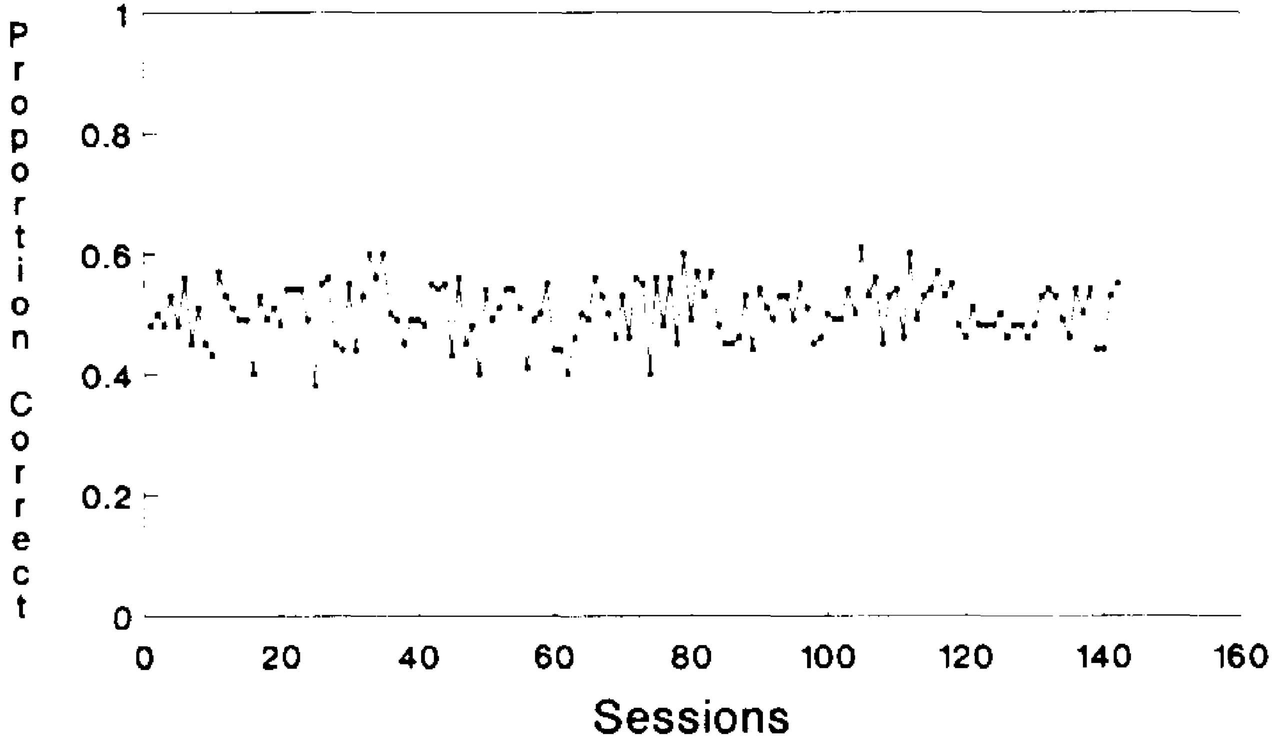


Figure 4 (continued)

Bird42

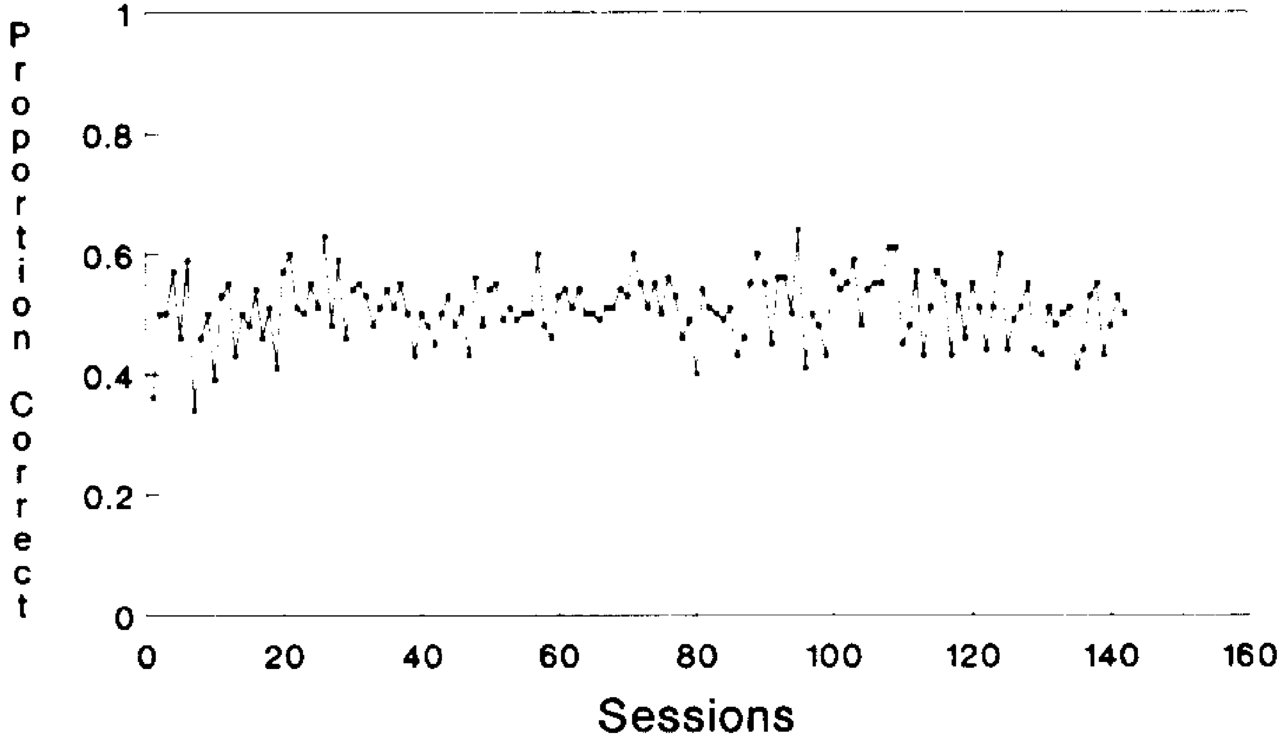


Figure 4 (continued)

Bird43

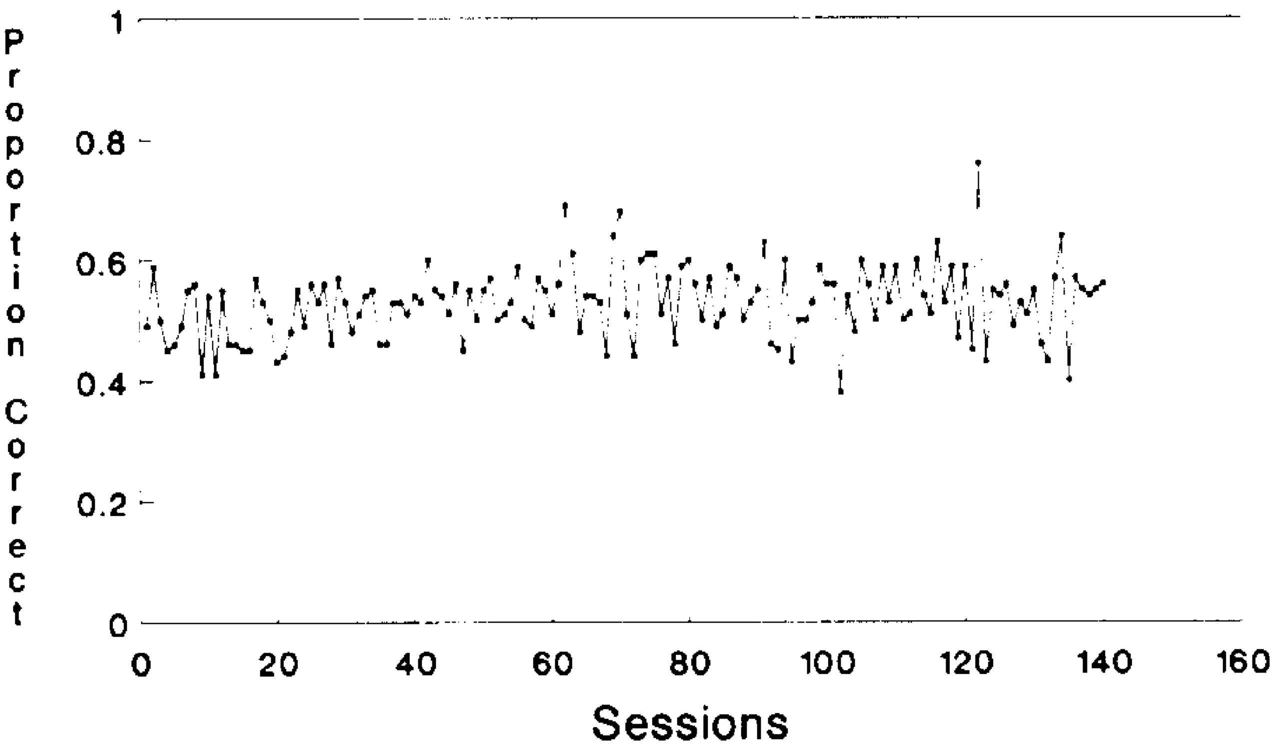


Figure 4
Bird44

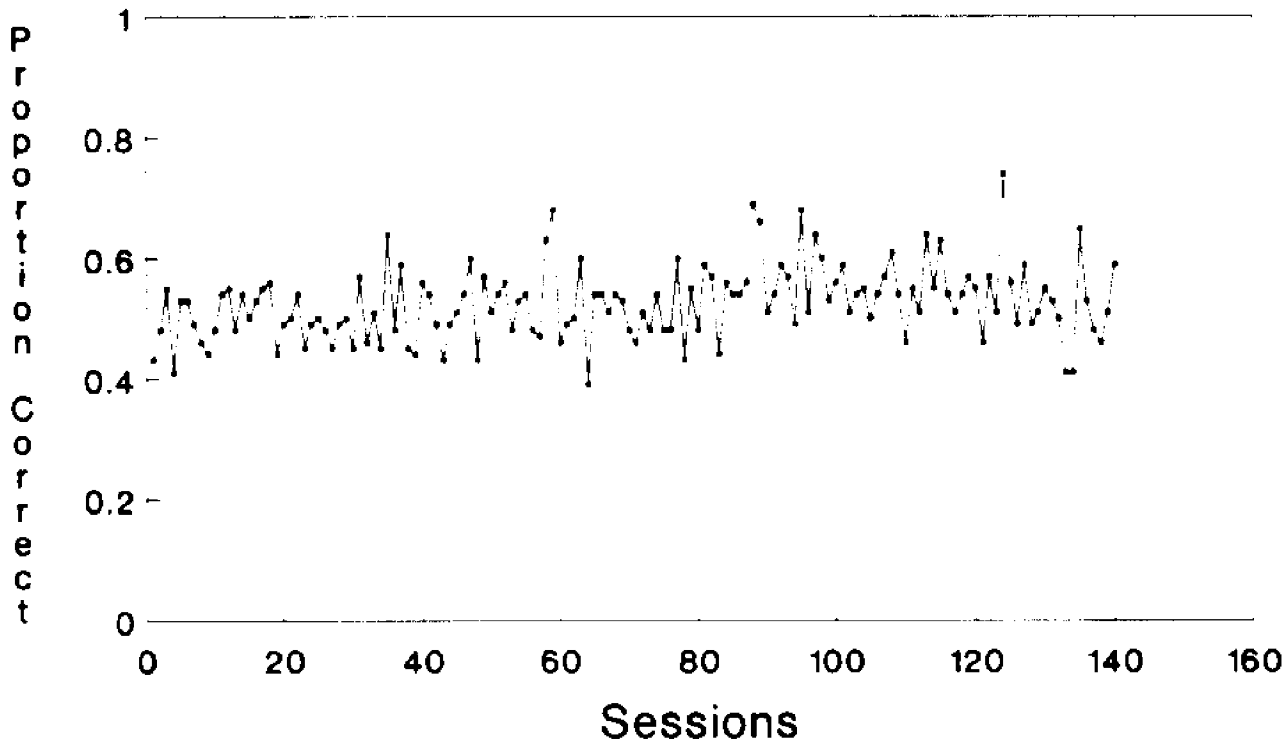


Figure 5

Mean Performance During Generalization Phase.

Figure 5 (continued)
Bird11

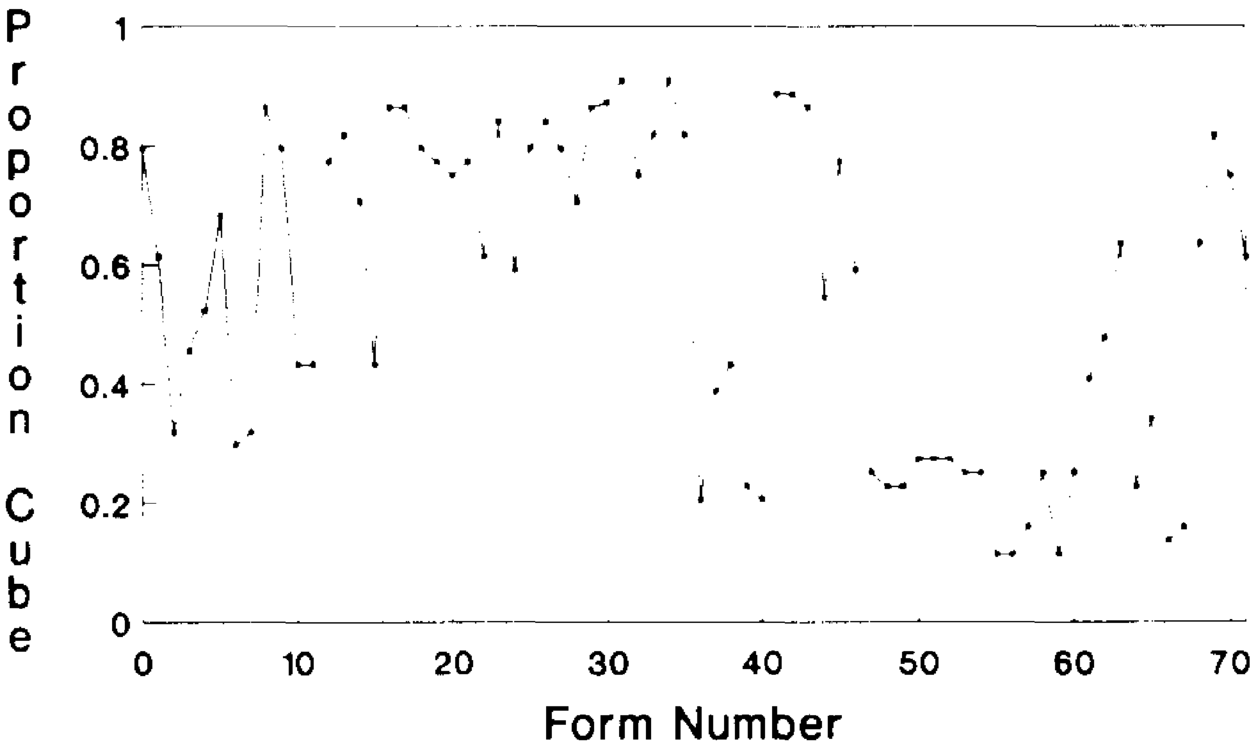


Figure 5 (continued)

Bird13

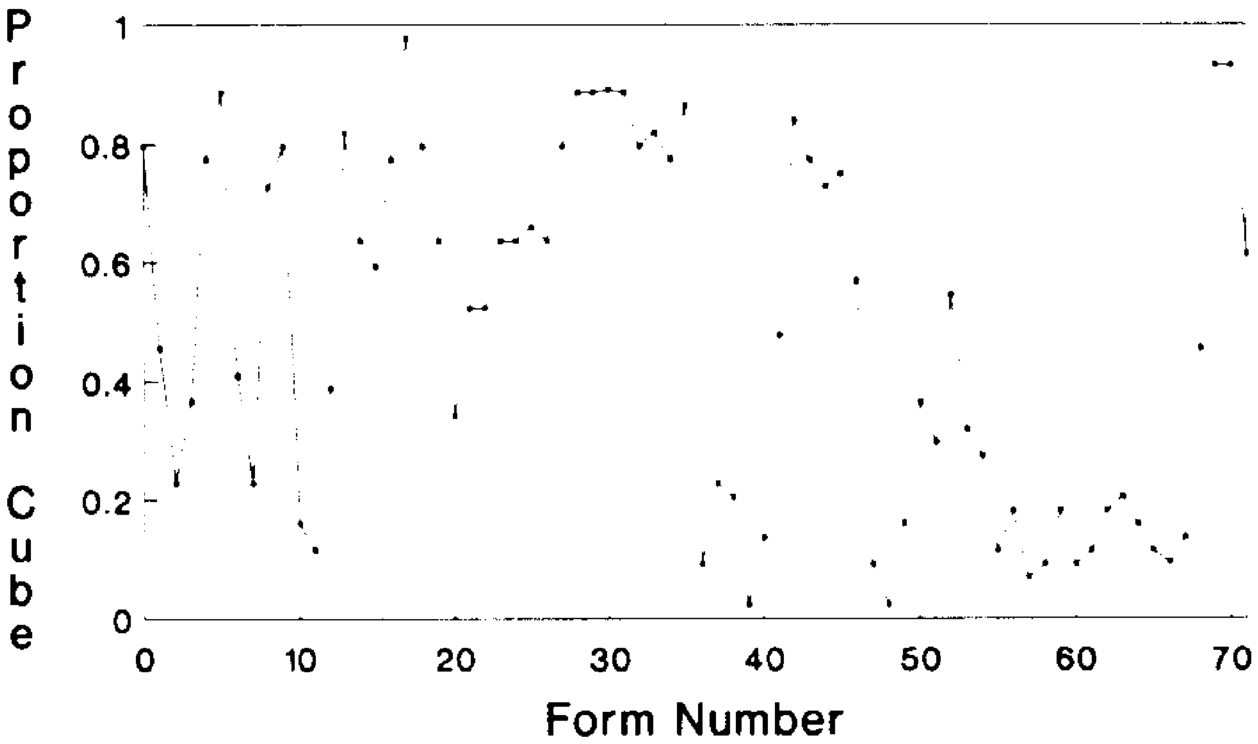


Figure 5 (continued)

Bird21

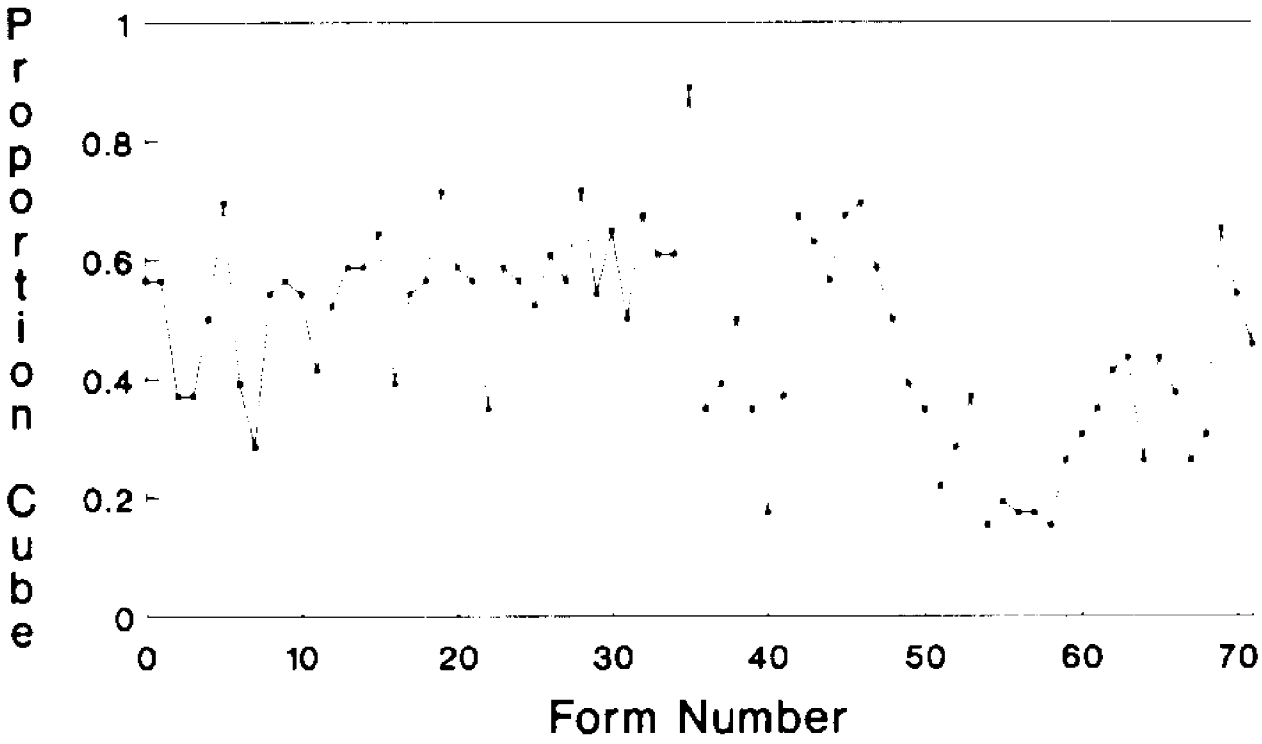


Figure 5 (continued)
Bird22

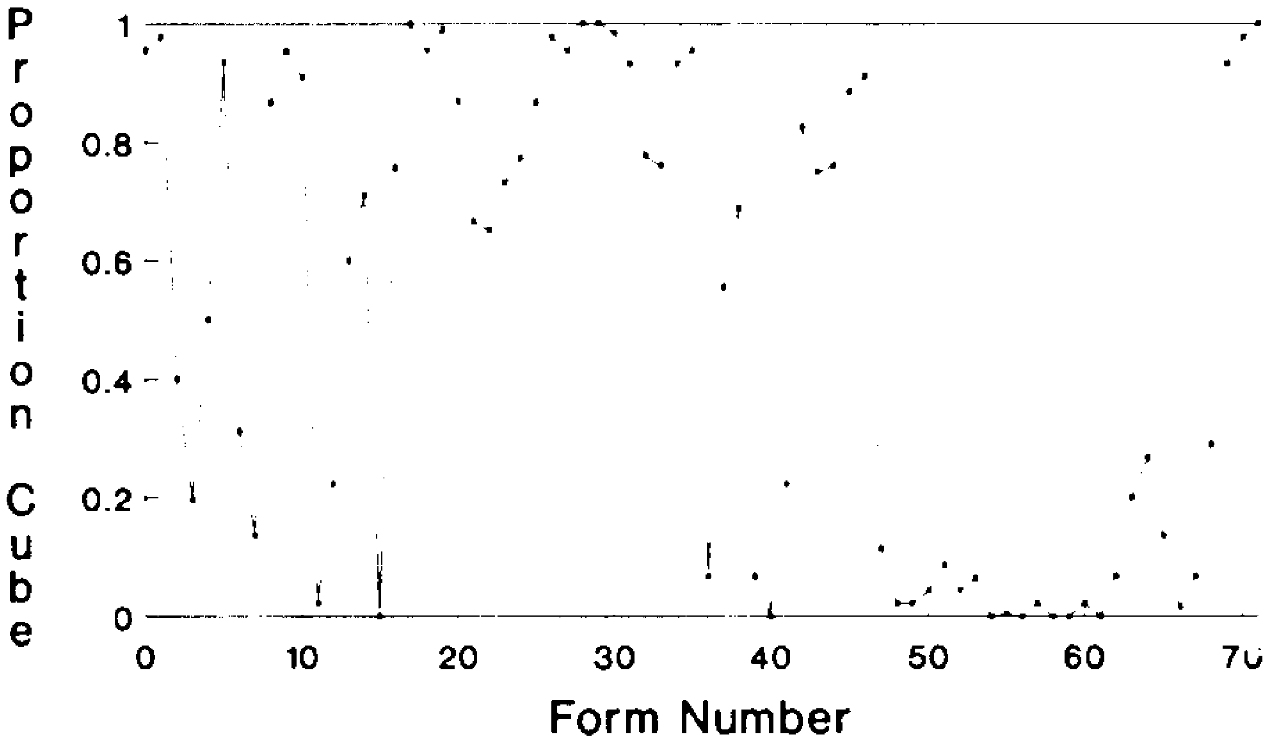


Figure 5 (continued)
Bird24

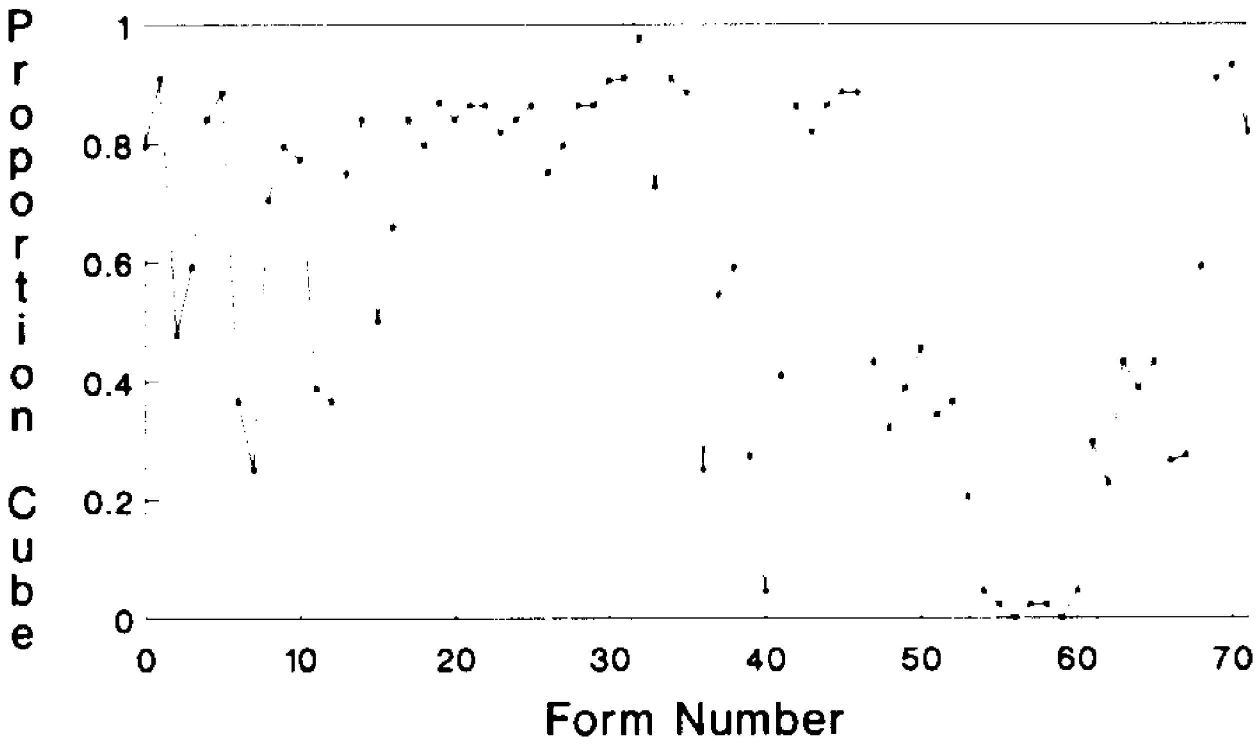
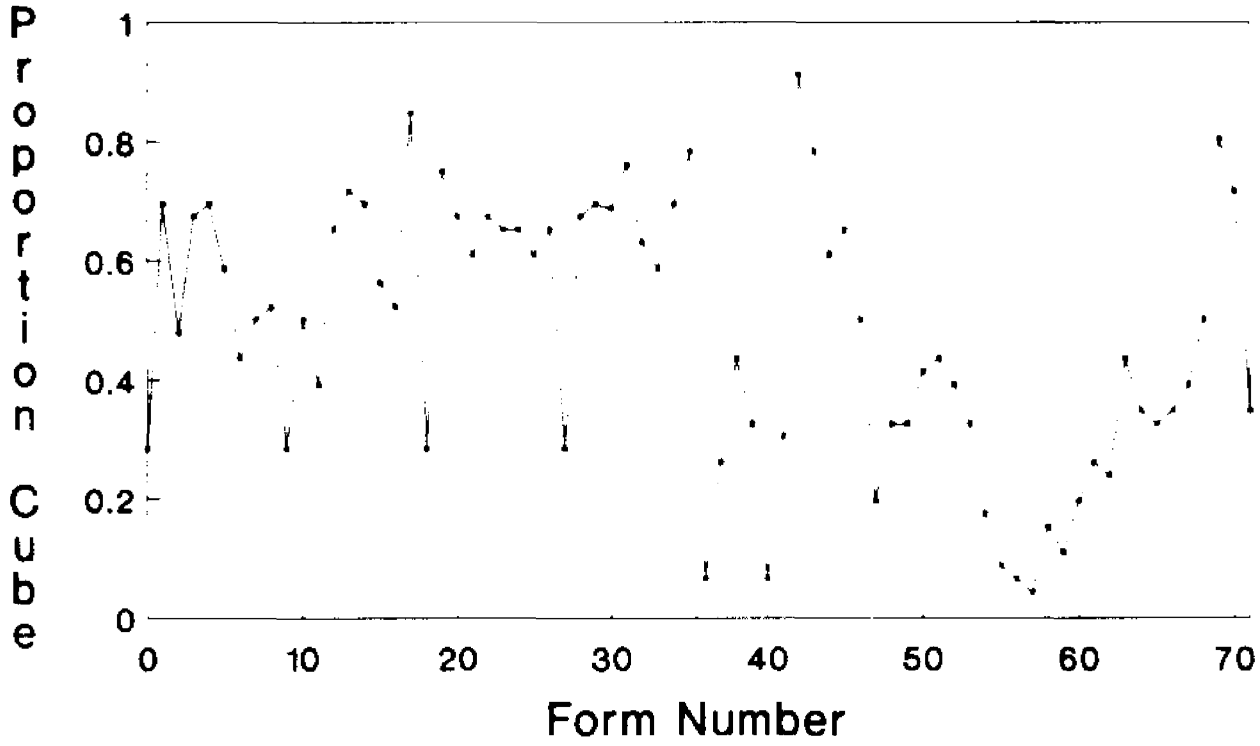


Figure 5
Bird34



around stimulus 55 (one of the training stimuli for Group 2, Group 3 and Group 4), and exhibit a rise in performance as the stimuli get further away from this point. Correlations (Pearson r) were performed between the generalization data for the six pigeons as a measure of the similarity between the pigeons. The correlation between Bird11 and Bird13 from Group 1 is 0.87. The mean correlation, obtained by averaging the three individual correlations, between Bird21, Bird22 and Bird24 from Group 2 is 0.83.

Between-group correlations, based on average group data, are 0.88 between Group 1 and Group 2, 0.7 between Group 1 and Group 3, and 0.74 between Group 2 and Group 3. This cursory analysis suggests that there may be some underlying dimension of the stimuli that controls the behavior of all the pigeons.

Table 1 presents the generalization data for the six pigeons that continued on to the generalization phase. Their performance on the both the training stimuli and the test stimuli are split into Cube and Distortions. As can be seen, the pigeons continued to perform well above chance on the training stimuli during the test.

Table 1

Proportion Correct on Generalization Stimuli

	Proportion Correct					
	Bird Number					
	BIRD11	BIRD13	BIRD21	BIRD22	BIRD24	BIRD34
CUBE						
Test	.695	.634	.545	.714	.744	.582
Training	.872	.890	.682	.988	.888	.696
DISTORTION						
Test	.597	.673	.606	.703	.578	.630
Training	.863	.905	.716	.990	.856	.744

Table 2 presents the overall performance of each pigeon on the generalization stimuli, as well as the number of generalization forms and the standard error of the mean for each pigeon. Significance testing showed that the pigeons performed significantly better than chance (0.5) on the generalization stimuli.

Table 2

Overall Proportion Correct on Generalization Stimuli

	Number of Forms	Mean Proportion Correct	Standard Error of the Mean
BIRD11	70	.646	.026
BIRD13	70	.653	.030
BIRD21	68	.576	.018
BIRD22	68	.708	.040
BIRD24	68	.661	.032
BIRD34	64	.606	.024

The forms are composed of a varying number of pixels (See Table 3). The pixels themselves are of equal size and radiance, no matter where they appear on the monitor. Therefore, the radiant flux of each form can be represented by the number of pixels in each form.

Table 3

Number of Pixels for Each Form

Form Number	Number of Pixels
0	54
1	90
2	87
3	97
4	99
5	96
6	91
7	87
8	77
10	77
11	89
12	91
13	97
14	100
15	96
16	91
17	90
19	93
20	95
21	98
22	102
23	98
24	93
25	89
26	86
28	85
29	89
30	93
31	101
32	102
33	98
34	96
35	92
36	59

(continued)

Form Number	Number of Pixels
37	64
38	71
39	73
40	68
41	68
42	85
43	94
44	95
45	101
46	82
47	80
48	90
49	92
50	97
51	95
52	98
53	93
54	77
55	62
56	64
57	59
58	69
59	71
60	74
61	74
62	77
63	80
64	79
65	88
66	93
67	93
68	98
69	97
70	88
71	73

Table 4 presents the number of forms, mean number of pixels and standard deviation of the number of pixels for each group. Each set of stimuli are divided into training and test stimuli, and further divided by whether the forms were Cube or Distortion stimuli.

As can be seen from Table 4, the test stimuli for all groups are virtually identical in terms of the average pixel number and standard deviation within each type. For the Cubes the mean number of pixels remained constant for the four groups at 91.4 while the standard deviation ranged from 9.3 to 12.9 pixels. Similarly, the mean number of pixels for the Distortions ranged from 80.8 to 81.7, while the standard deviation ranged from 12.4 to 12.9.

Across groups, the sets of test stimuli are virtually the same as the overall sets of cubes and distortions in terms of the mean and standard deviation of pixels (Cubes 91.5, 9.1; Distortions 81.1, 12.7)

The consistent pattern observed for the Cube test stimuli, is also found for the training stimuli. The number of pixels remained relatively constant over the four groups, and ranged from 91.6 to 93 pixels, while the standard deviations ranged from 0 to 1.5.

Table 4

Number, Average and SD of Pixels by Group by Type

	Number of Forms	Mean	Standard Deviation
GROUP 1			
TEST STIMULI			
Cubes	32	91.4	9.3
Distortions	35	80.8	12.7
TRAINING STIMULI			
Cubes	1	93.0	N.A.
Distortions	1	93.0	N.A.
GROUP 2			
TEST STIMULI			
Cubes	31	91.4	9.4
Distortions	34	81.4	12.5
TRAINING STIMULI			
Cubes	2	93.0	.0
Distortions	2	77.5	21.9
GROUP 3			
TEST STIMULI			
Cubes	29	91.4	9.8
Distortions	32	81.6	12.4
TRAINING STIMULI			
Cubes	4	91.8	1.5
Distortions	4	77.3	16.5
GROUP 4			
TEST STIMULI			
Cubes	25	91.4	10.5
Distortions	28	81.7	12.9
TRAINING STIMULI			
Cubes	8	91.6	1.3
Distortions	8	79.3	12.7

The distortion training stimuli; however, show a different pattern. While the mean number of pixels per group for Group 2, Group 3 and Group 4 are above the overall mean of 81.8 for Distortions (Range 77.3 to 79.3) the number of pixels for the Distortion in Group 1 is 93. In addition, the standard deviations of the distortions in Group 2, Group 3 and Group 4 range from 12.7 to 21.9.

Correlations between the pigeons' performance during generalization, as measured by the percent of the time the forms were identified as a cube, and the number of pixels in each form are presented in Table 5.

These correlations indicate that the more intense the stimulus the more likely it was to be chosen as a cube.

Table 5

Correlations of Actual Performance with Radiant Flux

	Proportion Correct/ Radiant Flux r
Group 1 Mean	0.30
Bird11	0.25
Bird13	0.34
Group 2 Mean	0.32
Bird21	0.42
Bird22	0.18
Bird24	0.39
Bird34	0.72
All Birds	0.38

DISCUSSION

In investigations of the categorization process, generalization tests are administered to subjects that successfully learn to discriminate a set of training stimuli. In this investigation, few of the pigeons (6 out of 16) were able to successfully discriminate between the training stimuli, and consequently, few proceded onto the generalization phase of the experiment. While this difficulty in discriminating among the training stimuli is not unique in experiments involving impoverished stimuli, it is rarely observed in experiments utilizing rich complicated stimuli, such as slides of natural objects.

Both humans and animals are limited in their ability to identify stimuli that vary along a single dimension. All subjects can identify a greater number of stimuli if the stimulus dimensions that compose the stimuli are increased. Therefore, it is not unexpected that the pigeons would have difficulty identifying the stimuli since they were simple.

While pigeons quickly learn discriminations involving rich, complicated stimuli such as apples or photographs of city streets, these stimuli are entirely impossible to analyze; and therefore, it is not possible to specify what aspects of the stimuli are controlling the birds response. Therefore, while experiments involving these stimuli result in perfect performance, they can give little insight into the underlying processes involved in categorization. While experiments utilizing simple, impoverished stimuli, result in poor performance, they also allow the results to be analyzed in terms of the characteristics of the stimuli. Therefore, it is this trade off, of performance for stimulus analyzability, that allows one to investigate the underlying processes involved in categorization.

It is not unreasonable to start at this point, since one does gain insight into the processes by starting with simple stimuli. Later investigations can utilize more complex stimuli, two dimensions, three dimensions and so on. But one must start at some simple point in order to first understand the mechanisms at work.

The pigeons performed significantly above chance on the generalization stimuli, thus indicating generalization to new instances of Cube and Distortion stimuli. As can be seen from Table 2, which presents their performance on the cube and distortion generalization stimuli separately, all the pigeons performed above chance on both types of stimuli. These data indicate that all the pigeons that were able to learn the discrimination, also "learned to categorize".

It is possible that categorization of new instances as cube or distortion was due to the differential radiant flux of the two sets of stimuli. Overall, the cubes contained more pixels than the distortions (Cubes 91.5 pixels, Distortions 81.1 pixels). However, this explanation cannot be applied to the two pigeons in Group 1. These pigeons were trained on stimuli that were equal in radiant flux (93 pixels). Consequently, for the pigeons in Group 1, categorization cannot be based on the differential radiant flux of the Cube and Distortion generalization stimuli. Given the high correlations between the generalization data for the six pigeons, it seems unlikely that the underlying dimensions of generalization would be different for each pigeon, or group of pigeons. Therefore, it is unlikely that the underlying dimensions of the generalization data are completely or primarily due to the number of pixels in the stimuli, or anything highly correlated with this number.

Whether or not the pigeons could detect the underlying three-dimensional properties of the cube and distortion stimuli, the dimension of rotation should have a controlling effect on the generalization gradients if the simultaneous 10 degree rotations about the X-Y-Z axes caused a regular variation in the dimension underlying the generalization process in the pigeons. If rotation were a controlling dimension in the generalization of the forms, then the generalization curves should show evidence of this effect in the form of a characteristic generalization curve (See Figure 5). The X axis indicates the form numbers, which are numbered consecutively to indicate the amount of rotation from the initial form. Both cubes and distortions were rotated by increments of 10 degrees simultaneously about the X, Y, and Z axis. In Figure 5, forms 0 through 35 represent cubes, while forms 36 through 71 represent distortions.

If the pigeons' choice of response were governed simply by degrees of rotation, one would expect that, as the forms rotated toward the training stimuli, the pigeons' performance would improve, and then decline as the forms rotated away from the training stimuli. A peaked generalization gradient would then be obtained around each training form. The irregular functions shown in Figure 5 suggest that rotation did not have control over the pigeon choice behavior. The curves are all similar, showing erratic performance on the Cube stimuli, with no definite peaks about the training stimuli. A characteristic U shaped function is obtained for the Distortions, around one of the training stimuli, but this function is found in all curves across groups. If rotation relative to the training forms were the controlling factor, the functions should vary from group to group. In addition, this clear and consistent drop in performance about Form 55, that seems to suggest generalization, is even found in the pigeons that were not trained with Form 55 (Bird11 and Bird13).

Visual inspection of the stimuli reveals that the stimuli close to Form 55 (Form 54 to Form 58) resemble each other; they all present two sided views of the Distortion to the pigeon, and seem to be small and compact. In addition they all contain fewer pixels than the average distortion (See Table 3), with only Form 54 having more than 70 stimuli. Perhaps it is this compactness that caused all the pigeons to respond to these stimuli in a similar manner. Further analysis has not produced any information on why this effect occurred, nor has it revealed why the pigeons responded to these stimuli with a Distortion response. Perhaps this dip around Form 55 is an artifact of the experimental situation.

The Heinemann and Chase Model suggests that neither the

Cube nor its Distortion are experienced by the pigeon observers as projections of a three-dimensional form rotated in space. According to this model, therefore, the dimension (degree of rotation) should not form a continuum along which smooth generalization gradients should be obtained. Simulation of the process by which Heinemann and Chase suggest pigeons categorize the various forms was accomplished by a BASIC program (See appendix A).

The stimuli are represented by the X-Y coordinates of the illuminated pixels that constituted the forms on the monitor. Since all pixels are of uniform size, hue, and brightness, this information is not employed in the simulation of the decision process. Gaussian noise, in the form of displacements of each pixel in the horizontal and vertical axes, is assumed to be added to each memory record. This noise can be described by a bivariate normal distribution, whose mean is the value of the sensory effect experienced when the record was originally stored in memory. It is assumed that a small number of such records are retrieved from memory when a decision is made. When retrieved, the X-Y Coordinates of each pixel is distorted.

The decision process is as follows: The X-Y coordinates for each pixel from the input-stimulus are compared to the X-Y coordinates of each pixel on a memory record by computing the horizontal and vertical distances, in standard units, from the pixel of the input stimulus, to each pixel on the memory record. To each such distance corresponds a probability density. The average probability density at the position of the input pixel is obtained by averaging these values. Mean densities are obtained in the same fashion for the remaining pixels from the input stimulus. A joint density (JD) is obtained by multiplying all the mean probability densities. In the same way, joint densities are obtained for each stimulus in the sample. If a point on the input stimulus is more than five standard deviation units distant from all other points on the memory record, the record is rejected, and its JD is set to zero. Once these joint densities are obtained the decision rule is: Make the response that is associated with the largest value of JD. If none of the joint densities is greater than zero, a new sample is drawn and the process repeats. If the repeated sampling fails to yield a record for which the joint density is greater than zero, then a response is chosen at random. The response to that stimulus is considered to be the one emitted, and is recorded as such. Variables in the program consist of memory size, sample size, and the spacing between the points of the stimuli.

The forms in the simulation were represented by the X-Y coordinates of points within a 20 by 60 pixel grid. These points represent the actual pixels that were illuminated during the experiment. The coordinates of the points were then saved in a file and used by the simulation program. In this way the actual illuminated pixels were used by the program while simulating the pigeons performance.

The program produces a confusion matrix containing the number of times each generalization stimulus was identified as one of the training stimuli. While the program simulates a pigeon categorizing each form as one of its training stimuli (2 for Group 1, 4 for Group 2, 8 for Group 3 and 16 for Group 4), the experimental apparatus limited the pigeons to two choices, and therefore required the pigeons to make a Cube/Distortion choice. For the purposes of comparison to actual data, other programs were used to collapse the matrices and transform the data into the Cube/Distortion choices that were available to the pigeons.

Using the data for the pigeons from Group 1 for the first step in analysis, the program was used to simulate performance by the pigeons that were trained on one Cube and one Distortion. The simulated data were then compared to the group average curve. The only variable manipulated in this simulation was the spacing of the points. Memory size and sample size remained fixed at 1200 and 10 respectively. In addition, while it is possible for the model to simulate the learning phase of the experiment, time constraints made it impractical to do. Therefore, the simulations assume a pigeon has mastered the learning phase. The memory of such a subject is assumed to contain an equal number of positive records of all training stimuli. Because the stimuli were presented equally often and a correction procedure was used.

Goodness of fit was evaluated by obtaining the correlation coefficient (Pearson r) between the actual and simulated data. The correlations increase rapidly with increasing spacing, reach a plateau at around 1.5 to 1.6, and then decrease. The best correlation was obtained at a spacing of 1.5 ($r = 0.60$) with a slightly lower correlation obtained at 1.6 ($r = 0.58$). Correlations of this magnitude were obtained for other comparisons between the simulation and actual data (Heinemann and Chase, 1990).

Figure 6 shows the correlations between the actual and simulated data for spacings varying from 1.4 to 2.0. The three curves shown are for the experimental data for the two pigeons in Group 1, and the Group 1 average. As would be expected, the three curves are highly similar. All rise rapidly to their plateau at a spacing of 1.5, and then fall.

Having determined the value of the spacing that yielded the highest correlation between the simulation and the average performance for Group 1, all variables were then fixed for the remaining simulations of the pigeons in Group 2 and Group 3.

Figure 7 presents simulated curves for the three groups of pigeons. As with the generalization stimuli, these curves represent the average proportion of trials on which the simulation produced a cube response to each form. Forms 0 through 35 represent Cube stimuli, and forms 36 through 71 are Distortion stimuli.
The simulated curves for all three groups exhibit better performance for the pigeons on the Cube stimuli, and worse performance on the Distortion stimuli than is actually observed.

Figure 6

Correlations Between Actual and Simulated Data for Various Spacings.

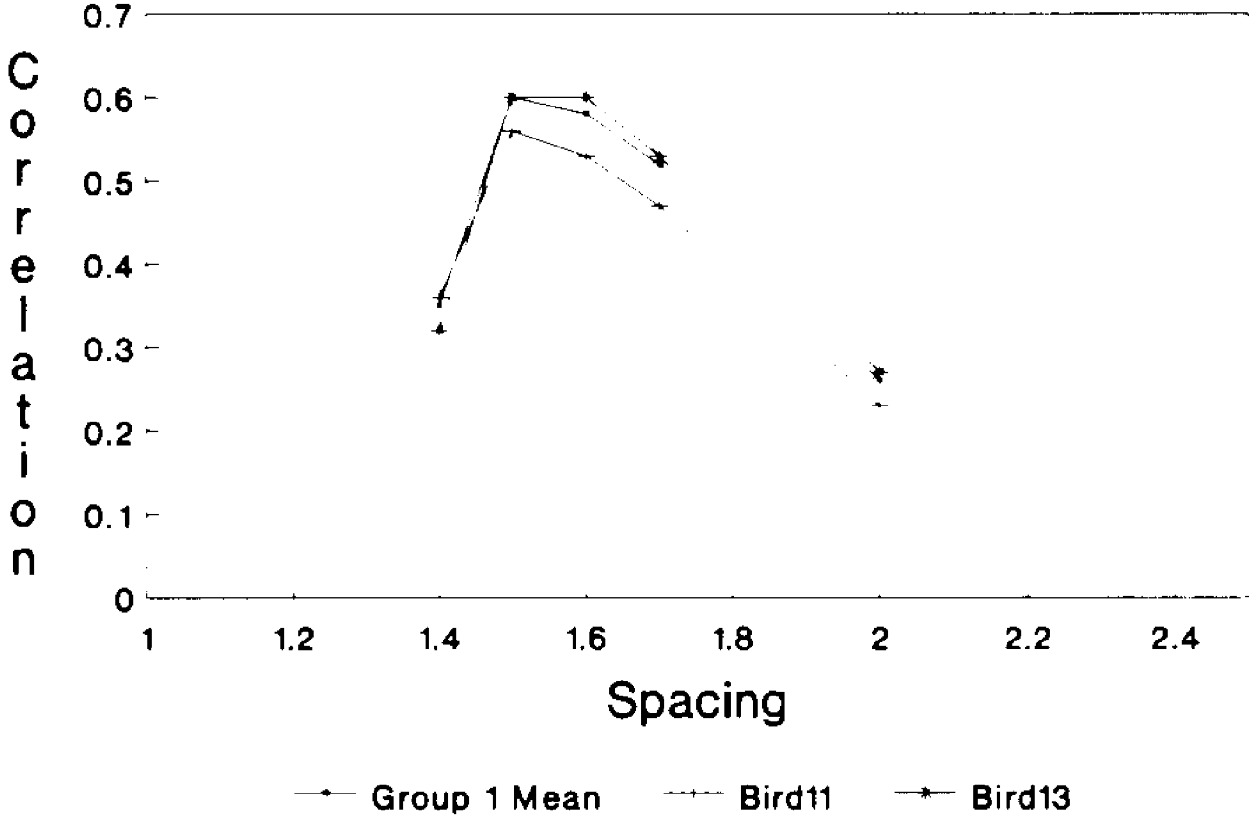

Correlation
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
1.2
1.4
1.6
1.8
2
2.2
2.4
Spacing
Group 1 Mean
Bird11
Bird13

Figure 7

Simulated Curves for the Three Groups of Pigeons.

Figure 7 (continued)
Group 1

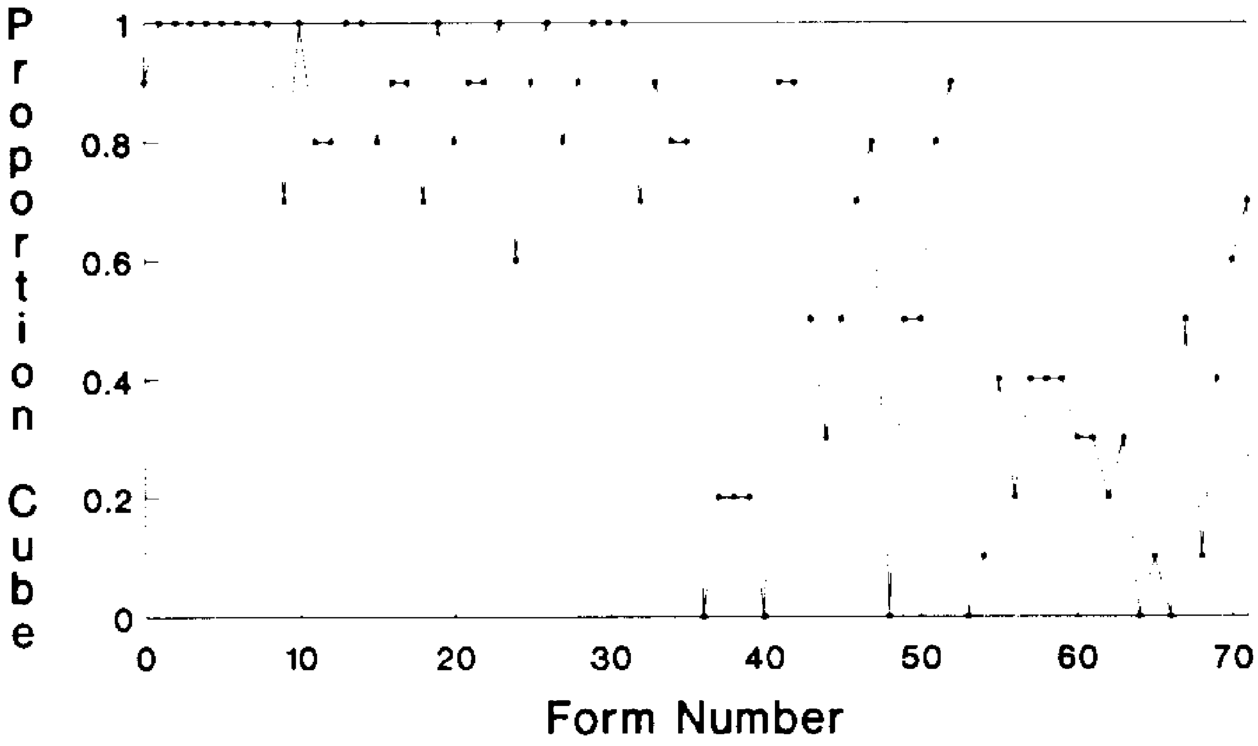


Figure 7 (continued)
Group 2

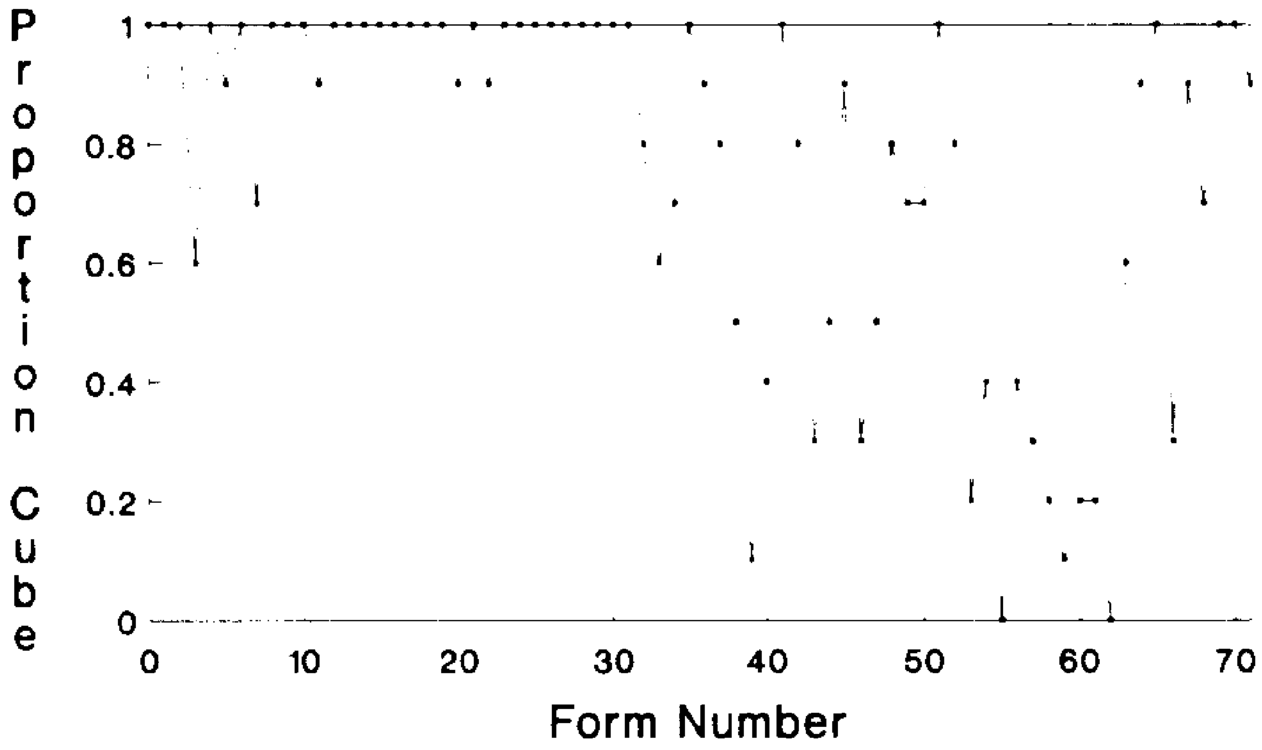


Figure 7
Group 3

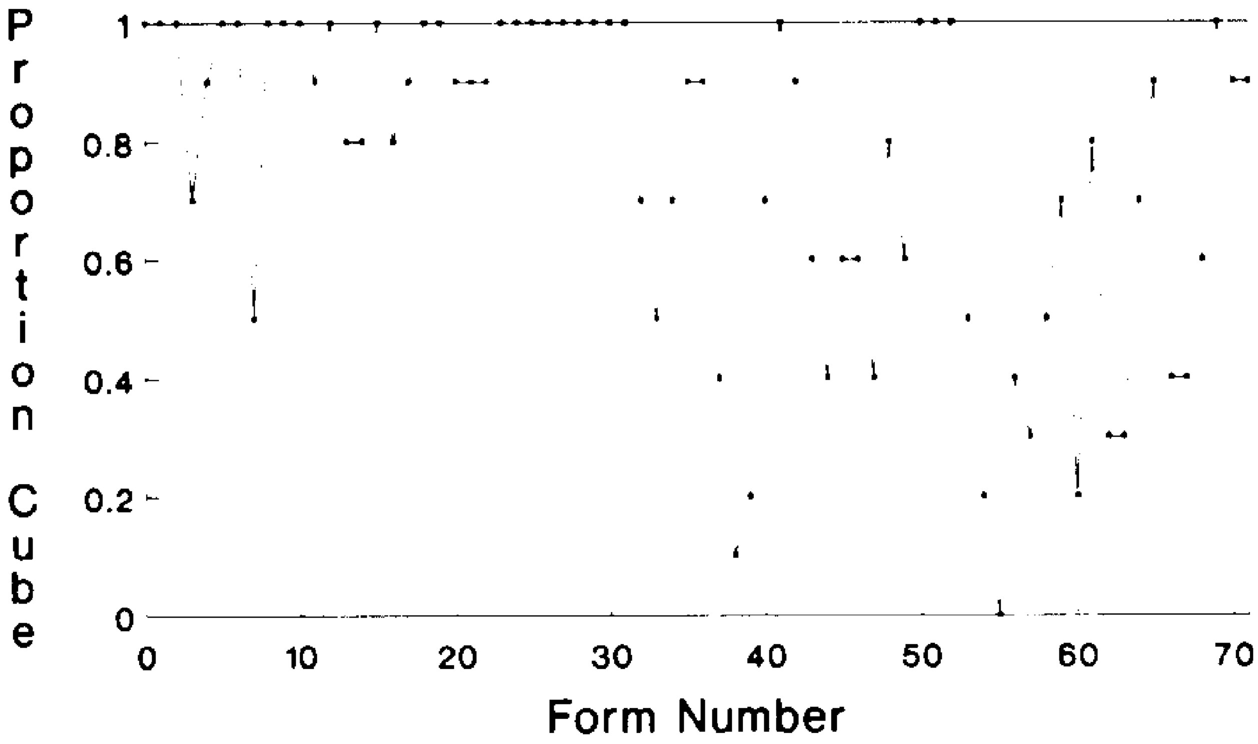


Table 6

Correlations of Actual Performance with Simulations

	Proportion Correct/ Simulation r
Group 1 Mean	0.60
Bird11	0.56
Bird13	0.6
Group 2 Mean	0.61
Bird21	0.48
Bird22	0.56
Bird24	0.65
Bird34	0.44
All Birds	0.55

Correlations between performance of the actual pigeons and simulated performance are presented in Table 6. The correlations for the pigeons in Group 2 and Group 3 varied widely, from 0.44 to 0.65. Compared to the average performance for Group 2, the simulation correlated 0.56, with the best correlations obtained for the two pigeons who performed best during the learning phase, Bird22 and Bird24. Correlations of 0.48 and 0.44 were obtained for Bird21 from Group 2 and Bird34 from Group 3.

While the correlations between the model and pigeon are much lower than the ones obtained between the pigeons, they are not uncharacteristic of previous correlations obtained between actual and simulated data (Heinemann and Chase, 1990). Furthermore, these low correlations are not unexpected. Theoretically, the process being simulated, the generalization phase, assumed mastery of the discrimination presented during the acquisition phase of the experiment. This was not the case for the actual pigeons. Only two of the six pigeons came close to mastering their discriminations, while the rest achieved asymptotic performance considerably below perfection.

Overall, the results point to the conclusion that the pigeons were able to correctly categorize new instances of Cube and Distortion stimuli, whether they were trained on one, two, or four Cube/Distortion pairs.

The dimension of rotation had no predictable or uniform effect on the generalization gradients. This was expected to occur if the pigeons had extracted the underlying three-dimensional aspects of the two-dimensional projections. Since no evidence of this effect was detected, the results lend further support to the hypothesis that pigeons do not extract the three-dimensional aspects of the projections.

While radiant flux was a possible dimension by which the Cube and Distortion stimuli could be correctly categorized, it seems unlikely that this was the major factor responsible. Performance on the generalization stimuli was consistent between groups for all the pigeons. This strongly supports the conclusion that all pigeons used the same underlying principles for categorization during the generalization phase. Since the first group of pigeons was trained on a set of stimuli that were equal in radiant flux, and it is unlikely that pigeons using different means of categorization would be so highly correlated, it is unlikely that radiant flux was the underlying dimension of categorization.

Finally, the evidence lends strong support to the hypothesis that the underlying process of categorization is the one suggested by the Heinemann and Chase model. Correlations demonstrate a high degree of agreement between the actual generalization performance of the pigeons, and the simulated data of the model. As expected, rotation had no effect on the performance of the pigeons during the generalization phase of the experiment. And the radiant flux of the forms, while a reasonable dimension to discriminate and categorize the forms on, was shown to be an unlikely dimension upon which to base the categorization process.

Appendix A
Simulation Program

```
00020 RANDOMIZE
00030 NUMSTIM = 72
00040 NUMRESP = 8
00050 SESSIONLEN = 5
00060 MEMSIZE = 1200
00070 THETA = 10
00080 DIM OBJECT(4,102)
00090 DIM LTM(1200),STM(10)
00100 DIM MATRIX(71,71)
00110 DIM FORMSX(71,102)
00120 DIM FORMSY(71,102)
00130 SPACING = 1.5
00140 FOR I = 1 TO MEMSIZE
00150 REM READMEM: LINE 150
00160 READ TEMP
00170 IF TEMP = -99 THEN RESTORE
00180 IF TEMP = -99 THEN GOTO 150
00190 LTM(I) = TEMP
00200 NEXT I
00210 GOSUB 7310
00220 FOR TRIAL = 1 TO SESSIONLEN
00230 FOR STIM = 0 TO NUMSTIM - 1
00240 PRINT
00250 PRINT 'Trial = ';TRIAL;'Stimulus = ';STIM
00260 FORMNUM = STIM
00270 SS = 1
00280 RESAM = 0
00290 GOSUB 7210
00300 REM          *****     DRAW SAMPLE     *****
00310 REM DRAWSAM: LINE 310
00320 FOR I = 1 TO THETA
00330 X = INT(RND * MEMSIZE)
00340 IF X = 0 THEN X = MEMSIZE
00350 STM(I) = LTM(X)
00360 NEXT I
00370 MAXDEN = -100
00380 CHOICE = -100
00390 FOR COMPARISON = 1 TO THETA
00400 JOINTDENSITY = 0
00410 FORMNUM = STM(COMPARISON)
00420 SS = 3
00430 GOSUB 7210
00440 FOR I = 1 TO OBJECT(3,0)
00450 ZZ = RND
00460 Z = ((ZZ ^ 0.135 - (1 - ZZ) ^ 0.135)/0.198)
00470 OBJECT(3,I) =  OBJECT(3,I) + Z
00480 ZZ = RND
00490 Z = ((ZZ ^ 0.135 - (1 - ZZ) ^ 0.135)/0.198)
```

```
00500 OBJECT(4,I) =  OBJECT(4,I) + Z
00510 NEXT I
00520 PRINT 'Comparison number ';COMPARISON
00530 FOR STIMPT = 1 TO OBJECT(1,0)
00540 D = 0
00550 DSUM = 0
00560 FOR MEMPT = 1 TO OBJECT(3,0)
00570 ZX = OBJECT(1,STIMPT) - OBJECT(3,MEMPT)
00580 ZY = OBJECT(2,STIMPT) - OBJECT(4,MEMPT)
00590 ZI = (ZX ^ 2) + (ZY ^ 2)
00600 IF ZI > 25 THEN D = 0 ELSE D = EXP(-ZI/2)/2.50663
00610 REM
00620 DSUM = DSUM + D
00630 NEXT MEMPT
00640 IF DSUM = 0 THEN JOINTDENSITY = 0
00650 DSUM = DSUM/OBJECT(3,0)
00660 IF DSUM = 0 THEN GOTO 730
00670 JOINTDENSITY = JOINTDENSITY + LOG(DSUM)
00680 NEXT STIMPT
00690 JOINTDENSITY = JOINTDENSITY/OBJECT(3,0)
00700 JOINTDENSITY = EXP(JOINTDENSITY)
00710 IF JOINTDENSITY > MAXDEN THEN CHOICE = FORMNUM
00720 IF JOINTDENSITY > MAXDEN THEN MAXDEN = JOINTDENSITY
00730 NEXT COMPARISON
00740 IF MAXDEN <> 0 THEN GOTO 810
00750 RESAM = RESAM + 1
00760 IF RESAM < 40 THEN GOTO 310
00770 G = G + 1
00780 X = INT(RND * MEMSIZE)
00790 IF X = 0 THEN X = MEMSIZE
00800 CHOICE = LTM(X)
00810 REM RECORD: LINE 810
00820 MATRIX(STIM,CHOICE) = MATRIX(STIM,CHOICE) + 1
00830 NEXT STIM
00840 NEXT TRIAL
00850 REM          *****     END OF PROGRAM     *****
00860 STOP
00865 AC = 0
00870 FOR I = 0 TO 71
00880 FOR J = 0 TO 71
00882 AC = AC + 1
00884 IF AC = 20 THEN PRINT
00886 IF AC = 20 THEN AC = 1
00890 PRINT MATRIX(I,J);
00900 NEXT J
00902 NEXT I
00910 STOP
00920 REM
00930 REM DATA 30,66,-99
00940 REM DATA 19,30,55,66,-99
00950 DATA 1,12,19,30,37,48,55,66,-99
00960 REM DATA 1,6,12,17,19,24,30,35,37,42,
```

```
00970 REM DATA 48,53,55,60,66,71,-99
00980 REM  *****     DATA FOR FORMS GOES HERE     *****
07200 REM *****     SUBROUTINE TO GET FORMS     *****
07210 REM GETFILE: LINE 7210
07220 OBJECT(SS,0) = FORMSX(FORMNUM,0)
07230 FOR I = 1 TO OBJECT(SS,0)
07240 XCOOR = FORMSX(FORMNUM,I)
07250 YCOOR = FORMSY(FORMNUM,I)
07260 OBJECT(SS,I) = XCOOR*SPACING+10
07270 OBJECT(SS+1,I) = YCOOR*SPACING+10
07280 NEXT I
07290 RETURN
07300 REM *****     SUBROUTINE TO LOAD ALL FORMS     *****
07310 REM START: LINE 7310
07320 RESTORE
07330 REM READAGAIN: LINE 7330
07340 READ TEMP
07350 IF TEMP = -99 THEN GOTO 7370
07360 GO TO 7330
07370 REM REAL: LINE 7370
07380 FOR I = 0 TO 71
07390 READ FORMSX(I,0)
07400 FOR J = 1 TO FORMSX(I,0)
07410 READ FORMSX(I,J)
07420 READ FORMSY(I,J)
07430 NEXT J
07440 NEXT I
07450 RETURN
07460 END
```

Appendix B
Acquisition Data

Proportion Correct During Acquisition Phase for Group 1

SESSION	BIRD11	BIRD12	BIRD13	BIRD14
1	.475	.375	.500	.588
2	.588	.350	.463	.288
3	.563	.350	.488	.450
4	.488	.413	.500	.438
5	.450	.400	.538	.450
6	.500	.438	.538	.550
7	.513	.463	.513	.450
8	.575	.500	.500	.475
9	.525	.475	.438	.438
10	.513	.550	.588	.413
11	.538	.475	.525	.513
12	.513	.488	.513	.488
13	.550	.475	.500	.500
14	.488	.450	.488	.488
15	.550	.488	.488	.613
16	.488	.500	.475	.613
17	.638	.575	.563	.600
18	.488	.450	.400	.538
19	.663	.563	.600	.525
20	.513	.475	.475	.475
21	.513	.550	.450	.488
22	.625	.438	.575	.500
23	.600	.488	.513	.538
24	.588	.500	.450	.513
25	.625	.500	.563	.475
26	.613	.438	.450	.538
27	.638	.450	.429	.363
28	.575	.525	.563	.550
29	.525	.563	.438	.600
30	.575	.500	.613	.663
31	.750	.425	.438	.638
32	.688	.475	.500	.550
33	.638	.475	.488	.613
34	.613	.600	.475	.525
35	.713	.538	.488	.525
36	.600	.538	.488	.538
37	.588	.350	.475	.563
38	.600	.488	.500	.538
39	.613	.488	.538	.525
40	.575	.475	.538	.425
41	.650	.463	.475	.550

(continued)

SESSION	BIRD11	BIRD12	BIRD13	BIRD14
42	.675	.488	.563	.475
43	.450	.525	.613	.550
44	.625	.463	.538	.413
45	.538	.575	.525	.488
46	.650	.513	.563	.463
47	.713	.563	.563	.463
48	.750	.463	.563	.550
49	.613	.525	.550	.513
50	.725	.450	.488	.438
51	.725	.538	.575	.475
52	.638	.500	.488	.513
53	.775	.438	.563	.475
54	.775	.513	.463	.463
55	.613	.513	.538	.475
56	.688	.475	.500	.563
57	.713	.513	.513	.538
58	.700	.513	.588	.550
59	.725	.500	.550	.550
60	.713	.500	.638	.500
61	.625	.500	.575	.513
62	.663	.513	.538	.463
63	.663	.488	.513	.463
64	.763	.488	.525	.475
65	.675	.450	.525	.538
66	.688	.463	.513	.488
67	.688	.513	.525	.475
68	.688	.475	.563	.575
69	.663	.463	.575	.500
70	.625	.525	.563	.538
71	.663	.513	.521	.525
72	.700	.538	.563	.463
73	.638	.525	.575	.538
74	.650	.425	.513	.638
75	.725	.563	.600	.488
76	.625	.525	.663	.475
77	.663	.475	.575	.525
78	.688	.583	.700	.500
79	.800	.538	.638	.450
80	.750	.450	.638	.525
81	.775	.413	.750	.513
82	.713	.500	.588	.438
83	.713	.474	.725	.463

(continued)

SESSION	BIRD11	BIRD12	BIRD13	BIRD14
84	.750	.500	.775	.475
85	.763	.508	.750	.538
86	.638	.500	.675	.613
87	.700	.513	.663	.450
88	.713	.588	.675	.450
89	.738	.425	.688	.588
90	.813	.550	.663	.475
91	.600	.488	.713	.475
92	.700	.563	.738	.438
93	.638	.425	.750	.550
94	.738	.463	.788	.413
95	.850	.463	.775	.525
96	.713	.514	.613	.413
97	.800	.470	.663	.525
98	.663	.538	.725	.463
99	.838	.541	.775	.463
100	.750	.513	.700	.563
101	.750	.463	.613	.500
102	.588	.550	.675	.563
103	.813	.500	.600	.550
104	.813	.488	.663	.463
105	.775	.488	.675	.450
106	.688	.550	.775	.500
107	.675	.425	.713	.538
108	.763	.513	.650	.525
109	.750	.550	.663	.513
110	.713	.575	.613	.400
111	.675	.488	.705	.463
112	.788	.438	.738	.488
113	.625	.450	.838	.525
114	.725	.513	.675	.488
115	.713	.488	.475	.425
116	.600	.475	.625	.563
117	.875	.463	.713	.438
118	.750	.500	.700	.438
119	.788	.463		.488
120	.838	.463		.463
121	.763	.475		.500
122	.750	.463		.488
123		.513		.513
124		.463		.500
125		.525		.463

(continued)

SESSION	BIRD11	BIRD12	BIRD13	BIRD14
126		.513		.525
127		.463		.513
128		.500		.563
129		.438		.450
130		.463		.463
131		.513		.488
132		.513		.525
133		.500		.575
134		.525		.550
135		.488		.550
136		.538		.438
137		.475		.500
138		.425		.525
139		.564		.438
140		.539		.475
141		.450		.525
142		.500		.525
143		.500		.425
144		.563		.550
145		.613		.488
146		.463		.588
147		.532		.513
148		.468		.463
149				.525
150				.513
151				.525

Proportion Correct During Acquisition Phase for Group 2

SESSION	BIRD21	BIRD22	BIRD23	BIRD24
1	.550	.563	.475	.400
2	.488	.170	.500	.475
3	.575	.338	.550	.288
4	.488	.450	.525	.450
5	.500	.488	.500	.475
6	.513	.538	.538	.625
7	.538	.588	.475	.575
8	.600	.525	.438	.538
9	.525	.588	.463	.513
10	.575	.600	.463	.588
11	.431	.613	.525	.575
12	.563	.788	.438	.663
13	.463	.625	.450	.763
14	.538	.775	.425	.638
15	.538	.825	.538	.700
16	.525	.650	.525	.650
17	.525	.663	.513	.488
18	.550	.825	.475	.625
19	.488	.875	.475	.775
20	.575	.875	.425	.688
21	.513	.763	.413	.663
22	.538	.763	.488	.750
23	.500	.500	.538	.750
24	.550	.775	.463	.763
25	.500	.850	.463	.750
26	.488	.750	.463	.750
27	.488	.863	.425	.713
28	.588	.800	.475	.650
29	.538	.725	.425	.663
30	.575	.713	.650	.650
31	.563	.863	.563	.825
32	.588	.913	.538	.750
33	.650	.913	.463	.850
34	.575	.963	.450	.813
35	.638	.888	.450	.788
36	.625	.863	.475	.813
37	.588	.850	.563	.850
38	.638	.825	.404	.800
39	.692	.838	.613	.775
40	.663	.850	.418	.675
41	.625	.788	.500	.775

(continued)

SESSION	BIRD21	BIRD22	BIRD23	BIRD24
42	.638	.913	.538	.700
43	.663	.775	.438	.725
44	.663	.875	.488	.850
45	.575	.813	.488	.738
46	.545	.925	.450	.863
47	.588	.888	.488	.788
48	.738	.850	.513	.788
49	.688	.863	.613	.775
50	.600	.888	.563	.788
51	.600	.888	.534	.838
52	.563	.925	.525	.838
53	.538	.800	.488	.813
54	.563	.838	.488	.763
55	.638	.888	.500	.850
56	.588	.900	.513	.825
57	.688	.825	.538	.900
58	.588	.938	.588	.900
59	.550	.900	.463	.825
60	.550	.888	.500	.850
61	.775	.888	.488	.850
62	.600	.950	.438	.900
63	.650	.913	.525	.850
64	.738	.838	.500	.875
65	.663	.863	.550	.888
66	.713	.925	.500	.900
67	.638	.988	.488	.863
68	.688	.938	.438	.875
69	.688	.913	.463	.913
70	.638	.950	.550	.938
71	.513	.913	.575	.863
72	.625	.925	.513	.913
73	.725	.938	.550	.975
74	.838	.925	.538	.913
75	.707	.975	.438	.800
76	.725	.938	.538	.925
77	.675	.963	.513	.925
78	.750	.950	.525	.900
79	.725	.975	.463	.913
80	.688	.975	.513	.875
81	.663	.963	.525	.625
82	.588	.988	.538	.875
83	.625	.975	.500	.913

(continued)

SESSION	BIRD21	BIRD22	BIRD23	BIRD24
84	.725	.963	.488	.925
85	.650	.988	.463	.863
86	.763	.988	.475	.850
87	.775	.963	.488	.750
88	.850	.988	.413	.800
89	.713	.963	.500	.813
90	.688	.975	.538	.888
91	.663	.938	.550	.838
92	.800	.963	.513	.913
93	.700	.963	.525	.838
94	.638	.925	.488	.938
95	.638	.950	.525	.950
96	.688	.975	.488	.950
97	.713	1.000	.438	.925
98	.675	.963	.525	.938
99	.625	.988	.475	.938
100	.725	.888	.500	.788
101	.713	.988	.538	.875
102	.713	.975	.438	.913
103	.638	.963	.488	.900
104	.763	.975	.488	.925
105	.775	.950	.513	.900
106	.713	.975	.513	.925
107		.988	.563	.863
108		1.000	.488	.963
109		.988	.550	.925
110		.988	.513	.963
111		1.000	.525	.913
112		.988	.463	.913
113		.988	.513	.963
114		.938	.488	.925
115		.988	.475	.888
116		.963	.550	.813
117		.988	.500	.950
118		.975	.475	.950
119		1.000	.463	.938
120		1.000	.538	.938
121		1.000	.500	.950
122			.513	
123			.488	
124			.475	
125			.475	

(continued)

SESSION	BIRD21	BIRD22	BIRD23	BIRD24
126			.388	
127			.475	
128			.600	
129			.475	
130			.475	
131			.488	
132			.425	
133			.438	
134			.525	
135			.513	
136			.475	
137			.563	
138			.513	
139			.513	
140			.563	
141			.500	
142			.475	
143			.488	
144			.463	
145			.450	
146			.500	
147			.463	
148			.500	
149			.488	

Proportion Correct During Acquisition Phase for Group 3

SESSION	BIRD31	BIRD32	BIRD33	BIRD34
1	.525	.350	.413	.450
2	.550	.500	.550	.538
3	.488	.538	.463	.500
4	.588	.488	.525	.463
5	.488	.488	.463	.488
6	.450	.461	.425	.475
7	.525	.438	.475	.500
8	.500	.475	.475	.500
9	.575	.500	.475	.400
10	.588	.513	.475	.513
11	.425	.688	.613	.475
12	.563	.500	.500	.575
13	.513	.513	.538	.475
14	.463	.538	.500	.575
15	.475	.513	.475	.438
16	.500	.400	.575	.425
17	.525	.538	.538	.525
18	.513	.525	.463	.575
19	.538	.513	.550	.575
20	.563	.563	.538	.513
21	.438	.438	.513	.575
22	.475	.488	.450	.563
23	.513	.488	.513	.538
24	.513	.538	.638	.513
25	.550	.550	.525	.538
26	.675	.463	.500	.600
27	.463	.538	.550	.488
28	.475	.575	.500	.525
29	.475	.538	.488	.600
30	.538	.450	.438	.650
31	.413	.563	.425	.663
32	.488	.525	.488	.650
33	.575	.588	.525	.650
34	.550	.525	.525	.588
35	.538	.563	.438	.675
36	.538	.563	.475	.563
37	.513	.538	.550	.588
38	.550	.625	.500	.638
39	.563	.450	.513	.600
40	.500	.500	.488	.638
41	.550	.600	.500	.575

(continued)

SESSION	BIRD31	BIRD32	BIRD33	BIRD34
42	.538	.475	.513	.550
43	.525	.538	.550	.638
44	.613	.513	.500	.625
45	.588	.500	.438	.638
46	.550	.675	.538	.588
47	.475	.525	.575	.663
48	.613	.625	.513	.613
49	.525	.538	.488	.600
50	.600	.575	.625	.738
51	.550	.500	.475	.675
52	.575	.563	.550	.700
53	.575	.550	.500	.688
54	.550	.563	.525	.688
55	.550	.525	.563	.713
56	.538	.650	.488	.663
57	.588	.550	.550	.713
58	.613	.538	.500	.563
59	.650	.618	.525	.775
60	.625	.525	.513	.738
61	.550	.625	.550	.713
62	.600	.475	.513	.650
63	.550	.550	.588	.700
64	.638	.613	.588	.738
65	.500	.625	.575	.550
66	.613	.613	.557	.713
67	.525	.563	.600	.750
68	.600	.550	.500	.775
69	.475	.650	.475	.713
70	.538	.538	.488	.750
71	.513	.475	.513	.700
72	.500	.550	.500	.713
73	.513	.463	.550	.750
74	.538	.451	.600	.700
75	.575	.467	.575	.700
76	.613	.574	.588	.750
77	.575	.538	.425	.713
78	.613	.488	.400	.738
79	.575	.438	.488	.788
80	.688	.500	.438	.750
81	.575	.663	.488	.788
82	.638	.550	.475	.650
83	.688	.575	.525	.738

(continued)

SESSION	BIRD31	BIRD32	BIRD33	BIRD34
84	.650	.590	.488	.688
85	.563	.538	.475	.713
86	.700	.513	.559	.788
87	.550	.525	.563	.713
88	.600	.488	.481	.763
89	.625	.481	.563	.738
90	.550	.538	.525	.688
91	.725	.488	.400	.738
92	.650	.575	.538	.738
93	.688	.588	.550	.688
94	.625	.500	.538	.713
95	.550	.488	.400	.738
96	.675	.575	.513	.788
97	.588	.538	.488	.788
98	.675	.563	.513	.788
99	.563	.650	.513	.763
100	.600	.563	.525	.675
101	.563	.488	.438	.663
102	.625	.500	.550	.788
103	.613	.513	.563	.863
104	.638	.488	.500	.800
105	.550	.563	.575	.763
106	.600	.538	.538	.788
107	.575	.550	.525	.925
108	.588	.513	.538	.738
109	.650	.588	.563	.800
110	.638	.538	.525	.813
111	.638	.538	.525	.763
112	.650	.563	.600	.813
113	.638	.513	.525	.775
114	.613	.550	.600	.838
115	.525	.563	.413	.800
116	.613	.525	.550	.825
117	.650	.538	.438	.788
118	.538	.550	.563	.775
119	.663	.550	.538	.788
120	.613	.538	.430	.700
121	.663	.575	.513	.675
122	.725	.513	.575	
123	.688	.613	.550	
124	.713	.550	.513	
125	.725	.563	.538	

(continued)

SESSION	BIRD31	BIRD32	BIRD33	BIRD34
126	.763	.538	.500	
127	.638	.513	.550	
128	.650	.525	.513	
129	.675	.563	.538	
130	.713	.550	.488	
131	.550	.525	.525	
132	.763	.550	.488	
133	.588	.538	.488	
134	.650	.550	.563	
135	.688	.500	.525	
136	.650	.600	.400	
137	.750	.600	.513	
138	.700		.500	
139	.725		.513	
140	.750		.400	
141	.650		.500	
142	.738		.525	
143	.700		.450	
144	.588		.588	
145	.775		.550	
146	.538		.425	
147	.725		.538	
148			.588	

Proportion Correct During Acquisition Phase for Group 4

SESSION	BIRD41	BIRD42	BIRD43	BIRD44
1	.475	.363	.488	.427
2	.500	.500	.588	.475
3	.475	.500	.500	.550
4	.525	.575	.450	.413
5	.475	.463	.463	.525
6	.563	.588	.488	.525
7	.450	.338	.550	.488
8	.513	.463	.563	.463
9	.450	.500	.413	.438
10	.425	.388	.538	.475
11	.575	.525	.413	.538
12	.525	.550	.550	.550
13	.513	.425	.463	.475
14	.488	.500	.463	.538
15	.488	.475	.450	.500
16	.400	.538	.450	.525
17	.525	.463	.575	.550
18	.488	.513	.525	.563
19	.513	.413	.500	.438
20	.475	.575	.425	.488
21	.538	.600	.438	.500
22	.538	.513	.475	.538
23	.538	.500	.550	.450
24	.488	.550	.488	.488
25	.375	.513	.563	.500
26	.550	.625	.525	.475
27	.563	.475	.563	.450
28	.450	.588	.463	.488
29	.438	.463	.575	.500
30	.550	.538	.525	.450
31	.438	.550	.475	.575
32	.525	.525	.513	.463
33	.600	.475	.538	.513
34	.563	.513	.550	.450
35	.600	.538	.463	.638
36	.500	.513	.463	.475
37	.488	.550	.525	.588
38	.450	.500	.525	.450
39	.488	.425	.513	.438
40	.488	.500	.538	.563
41	.475	.475	.525	.538

(continued)

SESSION	BIRD41	BIRD42	BIRD43	BIRD44
42	.550	.450	.600	.488
43	.538	.500	.550	.425
44	.550	.525	.538	.488
45	.425	.475	.513	.513
46	.563	.513	.563	.538
47	.450	.425	.450	.600
48	.475	.564	.550	.425
49	.400	.475	.500	.575
50	.538	.538	.550	.513
51	.488	.550	.575	.538
52	.513	.488	.500	.563
53	.538	.513	.513	.475
54	.538	.488	.525	.525
55	.513	.500	.588	.538
56	.413	.500	.500	.475
57	.488	.600	.488	.472
58	.500	.475	.575	.625
59	.550	.463	.547	.675
60	.438	.525	.513	.463
61	.438	.538	.563	.488
62	.400	.513	.688	.500
63	.463	.538	.613	.600
64	.500	.500	.475	.388
65	.488	.500	.538	.538
66	.563	.488	.538	.538
67	.525	.513	.525	.513
68	.500	.513	.438	.538
69	.463	.538	.638	.525
70	.525	.525	.675	.475
71	.463	.600	.513	.463
72	.563	.550	.438	.513
73	.550	.513	.600	.475
74	.400	.550	.613	.538
75	.563	.500	.613	.475
76	.475	.563	.513	.475
77	.563	.525	.575	.600
78	.450	.463	.463	.425
79	.600	.488	.588	.550
80	.488	.400	.600	.475
81	.575	.538	.563	.588
82	.525	.513	.500	.575
83	.575	.500	.575	.438

(continued)

SESSION	BIRD41	BIRD42	BIRD43	BIRD44
84	.475	.488	.488	.563
85	.450	.513	.513	.538
86	.450	.425	.588	.538
87	.463	.463	.575	.563
88	.525	.550	.500	.688
89	.438	.600	.525	.663
90	.538	.550	.550	.513
91	.513	.450	.625	.538
92	.488	.563	.463	.588
93	.525	.563	.450	.575
94	.525	.500	.600	.488
95	.488	.638	.425	.675
96	.550	.413	.500	.513
97	.513	.500	.500	.638
98	.450	.475	.525	.600
99	.463	.425	.588	.525
100	.500	.575	.563	.563
101	.488	.538	.563	.588
102	.488	.550	.375	.513
103	.538	.588	.538	.538
104	.500	.475	.475	.550
105	.613	.538	.600	.500
106	.525	.550	.563	.538
107	.563	.550	.500	.575
108	.450	.613	.588	.613
109	.525	.613	.525	.538
110	.538	.450	.588	.463
111	.463	.475	.500	.550
112	.600	.575	.513	.513
113	.488	.425	.600	.638
114	.525	.514	.540	.550
115	.538	.575	.513	.625
116	.575	.550	.629	.538
117	.525	.425	.525	.513
118	.550	.525	.588	.538
119	.475	.463	.472	.575
120	.463	.550	.589	.550
121	.513	.513	.450	.463
122	.475	.438	.763	.575
123	.475	.513	.425	.513
124	.475	.600	.550	.738
125	.500	.438	.538	.563

(continued)

SESSION	BIRD41	BIRD42	BIRD43	BIRD44
126	.463	.488	.563	.488
127	.475	.513	.488	.588
128	.475	.550	.525	.488
129	.463	.438	.513	.514
130	.475	.425	.550	.550
131	.525	.513	.463	.525
132	.538	.475	.425	.500
133	.525	.500	.575	.413
134	.488	.513	.638	.413
135	.463	.413	.400	.650
136	.538	.438	.575	.525
137	.500	.525	.550	.475
138	.538	.550	.538	.463
139	.438	.425	.550	.513
140	.438	.475	.563	.588
141	.525	.525		
142	.550	.500		

Appendix C
Generalization Data

Proportion of **Responses as Cube to Generalization Data**

	PROPORTION CUBE					
Form Number	BIRD11	BIRD13	BIRD21	BIRD22	BIRD24	BIRD34
0	.795	.795	.565	.955	.795	.283
1	.614	.455	.565	.978	.909	.696
2	.318	.227	.370	.400	.477	.478
3	.455	.364	.370	.196	.591	.674
4	.523	.773	.500	.500	.841	.696
5	.682	.886	.696	.935	.886	.587
6	.295	.409	.391	.311	.364	.435
7	.318	.227	.283	.136	.250	.500
8	.864	.727	.543	.867	.705	.522
9	.795	.795	.565	.955	.795	.283
10	.432	.159	.543	.911	.773	.500
11	.432	.114	.413	.022	.386	.391
12	.773	.386	.522	.222	.364	.652
13	.818	.818	.587	.600	.750	.717
14	.705	.636	.587	.711	.841	.696
15	.432	.591	.643	.000	.500	.563
16	.864	.773	.391	.756	.659	.522
17	.864	.977	.543	1.000	.841	.848
18	.795	.795	.565	.955	.795	.283
19	.773	.636	.714	.990	.870	.750
20	.750	.341	.587	.870	.841	.674
21	.773	.523	.565	.667	.864	.609
22	.614	.523	.348	.652	.864	.674
23	.841	.636	.587	.733	.818	.652
24	.591	.636	.565	.773	.841	.652
25	.795	.659	.522	.867	.864	.609
26	.841	.636	.609	.978	.750	.552
27	.795	.795	.565	.955	.795	.283
28	.705	.886	.717	1.000	.864	.674
29	.864	.886	.543	1.000	.864	.696
30	.872	.890	.649	.985	.905	.688
31	.909	.886	.500	.933	.909	.761
32	.750	.795	.674	.778	.977	.630
33	.818	.818	.609	.761	.727	.587
34	.909	.773	.609	.933	.909	.696
35	.818	.864	.891	.956	.886	.783
36	.205	.091	.348	.067	.250	.065

(continued)

	PROPORTION CUBE					
Form Number	BIRD11	BIRD13	BIRD21	BIRD22	BIRD24	BIRD34
37	.386	.227	.391	.556	.545	.261
38	.432	.205	.500	.689	.591	.435
39	.227	.023	.348	.067	.273	.326
40	.205	.136	.174	.000	.045	.065
41	.886	.477	.370	.222	.409	.304
42	.886	.841	.674	.826	.864	.913
43	.864	.773	.630	.750	.818	.783
44	.545	.727	.565	.761	.864	.609
45	.773	.750	.674	.886	.886	.652
46	.591	.568	.696	.913	.886	.500
47	.250	.091	.587	.114	.432	.196
48	.227	.023	.500	.022	.318	.326
49	.227	.159	.391	.022	.386	.326
50	.273	.364	.348	.043	.455	.413
51	.273	.295	.217	.087	.341	.435
52	.273	.545	.283	.044	.364	.391
53	.250	.318	.370	.065	.205	.326
54	.250	.273	.152	.000	.045	.174
55	.114	.114	.192	.004	.023	.087
56	.114	.182	.174	.000	.000	.065
57	.159	.068	.174	.022	.023	.043
58	.250	.091	.152	.000	.023	.152
59	.114	.182	.261	.000	.000	.109
60	.250	.091	.304	.022	.045	.196
61	.409	.114	.348	.000	.295	.261
62	.477	.182	.413	.067	.227	.239
63	.636	.205	.435	.200	.432	.435
64	.227	.159	.261	.267	.386	.348
65	.341	.114	.435	.136	.432	.326
66	.137	.095	.377	.015	.265	.348
67	.159	.136	.261	.067	.273	.391
68	.636	.455	.304	.289	.591	.500
69	.818	.932	.652	.933	.909	.804
70	.750	.932	.543	.977	.932	.717
71	.614	.614	.457	1.000	.818	.348

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