Object-discrimination learning set and hypothesis behavior in the northern bluejay *(Cynaocitta cristata)**

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Four bluejays received 700 problems of object-discrimination learning set. Acquisition of the task was shown by an average performance level of 72% correct for Trial 2 on the last 100 problems of the experiment. This figure is superior to asymptotic Trial 2 levels for many subprimate mammalian species and comparable to the marmoset (Warren, 1965). A detailed analysis of the data for "hypothesis behavior" (Levine, 1965) revealed several important features of the Ss' responding, many of potential comparative significance. In particular, consistent decreases in responding due to stimulus preferences and third trial learning, a dramatic drop in random responding, and steady increases in WSLS-object (maximum strategy) coincided with increasing proficiency.

Many species have been tested in learning-set experiments (see Warren, 1965, for review), and quantitative and qualitative species differences have been demonstrated. Very few of these efforts have involved avian forms. Recently, however, Kamil & Hunter (1970) demonstrated learning-set acquisition in the Greater Hill Myna *(Gracula religiosa)*, a member of the family *Corvidae*. The primary purpose of the present experiment was to increase the generality of the Kamil and Hunter results by examining the performance of another corvid, the Northern bluejay *(Cyanocitta cristata)*. In addition, the present experiment was specifically designed to provide estimates of hypothesis behavior (Levine, 1959) during learning-set acquisition.

SUBJECTS

The Ss were four bluejays *(Cyanocitta cristata)* captured locally when approximately 14 days old and hand-raised in the laboratory. The Ss were maintained on a free-feeding schedule of food and water for 4 months prior to the experiment.

APPARATUS

The apparatus was a modified version of the WGTA, identical to that employed by Kamil & Hunter (1970). The bird chamber was made of Masonite, 26.7 x 33 x 33 cm high, with a wooden perch located at one end. A smaller wooden enclosure was attached to the outside of the animal chamber on the end nearest the perch. The interior floor of this enclosure contained two shallow foodwells, 6.3 cm apart. The S's access was

through small rectangular ports in front of the foodwells. A Masonite guillotine door separated the foodwell area from the animal chamber during intertrial intervals, and a hinged door constructed of perforated circuit board separated the E from the foodwell enclosure during a trial. The interior of the foodwell area was lit by two 10-W bulbs. All interior portions of the apparatus were painted with nontoxic gray paint. During experimental sessions, the test chamber was inserted into an acoustically tiled cubicle, inside which masking white noise was generated.

The stimuli were three-dimensional "junk" objects (toys, wooden forms, etc.) varying in many dimensions. Reinforcement was one-half of a mealworm *(Tenebrio* larvae).

PROCEDURE

The experiment was conducted in three stages: habituation, shaping, and learning-set acquisition. During habituation, each S was gradually reduced to 85% of his free-feeding body weight and maintained at that level for the duration of the experiment. At the same time that habituation to deprivation was begun, each S was given daily sessions in the apparatus with the guillotine door up and reinforcement available in both foodwells.

The next stage consisted of shaping, by successive approximations, the response of displacing a stimulus object. Two plain wooden blocks served as stimulus objects. A shaping session consisted of 25 trials on which both foodwells were baited. The degree to which the objects covered the foodwells was gradually increased until the S was retrieving reinforcement from completely covered foodwells. After 10 shaping sessions, all Ss were displacing the stimulus objects from completely covered foodwells.

Learning-set training began immediately after shaping was completed. During the 183 learning-set sessions, each S received 700 object-quality discrimination problems. Problem length was systematically decreased according to the following schedule: Problems 1-25 were each 25 trials in length, Problems 26-60 were 15 trials in length, Problems 61-150, 10 trials each, and Problems 151-700, 6 trials each. A noncorrection procedure was used on each trial, and each session consisted of 25 or 30 trials each, depending on individual problem length at that point. The decreasing schedule of trials per problem was followed in order to insure that within-problem learning took place at every stage of the experiment, as suggested by Harlow (1959).

Each new problem was defined by introduction of a new pair of objects. Since only a limited set of 100 objects for Problems 1-200 and 180 objects for Problems 201-700 were available, a random re-pairing procedure, as described in detail by Kamil & Hunter (1970), was employed. In order to maximize the ability to get hypothesis estimates (Levine, 1959) during learning-set acquisition, care was taken to insure that all possible sequences of position of reward were employed in the first three trials of each problem. All six possible sequences were used equally during Problems 151-700. With this restriction, position of the correct object varied randomly in all problems for all Ss.

RESULTS AND DISCUSSION

Figure 1 shows the average within-problem performance on Trials 1-6 over four selected 100-problem blocks. It is clear from these data that learning-set acquisition occurred. This is best seen in the changed shape of the intraproblem learning curve. Whereas the curve for Problems 1-100 can be best described as an increasing linear function of trial number, the curve from Problems 601-700 is decidedly nonlinear. On this last problem block the largest increment in percentage correct occurs between Trials 1 and 2.

Figure 2 shows the average percentage correct for each trial, 2-6 inclusive, on each problem block of the experiment. Mean Trial 2 performance during the last problem block of the experiment was 73% correct. This result is quite similar to that found in mynas, as well as terminal Trial 2 performance in squirrel monkeys (Miles, 1957) and marmosets (Miles & Meyer, 1956).

However, while overall comparisons of learning-set acquisition in a variety
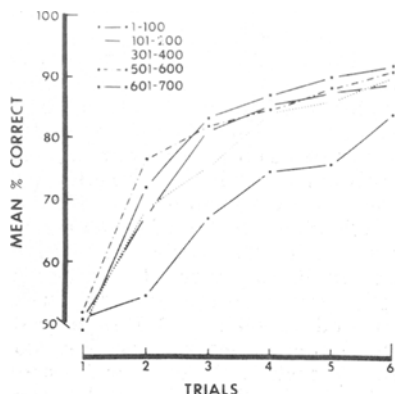
Fig. 1. Mean percentage correct on Trials 1-6 for five representative 100-problem blocks of acquisition.

of species have some interesting implications, a more important and basic question exists. This concerns the extent to which the learning processes utilized in the learning-set situation are similar or differ among various species. It seems relatively unlikely that learning-set behavior itself, improvement in problem solution after hundreds of problems, is of selective value. Rather, it is probably more profitable to think of the mechanisms or processes underlying the behavior in considering the problem of the evolution of behavioral plasticity.

The most interesting learning-set model developed at present is one which, in general, emphasizes the learning of response patterns or hypotheses which are present in all problems, as opposed to particular choice responses which change as problems change. This type of model seems particularly powerful, since a variety of different phenomena have been shown to be compatible with it, including transfer to learning set from reversal learning (Schusterman, 1964; Warren, 1966), short-term memory in experienced rhesus monkeys (Bessemer, 1966), and learning of alternation learning sets (Behar, 1961).

Levine (1959) has developed a descriptive mathematical model of learning-set performance which is based on a response strategy conception of learning-set. The model yields probability estimates of the occurrence of various possible hypotheses in the first three trials of each problem. Kamil & Hunter (1970) found that this model fit the data of learning-set experienced myna birds fairly well but did not apply the model to acquisition. In order to see if the model would provide an informative and more detailed description of acquisition, probability estimates were obtained for three blocks of group data using Levine's Method I (for details see Levine, 1959, 1964). These blocks were formed by dividing acquisition into thirds, i.e., Problems 1-233, 234-466, and 467-700. Table 1 gives the results of this analysis, as well as the results Kamil & Hunter (1970) obtained in 160 problems in four mynas who had had 1,140 previous learning-set problems.
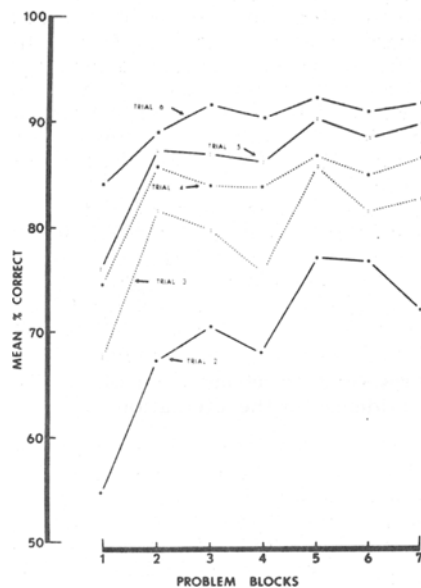

Fig. 2. Mean percentage correct on Trials 2 (bottom) to 6 (top) for each 100-problem block of the experiment.

The largest effect found in the hypothesis analysis was the increase in the win-stay/lose-shift object pattern. Since this is the only strategy which results in 100% correct responding on every trial after Trial 1 of all problems, this trend represents learning-set acquisition and does meaningfully parallel learning-set formation. This estimate is somewhat superior to that obtained in mynas, as should be expected by the higher level of percentage correct by the bluejays. During Problems 467-700, the bluejays were correct 75% and 83% on Trials 2 and 3, respectively. The comparable figures for the mynas on Problems 1,141-1,300 were 71% and 78%.

The increase in the frequency of occurrence of the win-stay/lose-shift object strategy, which maximizes reward across problems, was concomitant with a decrease in other less optimal strategies. Random responding, patterns which fit no particular response patterns, showed the largest drop. Third-trial learning refers to strategies which result in nonreward on Trial 2 and reward on Trial 3, a pattern which can be conceptualized as due to a change in hypothesis between Trials 2 and 3, showed a smaller decline. Finally, stimulus preference, which leads to 50% reward across problems, showed a small drop, which was consistent across blocks.

A third interesting pattern is the increase, then decrease, in the win-stay/lose-shift position estimates across acquisition. Kamil & Hunter (1970) found an unusually high probability for this particular pattern in mynas and suggested that this might represent the application of an appropriate learned response pattern, win-stay lose-shift, to an inappropriate stimulus dimension position. The pattern in bluejays during learning-set acquisition suggests that it is possible that the win-stay/lose-shift strategy is at first applied to position as well as object, but then the position dimension drops out, since it results in only 50% reward. Verification of this pattern for the win-stay/lose-shift

Table 1
Hypothesis Estimates for Bluejays and Learning-Set Experienced Mynas*

Group (Problem Block)	Hypotheses								
	Position Preference	Position Alternation	Win-Stay Lose-Shift (Position)	Stimulus Preference	Stimulus Alternation	Third-Trial Learning	Win-Stay Lose-Shift (Object)	Random Responding	PVE
Bluejay (1-233)	.012	.024	.065	.139	.022	.228	.249	.268	.71
Bluejay (234-466)	−.003	.033	.115	.100	.087	.175	.484	.084	.80
Bluejay (467-700)	.037	.040	.022	.079	.081	.128	.543	.084	.85
Myna (1141-1300)	.049	−.007	.143	.018	.074	.155	.412	.176	.78

*The Myna bird data is from Kamil & Hunter, 1970.

position in further experiments would be of considerable interest.

Levine (1959) devised a statistic, the percentage variance explained (PVE), which is a check of the internal consistency of the model, which can vary from 0 to 1. As seen in the last column of Table 1, these are quite respectable and, in general, are of the same order of magnitude as those Levine (1959) has reported for rhesus monkeys. The increasing magnitude of the PVE as acquisition proceeded is of interest. Levine's model assumes that the S does not change hypotheses during the three trials analyzed within a given problem. Violations of this assumption can show up as third-trial learning (when the shift in strategy is to the correct hypothesis) or as random responding (when the shift is to an incorrect hypothesis). Furthermore, since such changes in hypotheses are violations of the model, they might be expected to lower the PVE. The correlation of decreases in the probabilities of random responding and third-trial learning with an increase in the PVE suggests that changes in hypotheses do take place during Trials 1-3.

The meaningful patterns found in the results of the hypothesis analysis, as well as the reasonably high PVEs, clearly suggest that the hypothesis model is applicable to the learning-set behavior in bluejays. Certainly, the evidence obtained in mynas and bluejays suggest that a theoretical model, in terms of response patterns, rather than discrete trial-by-trial choice response, will be most appropriate. Further research designed to test this position is clearly necessary. Examples would include tests of transfer from reversal learning to learning set, attempts to shape other strategies, such as the win-shift/lose-stay position, by appropriate contingencies, or studies of short-term memory in learning-set experienced birds. Such research might well confirm the utility of the hypothesis or response strategy model for the learning process during learning set in corvids, as it seems to have done in macaque monkeys. If so, it will provide evidence for the parallel and independent development of similar modes of capability for behavioral modification in organisms different in nervous system structure and habitat.

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Spontaneous alternation of brightness?

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An attempt is made to dispel misunderstanding regarding a study which found spontaneous alternation to be affected by stimulus change but not by any tendency to alternate brightness. It is urged that the distinction between response to change and the alternation of brightness not be lost. Positive evidence for the alternation of brightness is presented.

Pate & DeLoache (1970) stated that several investigators (Glanzer, 1953; O'Connell, 1964; Walker, Dember, Earl, & Karoly, 1955) claimed to have found spontaneous alternation of visual stimuli. This is one-third incorrect. Glanzer, who separated alternation of relative turn from alternation due to other factors, used one black arm and one white arm; but this visual difference, and any other visual differences between the arms, were confounded with differences in spatial location in the room (absolute direction of turn) and odor. Walker et al still found alternation of brightness when the confounding with place (absolute turn) was eliminated, but the confounding with odor cues remained.

O'Connell used a design in which brightness difference between the arms was not confounded with any of the other cues and found no evidence that alternation to the combination of other cues was influenced by a brightness alternation tendency. This

study used a stationary T-maze to examine both spontaneous alternation and the response to stimulus change. "Response to stimulus change" refers to the tendency to select an arm which has been changed (or changed most) between a first, exposure trial and a second, choice trial (Dember, 1956). The term "stimulus change" can and has been used to refer to various events, but the specific event here intended is the temporal change in a stimulus which has been associated with a particular location. In addition to stimulus change, the study independently investigated the possibility that alternation might be increased if the Trial 2 brightness of the arm unentered on Trial 1 was different from the brightness of the arm entered on Trial 1. Note that the phenomenon of brightness alternation is defined in terms of operations which differ from those used to demonstrate the response to change, though in both cases one is, in some sense, investigating approach to a novel