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Animal Learning & Behavior
1975, Vol. 3 (2), 125-130

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Three experiments were conducted examining short-term retention within individual object-discrimination learning-set (ODLS) problems. In Experiment I, it was found that intraproblem retention decreased during ODLS acquisition. Experiment II demonstrated that this phenomenon was not due to simple recency of experience with other ODLS problems. Experiment III demonstrated that retention was not influenced by the number of trials per problem or number of problems per session. These results were interpreted as supporting a conditional discrimination model of ODLS acquisition in bluejays.

Recent experiments have shown that bluejays and rhesus monkeys experienced in object-discrimination learning set (ODLS) exhibit a rapid decline in performance when a retention interval is inserted between successive trials of individual ODLS problems (Bessemer & Stollnitz, 1971; Kamil, Lougee, & Shulman, 1973). This intraproblem retention loss (IRL), or forgetting, has been interpreted as reflecting the importance of relatively transient memory traces for events of previous trials of the ODLS problem as determinants of choice behavior on the current trial of the same problem. According to this model, these memory traces function as discriminative stimuli in a conditional discrimination which controls choice behavior in the sophisticated subject. For example, if the subject remembers having responded to Object x, and having been rewarded on the previous trial(s), then he approaches Object x on the next trial; however, if he remembers nonreward, then he avoids Object x. This model is obviously similar to the "win-stay, lose-shift" hypothesis proposed by Levine (1959), but would seem to have two advantages. First, it specifies the stimuli, specific memory traces of previous trial events, necessary for hypothesis behavior to occur. Second, it explains the finding of rapid IRL if we assume that these memory traces are transient, losing strength during retention intervals.

EXPERIMENT I

This conditional discrimination model implies that during ODLS acquisition, at least in bluejays and rhesus monkeys, the animal learns to make a conditional discrimination based upon transient memory traces for previous trial events. This conditional discrimination contributes to, and perhaps completely accounts for, the rapid problem solution of ODLS-experienced animals. If this were so, then the rapid IRL observed in ODLS-experienced animals should not be characteristic of ODLS-naive animals. Rather, the rapid within-problem forgetting should develop only as ODLS is acquired since it is only during this acquisition that transient memory traces become important in controlling choice responses. Evidence for this view has been provided by Deets, Harlow, & Blomquist (1972) for rhesus monkeys, who found increased IRL only late in ODLS acquisition. The purpose of the first experiment was to test this prediction in the bluejay.

Method

Subjects. The subjects were four experimentally naive bluejays (*Cyanocitta cristata*), 5-6 months of age at the start of the experiment. They were captured locally in the Amherst, Massachusetts area when 12-15 days of age and they were hand raised in the laboratory. During the experiment, each jay was maintained at 75%-80% of its free-feeding weight by controlled daily feedings.

Apparatus. A modified WGTA formboard apparatus, described in detail by Kamil et al. (1973), was employed. The small animal chamber had a perch at one end. The foodwell enclosure, with three shallow foodwells in the floor, was located outside of the wall nearest the perch. The jays had access to the foodwells through three small ports in the wall. A guillotine door separated the jay from the foodwell area between trials, and a swinging door separated the experimenter from the foodwell area during trials. During experimental sessions, the animal chamber was placed in a sound-deadening enclosure with masking white noise constantly present.

Two hundred three-dimensional "junk" objects (hardware, small household items, etc.) were employed as stimuli. Reinforcements were halves of mealworms (*Tenebrio* larvae).

Procedure. The first stage of the experiment consisted of habituation to the apparatus and shaping. While adapting to the controlled feeding schedule and slowly being reduced to deprivation weight, each jay was handled daily and hand-fed mealworms until it ate freely from the experimenter's hand. Each bird then received habituation sessions during which it was placed in the apparatus for 20 min with food freely available in the center foodwell. After three sessions, all jays were eating readily in the apparatus. In the next session, a plain wooden block, 5.2 cm square and 1.8 cm high, was introduced and each jay was shaped by successive approximations to displace the block from the center foodwell. After this response was acquired, each jay received 100 trials, in four 25-trial sessions, with 100 objects randomly selected from the object collection. Each object was displaced from the center foodwell once, and all responses were reinforced.

This research was supported by Grant GB-30501 from the National Science Foundation.

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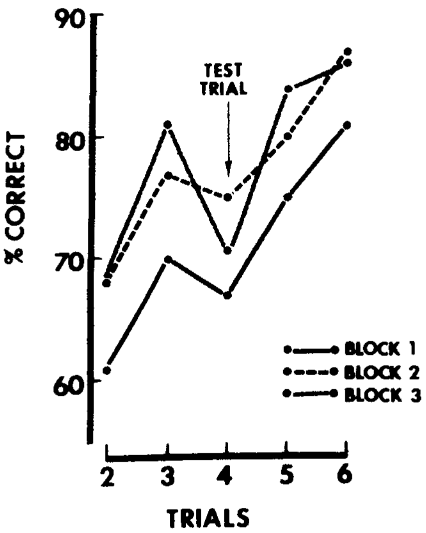

Figure 1. Mean performance on Trials 2-6 during learning-set acquisition in Experiment I. Trial 4 was a retention test trial throughout.

Following completion of this pretraining, ODLS acquisition and intraproblem retention testing began. Each problem consisted of the following sequence of events: three trials, a precriterion retention interval of 0, 1, 3, or 5 min, continued trials on the problem until a criterion of five consecutive correct responses was reached, a postcriterion retention interval of 0, 1, 3, or 5 min, and two final test trials. The retention intervals were simply lengthened intertrial intervals during which the jay remained in the apparatus with the guillotine door down. On nonretention test trials, and on 0-min test trials, the intertrial interval was 8-10 sec.

Each jay received 288 such problems, each problem defined by the introduction of a new pair of stimulus objects. On each trial of each problem, two objects were presented covering the side foodwells (the center foodwell was no longer employed). The correct object covered a reinforcement, and noncorrection procedures were employed. Daily sessions consisted of 31-36 trials. Since the criterion for terminating individual problems was five consecutive correct responses, the subject had to either reach criterion or make an error during Trials 31-36. The session was terminated either after the first error during these trials or after the subject met criterion, in which case the final retention test trials were included in the session. If criterion on a given problem was not met, the problem was continued in the next session.

Throughout ODLS testing, a number of factors were counterbalanced or randomized. Trial 1 outcome was controlled by baiting both objects on Trial 1 on half the problems (Tr 1+ problems) and defining the correct object as the object chosen on Trial 1. On the remainder of the problems (Tr 1– problems), neither object was baited on Trial 1, and the correct object was defined as the object not chosen on Trial 1. There are 16 possible combinations of the two Trial 1 outcomes and the eight possible sequences of the position of the correct object (relative to its position on Trial 1) over Trials 2-4. Each of these combinations was used equally often under each retention-interval condition during each of the three blocks of 96 problems. Within each block, the order of retention intervals tested was randomly determined with the restriction that each interval appeared 24 times during precriterion tests and 24 times during postcriterion tests. Sequences suggested by Fellows (1965) were used to determine the position of the correct object on each trial past Trial 4. Finally, the limited number of stimulus objects available required random re-pairings to be carried out to create new object pairs. This was done with the restriction that no object could appear twice within six consecutive sessions.

Results

In order to examine changes in retention performance during ODLS acquisition, data will be presented in three blocks of 96 problems each. One jay died during the third block of problems. The Block 3 data for that bird was calculated on the basis of the 67 problems of Block 3 it did complete.

ODLS acquisition. As can be seen in Figure 1, ODLS was acquired. Most of the improvement in performance took place between Blocks 1 and 2. Performance was clearly above chance on Trials 2 of new problems. The range of observed percentages correct for individual jays on Trial 2 during Block 1 was 58%-63%, during Block 2 58%-73%, and during Block 3 65%-72%.

Precriterion retention results. The precriterion retention results for the trial following the retention interval are presented in Figure 2. Analysis of these data indicated that there was an overall significant decline in percentage correct with longer retention intervals ($F = 11.88$, $df = 3/9$, $p < .01$). In general, performance on the precriterion retention test trial was better during Tr 1+ problems than during Tr 1– problems ($F = 30.30$, $df = 1/3$, $p < .05$). This phenomenon was not included in Figure 2, since it did not interact significantly with

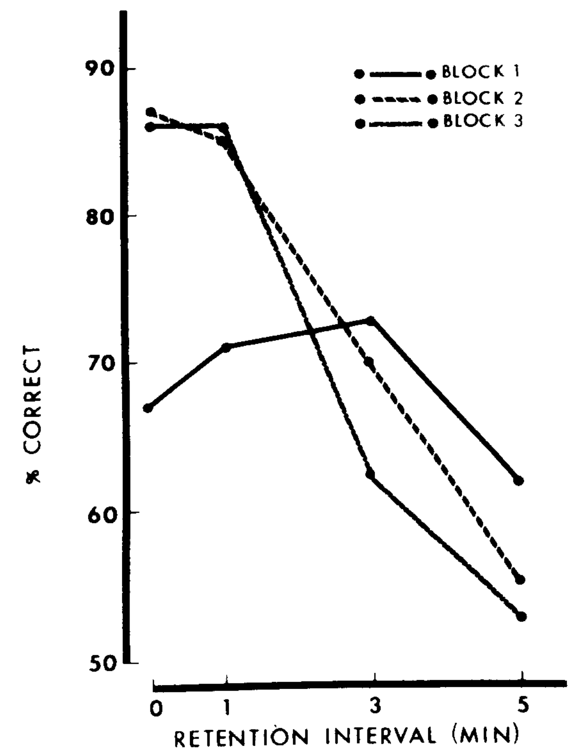

Figure 2. Mean performance on Trial 4, the precriterion test trial during the three problem blocks of Experiment I as a function of the duration of the retention interval between Trials 3 and 4.

Table 1
Mean Percentages Correct During Precriterion Retention Tests as a Function of Retention Interval Duration and Trial 1 Outcome

Interval (min)	Tr 1+ (Percent Correct)	Tr 1− (Percent Correct)	Difference
0	84.5	78.2	6.3
1	88.0	76.1	11.9*
3	78.9	59.9	19.0*
5	66.9	47.9	19.0**

$^*p < .06$ $^{**}p < .02$

either trials or intervals. However, as can be seen in Table 1, the size of this effect did tend to increase with longer retention intervals. This finding replicates previous findings with bluejays (Kamil et al., 1973).

Turning now to changes in retention during acquisition, the main effect of blocks on retention performance was marginally significant (F = 4.70, df = 2/6, p < .10). More importantly, there was a change in the shape of the intraproblem retention curves over blocks as indicated by a significant Blocks by Intervals interaction (F = 6.02, df = 6/18, p < .01). This reflects the fact that while there was virtually no IRL within 5 min during Block 1, a large degree of IRL was observed during Blocks 2 and 3. Subsequent tests indicated that mean percentage correct during Blocks 2 and 3 (combined) at 0 min was significantly higher than 0-min performance during Block 1 (t = 5.02, df = 3, p < .01). When a similar comparison was carried out on performance at 5 min, the difference between Block 1 and Blocks 2 and 3 was not significant (t = 1.55, df = 3, p < .20), although performance during Block 1 was higher than during Blocks 2 and 3. Thus, although the shape of the retention functions did change considerably across acquisition, it is possible that the differences between Block 1 and Blockss 2 and 3 in precriterion retention performance were primarily due to differences in 0-min performance.

Postcriterion retention results. The postcriterion retention test was included in the experimental design in an attempt to obtain retention measures that would not be confounded with large differences in initial performance at 0 min between problem blocks. As can be seen in Figure 3, this was largely successful. There was an overall decrease in percentage correct with longer retention intervals (F = 9.52, df = 3/9, p < .01). Performance on Tr 1+ problems was better than on Tr 1− problems, especially at longer intervals, but this effect only approached statistical significance (F = 7.23, df = 1/3, p < .10).

As in the precriterion test, the effect of blocks was only marginally significant (F = 3.68, df = 2/6, p < .10) but there was a significant Blocks by Intervals interaction, (F = 5.95, df = 6/18, p < .01) indicating a significant change in the shape of the retention function over blocks. It is clear from inspection of Figure 3 that there was no IRL during Block 1, but considerable retention loss within 5 min during Blocks 2 and 3. Subsequent tests indicated that at 0 min, the degree to which Block 1 performance was below performance during Blocks 2 and 3 approached significance (t = 2.54, df = 3, p < .10). However, at 5 min, performance during Block 1 was significantly higher than during Blocks 2 and 3 (t = 4.12, df = 3, p < .01).

Discussion

A number of different aspects of these data deserve discussion. First of all, these results replicate a number of previous findings involving ODLS in bluejays. ODLS formation was again obtained, although at a faster rate in terms of number of problems, than that reported by Hunter and Kamil (1971). This difference in rate is probably due to the criterion procedure used to terminate individual problems in the current experiment. Hunter and Kamil (1971) employed a fixed number of trials procedure. The retention performance of the bluejays in this experiment, during Blocks 2 and 3, is very similar to that reported by Kamil et al. (1973) for ODLS-experienced bluejays. After ODLS formation, the bluejays again showed rapid IRL, better performance on Tr 1+ problems than Tr 1− problems after retention intervals, and less IRL when the number of preretention

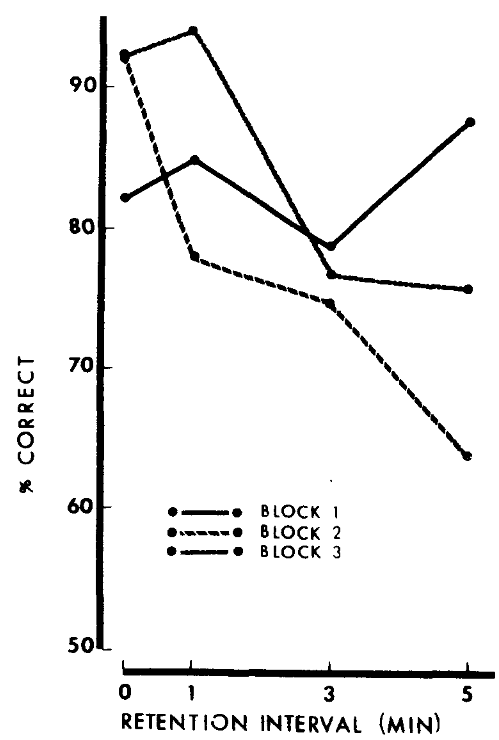

Figure 3. Mean performance on the postcriterion retention test trial (which followed five consecutive correct responses) during the three problem blocks of Experiment I as a function of the duration of the retention interval immediately preceding the test trial.

test trials was increased (precriterion vs. postcriterion measures in the present experiment; Experiment II vs. Experiment III in the Kamil et al. experiment). The Trial 1 outcome effects are virtually identical to those previously reported for primates and bluejays and are apparently due to object preferences (Bessemer and Stollnitz, 1971; Kamil et al., 1973).

The major new finding in this experiment was the change in intraproblem retention during ODLS acquisition shown by these bluejays. Especially when the pattern of the results obtained in both pre- and postcriterion testing is considered, it is clear that rapid IRL is not characteristic of naive bluejays at the beginning of ODLS training, but is characteristic of the jays later, after ODLS has been acquired. This finding is consistent with the hypothesis that the establishment of stimulus control over choice behavior by relatively transient memory traces for previous trial events is an underlying process during ODLS formation. However, a number of other explanations are also possible. Experiments II and III were intended to provide at least a preliminary evaluation of some methodological variables which might have produced this effect. The approach taken in these experiments was to examine factors which might reduce IRL in ODLS-sophisticated bluejays.

EXPERIMENT II

One alternative explanation for the development of rapid IRL which must be considered is proactive interference. That is, early in ODLS training, the jay has not experienced many problems previous to a current problem. However, later in training, the bird has had recent experience with a large number of previous problems. Thus, memory for events of recent problems might interfere with performance after a retention interval in ODLS sophisticated jays but not in naive jays. This possibility is made more plausible by our use of a limited stimulus object population during Experiment I, although no object occurred twice within six sessions. Experiment II was carried out to test this possibility.

Method

The subjects were the three bluejays which completed Experiment I. Experiment II began immediately after the completion of Experiment I and continued for two blocks of 96 problems each. The apparatus and procedures were identical to those of Experiment II except that there was a 30-day period during which the jays were not tested between the end of the fourth problem block and the beginning of the fifth.

Results and Discussion

If proactive interference is responsible for the IRL observed in ODLS-experienced jays, then the 30-day period between Blocks 4 and 5 should have reduced the amount of IRL observed. As can be seen in Figure 4, there was no substantial change in the retention loss observed within 5 min under either pre- or postcriterion testing. A number of analyses of these data were carried out, including analysis of variance. In no case were any even marginally significant effects indicating either a difference between the problem blocks or an interaction of retention intervals by problem blocks obtained.

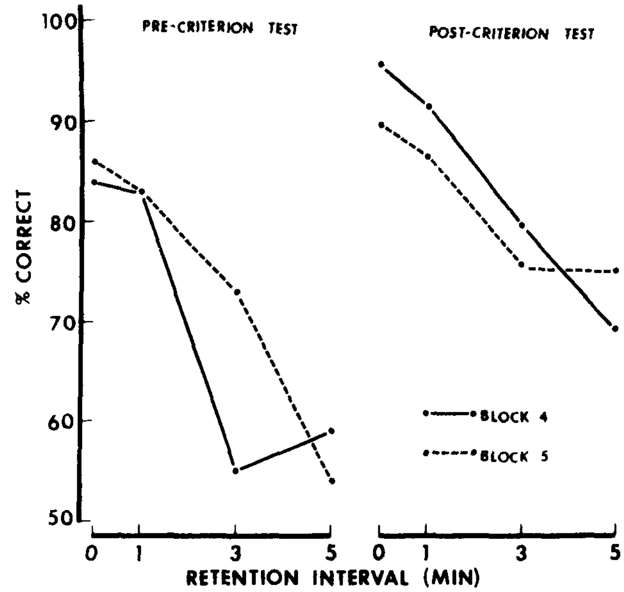

Figure 4. Mean performance on the pre- and postcriterion test trials as a function of the duration of the immediately preceding retention interval during Blocks 4 and 5 of Experiment II.

Since it is based on a limited number of subjects, this evidence on proactive interference is not compelling. In addition, there are two arguments which can be offered against the appropriateness of the design of Experiment II. It can be argued that a 30-day rest interval was not long enough to allow the effects of previous experience to dissipate. However, in Experiment III of the Kamil et al. (1973) paper, considerable IRL was observed in bluejays which had not been tested in 3 months. It can also be argued that proactive interference could build up within a 96-problem block. However, if this were so we would still need to explain why so little retention loss was observed during Block 1 of original acquisition. In addition, when the retention data of Block 5 were broken down into thirds, there was no trend toward increased IRL across the block of problems. Thus, on the whole, it seems unlikely that proactive interference, or simple recent experience with similar problems, was primarily responsible for the occurrence of rapid IRL during Experiment I.

These results differ from those obtained by Conner and Meyer (1971) employing a modified transfer suppression technique with rhesus monkeys. They found that a 2-week period during which no experimental sessions were conducted produced a large increase in retention performance. Although this may imply a species difference in the effects of breaks in experimental sessions on retention, procedural differences are more likely to account for the behavioral differences. Conner and Meyer not only employed long retention intervals of 72 or more hours, but presented novel problems during the retention interval.

EXPERIMENT III

Another factor which might have played a role in the appearance of rapid IRL during Experiment I is a simple methodological one. As the jays acquired ODLS, they learned to solve individual problems more rapidly and therefore received fewer trials per problem and more problems per session. These factors may affect IRL. For example, more problems per session may adversely affect retention performance through a proactive interference type of mechanism. Therefore, Experiment III was carried out to examine the effects of these variables on retention performance.

Method

Subjects. Eight ODLS-experienced bluejays were employed in Experiment III. They were 1-3 years of age at the start of the experiment. They had been captured locally in the Amherst, Massachusetts area when 12-15 days of age and hand raised in the laboratory. During the experiment, they were maintained at 75%-80% of their free-feeding weights by controlled daily feedings.

Apparatus. The apparatus of Experiments I and II was employed.

Procedure. The jays were randomly assigned to one of two groups The jays in each group received 96 problems., with a retention interval of either 0 or 4 min inserted between Trials 3 and 4 of each problem. Each group received 32 trials per session, but the groups differed in the number of trials per problem, and therefore in the number of problems per session. Group 4T received 4 trials per problem, 8 problems per session (for 12 sessions), while Group 16T received 16 trials per problem, 2 problems per session (for 48 sessions). All other aspects of the procedure–counterbalancing, control of Trial 1 reward, etc.–were as in Experiment I.

Results and Discussion

The retention results are shown in Figure 5. It is quite clear that the two groups performed at a high level of percentage correct at 0 min (on the test trial immediately following the retention interval), and that both groups showed considerable, but approximately equal, retention loss after 4 min. Analysis of variance supports this conclusion. The only significant factor was intervals ($F = 30.63$, $df = 1/6$, $p < .01$), reflecting the lower percentage correct after 4 min. Thus, it is unlikely that the changes in number of trials per problem and number of problems per session which occur during ODLS acquisition were responsible for the appearance of rapid IRL in Experiment I. While Experiments II and III do not clarify the causes of this rapid IRL, they do indicate clearly that neither recent experience with other ODLS problems nor the number of trials per problem or problems per session can account for the appearance of rapid IRL only late in training during Experiment I.

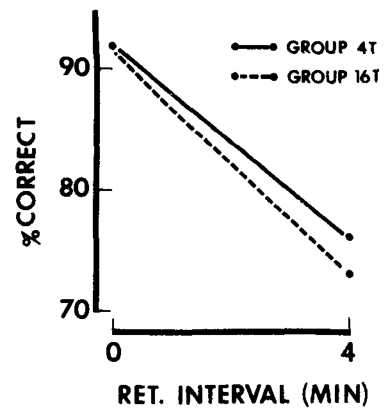

Figure 5. Mean performance of Groups 4T (which received eight 4-trial problems per session) and 16T (which received two 16-trial problems per session) on Trial 4 as a function of the duration of the retention interval between Trials 3 and 4.

GENERAL DISCUSSION

The most important phenomenon in these experiments was the finding that IRL is not typical of naive bluejays, but appears only during ODLS acquisition. This finding is similar to those of several experiments employing primates as subjects. For example, Deets et al. (1972) used two trial problems throughout ODLS acquisition with rhesus monkeys. They varied the intertrial interval and found that the longer intervals (20 sec) produced a decrement in performance only after considerable ODLS training had been given. Thus, in terms of species comparisons of ODLS performance, the results of the current experiments indicate another way in which the performance of bluejays is similar to that of primates. This further supports the conclusion that the learning processes underlying ODLS behavior in these species are qualitatively similar (Kamil et al., 1973). As has been previously pointed out (Kamil et al., 1973), this qualitative similarity in "complex" learning capabilities in species as diverse as bluejays and rhesus monkeys raises a number of comparative issues regarding the significance of the traits measured, perhaps indirectly, by ODLS techniques. We suspect the resolution of these issues will await a fine-grained analysis employing groups of closely related species.

The results of these experiments on IRL also have theoretical implications for models of ODLS formation. As Bessemer and Stollnitz (1971) pointed out, there seem to be two underlying mechanisms which affect the choice behavior of the ODLS-experienced animal: relatively permanent tendencies to approach or avoid stimuli, which they called habits; and relatively transient tendencies based upon memory for events of recent trials, which they called hypotheses. The hypothesis mechanism may be thought of as a conditional discrimination in which the memory traces are the discriminative stimuli for choice behavior.

The finding that IRL, which parallels the development of hypotheses in governing choice behavior, develops only as ODLS is acquired suggests that the critical process which produces the improvement in problem solution we call ODLS formation is the learning of the conditional discriminations based on memory traces for previous trial events. Another way to phrase this is to say that ODLS acquisition consists of the process by which the stimuli provided by memory for previous trial events come to have stimulus control over choice behavior. Initially during ODLS acquisition, problems are probably solved in a gradual, incremental way which is based upon changes in the response tendencies or habits elicited by the stimulus objects themselves. Since these changes are relatively nontransient, little IRL is observed. As ODLS acquisition proceeds, this process does not disappear. It continues to affect behavior and is reflected in a number of aspects of the behavior of ODLS-sophisticated animals such as above-chance performance at long retention intervals (Bessemer & Stollnitz, 1971; Kamil et al., 1973) and the improvement in retention performance with increasing numbers of trials before the retention interval (Kamil et al., 1973; pre- vs. postcriterion tests in the current experiments: Bessemer & Stollnitz, 1971).

However, although this incremental process remains as ODLS is acquired, ODLS acquisition, especially in terms of high levels of performance on Trial 2 of new problems, reflects the acquisition of the conditional discrimination such that the subject's choice behavior on these early trials is primarily under the control of memory traces for recent trial events. To use such a conditional discrimination, the subject must remember which stimulus was chosen and the reinforcement outcome of the previous trial. He then approaches the previously chosen object if reward is remembered and avoids it if nonreward is remembered. As this process becomes more important in determining choice behavior, IRL will increase.

We are not suggesting that the subject "learns to forget" during ODLS acquisition. Rather, we are proposing that a qualitative change takes place in the way the subject responds on the early trials of new problems. He becomes more efficient in his choice by using cues whose transient nature ensure that rapid IRL will be present. While this type of explanation of ODLS behavior is consistent not only with IRL characteristics, but with a wide variety of ODLS phenomena (see Bessemer & Stollnitz, 1971), it also implies that much more research needs to be done, especially focusing upon issues related to memory processes. More data needs to be collected on temporal patterns of trial and problem presentation, going into much more detail than Experiments II and III. These variables also need to be looked at during ODLS acquisition. For example, if long intertrial intervals were employed throughout ODLS acquisition, both IRL characteristics and rate of formation of ODLS might be affected. Indeed, the investigation of the effects of independent variables known to affect short-term and, perhaps, long-term memory on ODLS behavior may prove extremely fruitful in furthering our understanding of ODLS in a variety of species.

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(Received for publication July 5, 1974; revision received October 28, 1974.)