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ROLE OF REINFORCEMENT IN DISCRIMINATION LEARNING SET IN MONKEYS¹

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Following a review of empirical research on the role of reinforcement in learning-set formation, the major theoretical explanations of learning-set formation in monkeys are analyzed. Studies showing that a reward can function to decrease as well as increase the probability of choosing an object cast doubt upon theories based on an automatic strengthening function of reward. Hypothesis or strategy selection theories avoid this problem by assuming hypotheses, rather than responses, are subject to reinforcement principles, but hypothesis theories are at best incomplete in their treatment of retention. A theory which assumes that learning-set formation results from between-problem stimulus generalization of feedback from expected rewards is consistent both with retention studies and with experiments on the function of reward in learning set, suggesting that learning-set formation need not be considered a complex abstractive process.

When monkeys are given a series of two-choice object discriminations, their performance on new problems gets better and better. They start out making 50% errors on the second trial of new problems, but after being tested on a few hundred problems make only 10% or fewer errors on Trial 2 of new problems. The monkeys, so to speak, "learn how to learn." This improvement is not attributable to the problems having a common solution, since attributes correlated with reward in one problem may not be correlated with reward on a subsequent problem. Nor is this improvement simply a matter of the monkeys adjusting to the experimental situation—subjects typically receive extensive pretraining displacing objects and picking up rewards before learning-set (LS) training begins. Given that these uninteresting explanations of LS can be rejected, a major theoretical prob-

lem is to specify the source of this improvement in learning ability.

This study examines the major theoretical explanations of discrimination LS after a review of the principal findings on the role of reward in LS in monkeys. The review borrows heavily from and supplements the excellent earlier summaries by Harlow (1959), Reese (1964), and Miles (1965).

REVIEW OF LITERATURE

Basic Learning-Set Procedures and Data

In a typical LS experiment, subjects are given a series of simultaneous discrimination problems having the following procedural characteristics: (a) a pretraining involving single objects being displaced for rewards; (b) a small, fixed number of trials on each problem; (c) a different pair of stimuli for each problem; (d) a noncorrection procedure; (e) a reward for every correct response; (f) an intertrial interval of 10–20 seconds. The basic measure of LS performance is improvement in within-problem learning as a function of number of problems given. Subjects cannot improve their performance on Trial 1 across

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problems as it functions solely as an information trial.

Harlow (1949) performed the first experiment specifically designed to study between-problem transfer in monkeys.³ In this classic LS study, monkeys were tested in 344 independent discrimination problems in a Wisconsin General Test apparatus. On the initial problems, learning improved gradually across trials, and subjects averaged 52% correct responses on Trial 2 of the first 8 problems. On the last set of discriminations, virtually all the learning took place between the first and second trials of a problem—subjects averaged over 90% correct responses on Trial 2 for the last 112 problems. This apparent change from gradual or trial-and-error learning to immediate solution of new problems Harlow labeled “learning set formation.”

Harlow (1950) suggested that the response patterns of the monkeys might provide an informative supplement to proportion correct as a dependent variable. He showed that errors made during LS were not random but represented systematic response tendencies that were inappropriate to the solution of the problems. The four principal error factors identified were stimulus perseveration, differential cue, position preference, and response shift. A brief description of these errors follows:

1. *Stimulus perseveration.* Stimulus perseveration errors consist of repetitive choices of the incorrect stimulus object. These errors are attributed to innate or learned preferences for, or avoidance of, particular stimulus objects. Stimulus perseveration errors, as measured by runs of consecutive errors, decrease as the LS progresses.

2. *Differential cue.* If the correct object occupies the left side of the apparatus on Trial 1, there is some ambiguity as to whether responses to the left or to the object itself are being reinforced. Differential cue errors are measured by the excess of errors on the trial when the correct object first shifts position over the errors made on comparable trials

when the correct object has not yet shifted positions. The number of errors on shift trials divided by the number of errors on corresponding nonshift trials is called the comparable-trial error ratio. When this ratio is equal to 1, presumably no differential cue errors occurred. Harlow (1950) also reported that differential cue errors decreased across trials, and the comparable-trial error ratio approached 1.0. However, Davis, McDowell, and Thorson (1953) found that while the absolute number of differential cue errors decreased across trials, the comparable-trial error ratio, if anything, increased.

3. *Position preference.* Position preferences are consistent responses to the left or right foodwell, regardless of the position of the correct object. Abordo and Rumbaugh (1965) found that squirrel monkeys given training such that the correct object switched positions after each correct response performed better under conventional LS procedures than subjects given conventional training throughout. In general, however, position preferences are only a minor source of errors in monkeys' LS formation.

4. *Response shift.* Response shift errors are errors of responding to the incorrect object after the correct object has been displaced on previous trials. This is normally measured as an excess of errors following a correct rewarded trial over the errors following an incorrect trial. Harlow suggested that this was attributable to the monkeys' tendency to explore the test situation, that is, the unchosen alternative.

Learning-Set Performance after Trial 1 Reward and Nonreward

On logical grounds reward and nonreward on Trial 1 of a problem should be equally informative—that is, if the object chosen was rewarded, the subject should continue to respond to it; while if the object chosen was nonrewarded, he should avoid that object on future trials and choose the other (correct) object. However, initial reward and nonreward do not have equivalent effects on performance within a problem nor is their effect constant across problems.

The following generalization can be made: Early in training there are more correct re-

³ The term “monkeys” refers to rhesus monkeys since approximately 90% of learning-set studies in primates have used rhesus monkeys. Departures from the use of rhesus are noted in the text.

sponses following a correct Trial 1 response than following a Trial 1 error; but later in LS training the opposite holds—there are more correct responses following an error than following a correct Trial 1 response (e.g., Warren, 1966; see also Reese, 1964, for other work). An exception may be for difficult two-dimensional pattern discriminations, in which strong stimulus preferences appear to occur, in which correct first-trial responses are more efficient in reducing errors throughout LS training (e.g., Leary, 1958a; McConnell & Schuck, 1962).

If only a single object is presented on Trial 1 and either rewarded or nonrewarded before the two-choice trials begin, a different picture emerges. This procedure has the advantage of breaking the correlation between stimulus preferences and Trial 1 choices. With single-stimulus training one finds that throughout LS training, Trial 1 nonreward uniformly reduces errors more than does Trial 1 reward (Boyer [1965],⁴ 1966; Fletcher & Cross, 1964; see Reese, 1964, for earlier work; Schwartzbaum & Poulas, 1965).

Two possible confoundings present in studies employing single-stimulus pretraining obviate drawing any firm conclusions as to the effectiveness of reward and nonreward. First, there is the possibility that adapting animals to the test situation by having them displace single objects for rewards prior to LS training teaches the monkeys not to attend to a singly presented rewarded object. Harlow (1959) cited an unpublished study by Schrier and Harlow in which the difference in performance between initial reward and nonreward (favoring nonreward) was five times greater than the usual 10% difference, implying that monkeys learned virtually nothing following an initial rewarded response. The only difference in procedure was that the Trial 1 object was placed over the center foodwell which otherwise was used solely for adapting animals to displace objects. This study suggests that processes related to attention are probably producing effects during single-stimulus

pretraining which make the relative effectiveness of reward and nonreward difficult to evaluate using this procedure. A second shortcoming of the single-stimulus pretraining paradigm is that responses to novel objects have differential effects on performance following rewarded and nonrewarded first trials. Any tendency to respond to novel objects would increase the estimate of amount learned from a nonrewarded first trial and decrease the estimate of the amount learned from a rewarded trial. As the following section of this study indicates, novelty and familiarity can be distinctive cues for monkeys.

Effects of Novelty and Familiarity

Test-experienced monkeys appear to retain a tendency to approach novel stimuli, but under conditions favorable to generalization from the positive to the negative stimulus (e.g., the negative stimulus has not been chosen and nonrewarded), the tendency to approach familiar, negative stimuli becomes stronger than the tendency to approach novel objects (Behar, 1962a, 1962b; Leary, 1956; see also Reese, 1964).

Monkeys can solve two-trial LS problems when the correct solution is to choose a newly presented Trial 2 object and to avoid either the correct or incorrect Trial 1 object (Brown, Overall, & Blodgett, 1959). Monkeys can also learn to approach or avoid specific recurring stimuli from previous problems (Gentry, Overall, & Brown, 1958) even on Trial 1 of new problems (Riopelle, Chronholm, & Addison, 1962).

Cross, Fletcher, and Harlow (1963) showed that the cue of familiarity can be established from home-cage experience with objects. For one group (positive) the home-cage objects were designated as correct in the test situation, for another group (negative) the objects were always incorrect in the experiment, and for the third group (mixed group) the home-cage stimuli were arbitrarily designated as correct and incorrect. A control group received no home-cage experience with the objects. The positive group and the negative group performed significantly better than chance on Trial 1 of the problems involving one home-cage stimulus, showing that they

⁴W. N. Boyer. Discrimination performance in three species of monkeys as a function of Trial 1 reward contingency, intertrial interval, and prior test experience. Unpublished doctoral dissertation, Oklahoma State University, 1965.

were able to use familiarity as a cue. The negative group performed better than the positive group, suggesting that subjects had a tendency to approach the novel objects. The mixed group did not differ from control subjects on Trial 1 of new problems and were actually inferior to them on Trials 2–12 (see also Shell & Riopelle, 1958).

In summary, novelty and familiarity can be and are effective cues for monkeys and, as such, complicate inferences concerning the effectiveness of reward and nonreward. In the following section, we see that experiencing a diversity of problems is important in LS formation.

Problem Diversity

Schusterman (1962, 1964) demonstrated that chimpanzees given repeated reversal of a single discrimination problem show immediate efficient Trial 2 performance when switched to LS training. Schusterman's apes seemed to transfer a generalized strategy of win-stay, lose-shift with respect to objects.

Monkeys in contrast to apes may require a more diverse selection of stimuli to form an LS. Riopelle (1953) reported that giving 2,000 training trials on six object discriminations followed by conventional LS training resulted in LS performance similar to that of a group of monkeys that had not received prior training. Treichler (1966) trained monkeys for 840 trials on two discrimination problems and found that an immediate win-stay, lose-shift strategy did not result. The modest transfer observed in his experiment may be attributable to specific interproblem stimulus generalization.

A study by Riopelle (1955a) suggests that the minimum number of different stimuli needed for LS formation may be quite small. Five naive monkeys who had learned 10 preliminary discriminations were trained to a criterion of 5 trials in a row correct (or a maximum of 50 trials) on two-choice problems consisting of the various combinations of four different objects. They received 18 scrambled repetitions of each of the 12 possible combinations of the four stimuli, or a total of 216 problems, before being shifted to conventional LS. Since all the combinations of the four objects were used, subjects received consider-

able reversal learning experience. The monkeys showed immediate excellent LS performance on the conventional six-trial problems.

On the other hand, Riopelle and Moon (1968) found that diversity of problems enhances the LS formation. Two groups of four stumptail monkeys were given 10 six-trial problems each day of training consisting of 7 familiar (repeated) and 3 new problems. The predictable reward group had the same objects designated as correct for the repeated problems, and the unpredictable reward group had reward randomly assigned to objects for the repeated problems. For a control group all 10 problems each day were new. After this differential pretraining, all three groups were given 50 six-trial problems with all new stimuli. The predictable reward group quickly reached perfect performance on the first trial of recurrent problems. On transfer to LS problems that employed all new stimuli, the control group performed significantly better than either of the other groups having received less diverse stimuli. This suggests experiencing a variety of stimuli is important for the establishment of LS in monkeys (see also the section on transfer of learning sets).

Retention of Discriminations

Most theoretical descriptions of LS lead one to expect relatively poor retention of individual discriminations. According to Harlow:

By the time the monkey has run 232 discriminations and followed these by 112 discriminations and reversals, he does not possess 344 or 456 specific habits, bonds, connections, or associations. We doubt if our monkeys at this time could respond with much more than chance efficiency on the first trial of any series of previously learned problems. But the monkey does have a generalized ability to learn *any* discrimination problem or *any* discrimination reversal problem with the greatest of ease [Harlow, 1949, p. 63].

1. Intertrial interval. Relatively short-term retention of object discriminations can be assessed by studies varying intertrial interval. For intertrial intervals between 10 and 150 seconds, performance typically declines although only modestly (Boyer, 1966; Fletcher & Cross, 1964; Harlow, 1959; Harlow & Warren, 1952; Kruper, Patton, & Koskoff, 1961; Riopelle & Churukian, 1958). For example, in the Riopelle and Churukian study there was

about a 5% decrease in performance as the intertrial interval increased from 10 to 60 seconds.

2. *Concurrent versus consecutive problem sequences.* Typically, a series of problems is presented to a monkey such that he receives all the predetermined trials on one problem before being given the next problem. In the concurrent procedure the problems are presented in a paired-associate fashion so that Trial 1 of each problem appears before Trial 2 on any problem is given. The concurrent procedure may involve both interference from other pairs in the list and increased forgetting from longer interpresentation intervals. As one might expect, consecutive stimulus presentation results in better performance than concurrent (Darby & Riopelle, 1955), and concurrent list performance decreases with increases in list length at least for squirrel monkeys (King & Goodman, 1966) and chimpanzees (Hayes, Thompson, & Hayes, 1953). The concurrent presentation procedure on the other hand is not especially difficult for rhesus monkeys (e.g., Leary, 1958a, 1962), and retention of a well-learned list is excellent at a 24-hour retention interval (Sledjeski & French, 1968).

3. *Long-term retention.* Monkeys are able to retain not only object discrimination LS (e.g., Braun, Patton, & Barnes, 1952) but also specific object discriminations. Monkeys have been found to retain discriminations virtually perfectly for at least 24 hours after as few as six acquisition trials per problem (Riopelle & Moon, 1968; Riopelle et al., 1962). Mason, Blazek, and Harlow (1956) reported above-chance first-trial performance by young monkeys on a series of 90 six-trial object discriminations which were unintentionally repeated after a 1-month interval. Strong (1959) gave four naive monkeys extensive training on 72 pairs of stimulus objects and found extremely good performance (90% correct) at retention intervals between 30 and 210 days. Zimmermann (1969) reported about a 15% retention loss in monkeys for each cycle of 100 discrimination problems, which were repeated every 20 days. By the sixth cycle, Trial 1 retention was 83% correct. A 3-month retention interval before the last cycle resulted in a 20% memory loss.

In a series of studies of retention in LS-experienced monkeys, Bessemer⁵ found efficient performance on object discriminations over a 24-hour retention interval but that, strikingly, the retention loss appeared to be confined to those problems on which the first trial response during training had been incorrect and nonrewarded. Since subjects presumably responded to their preferred stimulus on Trial 1, stimulus preferences can be pinpointed as playing a significant role in retention; when the preferred stimulus is correct, retention performance is better. Even if the associative information were lost, stimulus preferences would insure good retention performance when the preferred stimulus is correct. In an experiment that eliminated stimulus preferences by using single-stimulus presentations, the differential retention effect disappeared. Bessemer's finding that stimulus preferences were strongly influencing retention is of considerable theoretical importance since the manifestation of stimulus preferences in these LS-experienced subjects would perhaps be unexpected.

4. *Transfer suppression and interproblem interference.* Riopelle (1953) proposed that in the course of LS, monkeys suppress transfer of inappropriate problem solutions and treat successive problems increasingly independently. Eventually, according to the transfer suppression theory, responses to a particular problem do not transfer to succeeding problems. To assess this idea, Riopelle tested naive monkeys on six problems each day for 63 days, with the sixth problem being a reversal of either the first or fourth problem of that day. Initially the subjects made 80% errors on the first trial of the reversed problems, but eventually their performance reached 60% errors on the first trial of reversals and was not different from that on nonreversal problems on Trials 2-6.

However, these results do not imply that LS is accompanied by increased forgetting about specific object discriminations. As Stollnitz and Schrier (1968) pointed out, LS formation could not have been based on the

⁵ D. W. Bessemer. Retention of object discriminations by learning set experienced monkeys. Unpublished doctoral dissertation, University of Wisconsin, 1966.

development of stimulus independence, since the monkeys in Riopelle's study had largely formed their LS before they started to suppress transfer. Schrier and Stollnitz tested LS-experienced monkeys for transfer suppression by replicating Riopelle's (1953) procedure. Their monkeys averaged only 17% correct responses on Trial 1 of the reversals. Transfer suppression had not resulted from their prior LS training. A second experiment employed LS-experienced stump-tail monkeys using Riopelle's procedure for a more extensive testing period. Trial 1 performance on reversals was initially poor and, surprisingly, did not improve with practice. A replication of Schrier (1969) employed both rhesus and stump-tail monkeys, and again stump-tails failed to improve on Trial 1 of reversed problems over a 13-week practice period. The rhesus monkeys did improve (showed transfer suppression), and one subject performed significantly *above* chance on Trial 1 of the reversals. This above-chance performance is contrary to the transfer suppression proposition of problem independence. The pattern of results supports the contention that improvement in performance on Trial 1 of reversals that are interspersed during LS training represents learning to reverse when familiar stimuli reappear rather than any forgetting phenomenon such as implied by transfer suppression theory. There is independent evidence that monkeys can learn to reverse a previous choice after an arbitrary signal (Riopelle & Copeland, 1954).

Transfer of Learning Sets

Learning sets may facilitate or hinder performance on different types of stimuli or problems. Wilson and Wilson (1962) reported a small but reliable transfer between visual and tactual LS (see von Wright, 1970, for a review of cross-modal transfer). Harlow and Warren (1952) reported positive transfer between pattern-discrimination LS and object-discrimination LS. Takemura (1960) tested two Japanese and one Formosan monkey on form-discrimination LS after they had received 168 color-discrimination LS problems. Performance on the form-discrimination problems started at chance on Trial 2, but the form LS developed faster than the color-dis-

crimination LS. King (1966) found that concept-formation training (i.e., choose red, regardless of form) transferred to object-discrimination LS better than training involving rewarded presentations of single objects. Rumbaugh, Sammons, Prim, and Phillips (1965) reported that giving squirrel monkeys pre-training for 3,000 trials with either a single stimulus or with 500 different stimuli under a 50% reward schedule retarded LS formation. Interposing a task where monkeys' performance does not rise much above chance (such as double alternation) also may disrupt object-discrimination LS (Rumbaugh & Prim, 1964; Warren & Sinha, 1959).

Particular theoretical significance attaches to transfer between object-discrimination LS and reversal LS. In terms of abstract rules for problem solution, both procedures have the solution win-stay, lose-shift (with respect to objects), and on some grounds one might expect perfect transfer between them. Chimpanzees show immediate direct transfer from repeated reversals involving just a few pairs of stimuli to object LS (Schusterman, 1962, 1964). Repeated reversal learning also facilitated the LS formation of Philippine and stump-tail monkeys but to a much smaller extent (Schrier, 1966). Even repeated reversal of a position discrimination may facilitate object-discrimination LS in monkeys (Warren, 1966).

If the nonreward on the first trial of reversal comes to act as a cue or sign for reversal, then object-discrimination LS might facilitate reversal LS only to the extent that efficient prereversal performance makes the nonreward on the first reversal trial a distinctive cue. The results of a number of studies with a variety of primate species suggest that object-discrimination LS facilitates reversal LS but that the transfer is by no means complete or perfect (Cross & Brown, 1965; Harlow, 1944, 1950, 1959; Meyer, 1951; Rumbaugh & Ensminger, 1964; Schrier, 1966). In other words, transfer between object and reversal LS does not consist simply of employing a win-stay, lose-shift rule.

Information Value of Rewards

1. *Partial reinforcement.* Behar (1961b) gave naive and sophisticated monkeys a

choice between receiving two units of reward 50% of the time or one reward 100% of the time. Naive subjects showed no preferences while the test-experienced monkeys chose the consistently rewarded object suggesting that nonreward had a greater effect on the sophisticated than on the naive monkeys.

Bowman (1963) tested LS-experienced monkeys under conditions where correct responses were rewarded with various probabilities. The within-subject design used reward percentages of 100%, 75%, 50%, and 25%. Discrimination performance was efficient only for reward percentages of 100% and 75%. For another condition, one of two colors was revealed when the objects were displaced. These color markers followed the positioning of the correct and incorrect objects and thus could serve as secondary reinforcers. The particular colors used changed from problem to problem, so the color information could be useful only after the first rewarded trial. Under this procedure, performance on the 25% and 50% conditions improved significantly.

2. *Ambiguous problems.* Consider three stimuli, A, B, and C, that are presented in pairs consisting either of A and B, with A correct, or B and C, with B correct. To solve the problem, B must be chosen when paired with C and must be avoided when paired with A. Performance on AB trials versus BC trials may serve to estimate the relative effects of reward and nonreward. The data reveal that BC trials typically result in fewer errors than AB trials for objects, while the reverse appears to hold true for two-dimensional stimuli (Bernstein, 1961; Fletcher, Grogg, & Garske, 1968; Leary, 1958b; Thompson, 1954). Unfortunately, inferences concerning the effectiveness of reward and nonreward depend crucially upon assumptions concerning the absence or presence of within-problem generalization so that no strong conclusions have been drawn.

3. *Information acquired in one trial.* Stollnitz (1965) summarized a number of studies showing that when the stimuli are separated from the site of the monkey's response by only a minimal distance, discrimination performance is severely retarded. It would follow from this that monkeys might learn only

about the object chosen in a discrimination problem. Lockhart, Parks, and Davenport (1963) used test-experienced pigtail monkeys to directly test this proposition. For one group of animals, the object not chosen on the first trial was replaced for Trials 2-6 of six-trial problems, while for the other group the displaced object was replaced for Trials 2-6. The reward conditions were dictated by and consistent with the first trial outcome. The subjects having the unchosen object replaced were correct on 85% of their Trial 2 choices, while the subjects having their chosen object replaced performed at chance level, regardless of whether their first trial was correct or incorrect.

Learning is not solely restricted to the object chosen. Brown and Carr (1958) placed the objects for the next problem 6 inches behind the objects being used for the current problem. The object which was to be correct on the following problem was always behind the object which was currently correct. Their monkeys showed significantly better-than-chance performance on the first trial of the new problems, indicating that they had learned something about the incidental cues (see also Davis, 1965 and Zeis [1964],⁶ for other incidental learning studies).

There is some evidence that with extended practice, animals can learn something about the unchosen object. Bowman and Takemura (1966) also used the procedure of replacing either the chosen or the unchosen Trial 1 object which could be rewarded or nonrewarded. For one group the recurring object was always correct, while for the other the recurring object was incorrect. When the chosen object was brought forward, both groups were able to master the problems. The group having the unchosen object brought forth as correct learned much more slowly but eventually did master the problem. One might argue that subjects were using familiarity as a cue, since the recurring object was always correct. Even so, this would indicate that familiarity with objects can be acquired without directly displacing them.

⁶ S. M. E. Zeis. The use of peripheral cues in learning set formation by rhesus monkeys. Unpublished doctoral dissertation, Catholic University of America, 1964.

The monkeys having the unchosen object brought forward as incorrect immediately reached a level of 70% correct on Trial 2 and did not appear to improve their performance. Note that one need not invoke any associative process to explain this result if stimulus preferences are assumed to occur. Variables leading to not choosing the object on the first trial may also operate on Trial 2 to produce 70% performance even in the absence of learning.

Fletcher and his associates (Fletcher, 1966; Fletcher & Takemura, 1965; Fletcher et al., 1968) have employed a prompting procedure where a cue (i.e., the prompt) is attached to either the correct (positive prompt) or incorrect (negative prompt) object. Groups are given pretraining with either a positive or a negative prompt to teach the monkeys the significance of the prompt. As a result, few errors occur on prompted trials during the main experiments. Learning is assessed by trials in which the prompts are removed; and, in general, negative prompting results in better performance than positive prompting. Replacing the correct object with a new object on transfer tests after negative prompting trials shows that monkeys apparently learn about the incorrect object on the basis of its previous pairings with the negative prompt, even though they have never chosen it.

4. *Control by positive and negative cue.* French, Birnbaum, Levine, and Pinsky (1965) tested monkeys under the following experimental procedures: (a) both the correct and incorrect objects were constant; (b) the correct object remained the same, but a new incorrect stimulus was constantly introduced; (c) the correct object remained the same, and new incorrect stimuli were introduced; (d) both new correct and incorrect objects were introduced for each problem. The first condition yielded the best performance, the next two conditions had intermediate effects, and performance was least efficient under the fourth condition. In a somewhat related experiment Ettliger (1960) found for both tactile and visual discriminations that separating the correct cue by 2 inches from the response site was more disruptive than separating the incorrect object from the normal response sites.

By using an automated apparatus and two-dimensional stimuli, Sheridan, Horel, and Meyer (1962) were able to allow either correct, incorrect, both, or neither stimuli to persist for certain time intervals after an animal's choice response. Persistence of the correct stimulus aided performance more than persistence of the incorrect stimulus, both of which were better than either of the other two conditions.

5. *Rewards as cues.* Apart from any strengthening function, rewards can serve as cues. A suitable paradigm to show this involves two-trial problems where the correct response on Trial 2 is determined by the Trial 1 outcome. That is, one can give problems having the solution win-stay, win-shift, lose-stay, or lose-shift with respect to objects. The combination of the first and fourth type of problem is simply the usual object-discrimination LS, but the second and third type of problem require the subject to abandon responses to the just-rewarded cue or to persist in responding to a cue despite nonreward, respectively. The four types of problems are typically administered in a between-subjects design where only one of the four problems is presented to a given group of monkeys. For example, if a group is tested on win-shift, its Trial 1 response will always be rewarded, and on Trial 2 subjects must select the previously unchosen object. The results of a number of studies (Brown, McDowell, & Gaylord, 1965; McDowell & Brown, 1963a, 1963b, 1963c; McDowell & Brown, 1965a, 1965b, 1965c, 1965d, 1965e; McDowell, Gaylord, & Brown, 1965a, 1965b; see Reese, 1964) show that monkeys can learn all four solution types. Win-stay is by far the most difficult of the four solutions to learn—a result puzzling from the point of view that rewards directly strengthen responses. In a few experiments (Brown et al., 1965; McDowell et al., 1965b), win-stay was not learned at all. Perhaps responses to novelty and overall reward probability are related to this result, but there is at present no clear explanation. Within-subjects comparisons of compatible problem types (e.g., win-stay combined with lose-stay) would control overall reward probabilities and might elucidate matters. Finally, Behar (1961a) has shown that

monkeys can form an object-alternation (win-shift, lose-stay) LS.

Riopelle, in a series of studies (Riopelle, 1955b; Riopelle & Francisco, 1955; Riopelle, Francisco, & Ades, 1954), has used a marble as a Trial 1 signal. Six-trial problems were given with no food, food, or a marble on Trial 1 signaling the chosen or unchosen object to be correct and rewarded with food in Trials 2-6. Under these conditions, where win-shift and lose-stay were not rewarded on Trials 3-6 of a problem, win-stay and lose-shift were performed better than win-shift and lose-stay (see also Schwartzbaum & Poulas, 1965). An interesting feature of Riopelle's data is that groups trained on marble-stay, if anything, perform better than groups trained on food-stay. It may be that food cues are less efficient than marble cues since the food may distract the animals' attention from the chosen object. These experiments show that as a Trial 1 cue (reinforcer), a marble can function as effectively as food reward, and they support emphases on the cue value of reward.

ANALYSIS AND REVIEW OF THEORIES

This section reviews several theories that have addressed themselves to the question of what is learned during LS formation.

Modified Hull-Spence Theory

Reese (1964) suggested a modified version of Hull-Spence theory that might account for LS formation. It correctly predicts that early in LS training a success will reduce future errors more than an error, while later in training an error will reduce future errors more than a success. Reese also drew the implications that the stimulus preferences must be overcome before the efficient LS performance can occur, and retention should be greater early in training than later. Doubt is cast on the former proposition by Bessemer's (see Footnote 5) finding that stimulus preferences persist in LS-sophisticated animals and on the latter by the efficient retention of specific discriminations and the corresponding failure to obtain transfer suppression.

More fundamentally, one might question the assumption of a direct strengthening function of rewards. We have seen that monkeys

can learn problems requiring the animal to avoid the object just chosen and rewarded (i.e., win-shift) and to approach an object that had just been followed by nonreward (i.e., lose-stay) (e.g., McDowell et al., 1965a) and that a marble is as reinforcing as a raisin (e.g., Riopelle et al., 1954).

Hypothesis Theories

The previously mentioned difficulty with Reese's modification of Hull-Spence theory is resolved by hypothesis theories. They view LS formation as a more abstract process in which hypotheses rather than single responses are regarded as subject to principles of reinforcement. Strategies or hypotheses rather than single responses may incorporate Trial 1 outcomes as cues, and thus a win-shift hypothesis is just as possible as a win-stay hypothesis.

1. *Harlow's error-factor theory.* Harlow's error-factor theory is a uniprocess theory, and only one basic learning process, inhibition, is assumed to occur. It is assumed that the correct response is immediately available but must compete with many inappropriate responses in the learning situation. Formation of a LS, according to the theory, occurs when the monkey has eliminated these error factors or inappropriate response tendencies.

Error-factor theory is not fully developed since specific assumptions and postulates have not yet been presented. For example, while transfer suppression would seem to be consistent with error-factor theory, it is not obvious that lack of suppression constitutes evidence against the theory. The various error factors do not completely disappear during LS formation (e.g., Bessemer, see Footnote 5; Davis et al., 1953), but the implications of this are unclear because the proportion of responses controlled by a given error factor presently cannot be determined, and consequently the strengths of the various error factors cannot be compared.

2. *Levine's hypothesis behavior model.* Levine's model (Levine, 1959, 1965) differs from Harlow's in several fundamental ways. The model includes both error-producing and reward-producing response patterns, hence the term hypothesis rather than error factor. Formation of LS occurs by the strengthening

of the correct hypothesis by 100% reinforcement and the gradual extinction of other hypotheses because of 50% reinforcement. All response patterns are measured, and from this the proportion of the time a specific hypothesis is used can be estimated. The detailed hypotheses are specific enough so that by some algebraic manipulations Levine can derive the proportion of time each of these hypotheses was used in a set of data. The model was tested (Levine, 1959) by observing some proportions of response sequence patterns and then predicting the proportion of occurrence of other response patterns. In general the agreement between predicted and observed proportions of responses is quite good. Interestingly, with monkeys, nonzero estimates of hypotheses seem to occur only for position preference, stimulus preference, the correct solution,⁷ and random or residual responding. At present, the model says nothing about retention of specific information except that hypotheses, and therefore memory concerning stimulus properties, persist for at least three trials.

3. *Restle's mathematical model.* Restle's (1958) explanation of LS formation emphasizes the cue function of rewards and centers importantly on an assumption of abstract cognition. The theory assumes three classes of cues are available during LS formation. There are Type *a* cues, which are relevant and common to all problems of the experiment; Type *b* cues, which are relevant within any one problem but which are not valid across problems; and Type *c* cues, which are not valid at any time. The Type *a* cues are abstract, and LS formation is seen to involve learning to use Type *a* cues and to ignore or adapt out invalid cues (Type *c*) and those valid within individual problems (Type *b*).

Restle cast his theory in mathematical form and discovered parameter values which allowed him to accurately describe both intra- and interproblem learning curves of data from previous LS studies.

⁷ Bowman (Bowman, 1963; Bowman & Takemura, 1965) has suggested separating win-stay and lose-shift from each other since the two components may be learned separately. Bowman's analysis is similar enough to Levine's that it is not given separate treatment here.

Since Type *b* cues get adapted, it seems crucial for the theory to predict transfer suppression, and, unfortunately for the theory, transfer suppression does not occur.

A question applying to all three models concerns the interplay between abstract cues or rules and specific stimulus properties. Hypothesis models principally have been concerned only with describing or representing differences in performance between initial and terminal states of learning with little emphasis on transitional functions. Little attention has been directed to ways in which learning processes studied in other contexts operate in LS formation. The escape from the assumption of an automatic strengthening function of reward appears to have been at the expense of a loss of contact with such fundamental areas of learning theory as stimulus generalization and retention. The model discussed in the next section ties LS formation more closely to specific stimulus properties and is consistent with efficient retention of specific discriminations.

Feedback Theory of Learning-Set Formation

The reader is referred to a companion paper⁸ by this author for a full treatment of the feedback theory of LS formation. This theory is an elaboration of a scanning model (Estes, 1966) which has already been successfully applied to reward magnitude learning by monkeys (Meyer, LoPopolo, & Singh, 1966). The main feature of the scanning model is that on a given trial, the subject scans the available cues, generates a feedback (covert prediction of reward value) for each cue, and makes the response which he predicts will yield the highest feedback.

Choices are controlled by stimulus properties of cues (i.e., their salience) and by expected feedback from previous rewards. Rewards affect choices by the facilitatory or inhibitory feedback their anticipation causes, but they do not directly affect learning. As applied to LS, the model assumes that rewards and nonrewards increase or decrease the expected feedback or anticipated reward value for the cue to which the animal re-

⁸ D. L. Medin. A feedback model for discrimination learning set in monkeys. Unpublished manuscript.

sponded.⁹ An individual problem is solved by an active selection of valid cues rather than an adaptation of irrelevant cues. For object-discrimination LS, the model assumes the monkey responds to one of four cues: (a) one object, (b) the other object, (c) the left position, and (d) the right position.

The basis for LS improvement is assumed to be interproblem stimulus generalization of feedback from expected rewards. This idea requires some explanation, since the suggestion that LS is mediated by specific between-problem stimulus generalization was rather casually dismissed in the introduction to this review. According to the model, transfer of feedback from anticipated rewards does not mysteriously become associated solely with the object to be correct on future problems. Positive feedback from rewards associated with similar cues on previous problems is transferred by stimulus generalization to *both* the future correct and incorrect objects. Even though no differential advantage accrues to the object to be correct on new problems, the scanning or cue-selection process functions more efficiently when initial feedback from anticipated rewards is high. Given high initial expectation of rewards, the monkey is able to focus on the correct cue almost immediately, and the discrimination is solved quickly. When the feedback associated with the correct and incorrect stimuli is low, even large differences in feedback for the correct and incorrect cues do not lead to efficient performance. One reason for this is that both cues would be at a disadvantage in competing for attention with other cues in the situation. When the feedback associated with both cues is high, the scanning process functions to narrow attention down to these two cues. Though the feedback associated with the incorrect object may be large, the feedback associated with the correct cue need only obtain a small advantage in order to control responding virtually perfectly. High initial feedbacks, in addition to placing certain cues at a competitive advantage, allow the scanning process to

perform more efficiently. This ability to efficiently focus on, or so to speak, home in on, cues with high feedback is a property of many stochastic learning models.

Most of the detailed predictions of the model were drawn from a computer simulation. The model is able to generate typical between- and within-problem LS functions. It correctly predicts that early in LS training a correct response reduces future errors more than an error, while late in LS an error reduces future errors more than a correct response. In addition, data produced by the model showed a pattern of error factors quite similar to that of real monkeys (Davis et al., 1953).

Specific criticisms of the feedback model await its future development and testing. If the feedback model for discrimination LS were to receive consistent support, it would have major implications for what monkeys learn during LS training. Historically, LS formation has been considered to be a complex abstractive process involving a conceptual understanding on the part of the monkeys. The feedback model does not assume any such abstract cognition and suggests that specific stimulus properties play a major role in LS formation. The feedback model suggests that the monkey does not so much learn how to learn as learn what to expect.

REFERENCES

- ABORDO, E. J., & RUMBAUGH, D. M. Response contingent learning set training in the squirrel monkey. *Psychological Reports*, 1965, **16**, 797-802.
- BEHAR, I. Analysis of object-alternation learning in rhesus monkeys. *Journal of Comparative and Physiological Psychology*, 1961, **54**, 539-542. (a)
- BEHAR, I. Learned avoidance of nonreward. *Psychological Reports*, 1961, **9**, 43-52. (b)
- BEHAR, I. Evaluation of cues in learning set formation in mangabeys. *Psychological Reports*, 1962, **11**, 479-485. (a)
- BEHAR, I. Evaluation of the significance of positive and negative cue in discrimination learning. *Journal of Comparative and Physiological Psychology*, 1962, **55**, 502-504. (b)
- BERNSTEIN, I. L. Presentation factors in discrimination learning by chimpanzees. *Psychological Reports*, 1961, **8**, 151-153.
- BOWMAN, R. E. Discrimination learning set performance under intermittent and secondary reinforcement. *Journal of Comparative and Physiological Psychology*, 1963, **56**, 429-434.

⁹ However, in general, reward does not automatically strengthen responses since a decrease in feedback might follow reward after the monkeys have been trained that nonreward follows reward as on a win-shift problem.

- BOWMAN, R. E., & TAKEMURA, K. Hypothesis behavior of monkeys as inferred from intermittently rewarded and other modified learning sets. *Proceedings of the 73rd annual convention of the American Psychological Association Convention 1965*. Washington, D. C.: APA, 1965.
- BOWMAN, R. E., & TAKEMURA, K. The response shift phenomenon in discrimination learning set. *Psychonomic Science*, 1966, **4**, 31-32.
- BOYER, W. N. Discrimination performance in three species of monkeys as a function of Trial 1 reward contingency, intertrial interval, and prior test experience. *Psychonomic Science*, 1966, **5**, 27-28.
- BRAUN, H. W., PATTON, R. A., & BARNES, H. W. Effects of electroshock convulsions upon the learning performance of monkeys: I. Object-quality discrimination learning. *Journal of Comparative and Physiological Psychology*, 1952, **45**, 231-238.
- BROWN, W. L., & CARR, R. M. The learning of incidental cues by rhesus monkeys. *Journal of Comparative and Physiological Psychology*, 1958, **51**, 459-460.
- BROWN, W. L., & MCDOWELL, A. A. Response shift learning set in monkeys. *Journal of Comparative and Physiological Psychology*, 1963, **56**, 335-336.
- BROWN, W. L., MCDOWELL, A. A., & GAYLORD, H. A. Two-trial learning-set formations by baboons and by stump-tailed macaques. *Journal of Comparative and Physiological Psychology*, 1965, **60**, 288-289.
- BROWN, W. L., OVERALL, J. E., & BLODGETT, H. C. Novelty learning sets in rhesus monkeys. *Journal of Comparative and Physiological Psychology*, 1959, **52**, 330-332.
- BROWN, W. L., OVERALL, J. E., & GENTRY, G. V. Conceptual discrimination in rhesus monkeys. *Journal of Comparative and Physiological Psychology*, 1958, **51**, 701-705.
- CROSS, H. A., & BROWN, L. T. Discrimination reversal learning in squirrel monkeys as a function of number of acquisition trials and prereversal experience. *Journal of Comparative and Physiological Psychology*, 1965, **59**, 429-431.
- CROSS, H. A., FLETCHER, H. J., & HARLOW, H. F. Effects of prior experience with test stimuli on learning-set performance of monkeys. *Journal of Comparative and Physiological Psychology*, 1963, **56**, 204-207.
- DARBY, C. L., & RIOPELLE, A. J. Differential problem sequences and the formation of learning sets. *Journal of Psychology*, 1955, **39**, 105-108.
- DAVIS, R. T. The radiation syndrome. In A. M. Schrier, H. F. Harlow, & F. Stollnitz (Eds.), *Behavior of nonhuman primates: Modern research trends*. New York: Academic Press, 1965.
- DAVIS, R. T., MCDOWELL, A. A., & THORSON, N. Four-trial object-quality discrimination learning by monkeys. *Proceedings of the South Dakota Academy of Science*, 1953, **32**, 132-142.
- FESTES, W. K. Transfer of verbal discriminations based on differential reward magnitudes. *Journal of Experimental Psychology*, 1966, **72**, 276-283.
- ETTLINGER, G. Discrimination learning theory: Excitation vs. inhibitory tendencies in monkeys. *Quarterly Journal of Experimental Psychology*, 1960, **12**, 41-44.
- FLETCHER, H. J. Prompted vs trial-and-error 3-trial object discrimination learning by monkeys. *Psychonomic Science*, 1966, **4**, 111-112.
- FLETCHER, H. J., & CROSS, H. A. Effects of trial 1 reward contingency, intertrial interval, and experience on intraproblem discrimination performance of monkeys. *Journal of Comparative and Physiological Psychology*, 1964, **57**, 318-320.
- FLETCHER, H. J., GROGG, T. M., & GARSKE, J. P. Ambiguous cue problem performance of children, retardates, and monkeys. *Journal of Comparative and Physiological Psychology*, 1968, **66**, 477-482.
- FLETCHER, H. J., & TAKEMURA, K. Prompted vs trial and error concept discrimination learning in monkeys. *Perceptual and Motor Skills*, 1965, **20**, 737-743.
- FRENCH, G. M., BIRNBAUM, I., LEVINE, R., & PINSKER, H. Discrimination choice in normal and prefrontal rhesus monkeys. *Journal of Comparative and Physiological Psychology*, 1965, **59**, 225-230.
- GENTRY, G. V., OVERALL, J. E., & BROWN, W. L. Discrimination after pretraining on component stimuli. *Journal of Comparative and Physiological Psychology*, 1958, **51**, 464-466.
- HARLOW, H. F. Studies in discrimination learning by monkeys: I. The learning of discrimination series and the reversal of discrimination series. *Journal of General Psychology*, 1944, **30**, 3-12.
- HARLOW, H. F. The formation of learning sets. *Psychological Review*, 1949, **56**, 51-65.
- HARLOW, H. F. Analysis of discrimination learning by monkeys. *Journal of Experimental Psychology*, 1950, **40**, 26-39.
- HARLOW, H. F. Learning set and error factor theory. In S. Koch (Ed.), *Psychology: A study of a science*. Vol. 2. New York: McGraw-Hill, 1959.
- HARLOW, H. F., & WARREN, J. M. Formation and transfer of discrimination learning sets. *Journal of Comparative and Physiological Psychology*, 1952, **45**, 482-489.
- HAYES, K. J., THOMPSON, R., & HAYES, C. Concurrent discrimination learning in chimpanzees. *Journal of Comparative and Physiological Psychology*, 1953, **46**, 105-107.
- KING, J. E. Transfer relationships between learning set and concept formation in rhesus monkeys. *Journal of Comparative and Physiological Psychology*, 1966, **61**, 416-420.
- KING, J. E., & GOODMAN, R. Successive and concurrent discrimination by rock squirrels and squirrel monkeys. *Perceptual and Motor Skills*, 1966, **23**, 703-710.
- KRUPER, D. C., PATTON, R. F., & KOSKOFF, Y. D. Delayed object-quality discriminations in hemispherectomized monkeys. *Journal of Comparative and Physiological Psychology*, 1961, **54**, 619-624.

- LEARY, R. W. The rewarded, the unrewarded, the chosen and the unchosen. *Psychological Reports*, 1956, 2, 91-97.
- LEARY, R. W. Analysis of serial-discrimination learning by monkeys. *Journal of Comparative and Physiological Psychology*, 1958, 51, 82-86. (a)
- LEARY, R. W. The learning of ambiguous cue-problems by monkeys. *American Journal of Psychology*, 1958, 71, 718-724. (b)
- LEARY, R. W. The temporal factor in reward and nonreward of monkeys. *Journal of Experimental Psychology*, 1958, 56, 294-296. (c)
- LEARY, R. W. 'Spontaneous reversal' in serial discrimination reversal learning of monkeys. *Canadian Journal of Psychology*, 1962, 16, 228-233.
- LEVINE, M. A model of hypothesis behavior in discrimination learning set. *Psychological Review*, 1959, 66, 353-366.
- LEVINE, M. Hypothesis behavior. In A. M. Schrier, H. F. Harlow, & F. Stollnitz (Eds.), *Behavior of nonhuman primates: Modern research trends*. New York: Academic Press, 1965.
- LOCKHART, J. M., PARKS, T. E., & DAVENPORT, J. W. Information acquired in one trial by learning-set experienced monkeys. *Journal of Comparative and Physiological Psychology*, 1963, 56, 1035-1037.
- MASON, W. A., BLAZEK, N. C., & HARLOW, H. F. Learning capacities of the infant rhesus monkey. *Journal of Comparative and Physiological Psychology*, 1956, 49, 449-453.
- MCCONNELL, D. G., & SCHUCK, J. R. An analysis of primate responses to colored filmstrips stimuli. *Journal of Comparative and Physiological Psychology*, 1962, 55, 505-510.
- MCDOWELL, A. A., & BROWN, W. L. The learning mechanism in response shift learning set. *Journal of Comparative and Physiological Psychology*, 1963, 56, 572-574. (a)
- MCDOWELL, A. A., & BROWN, W. L. Learning mechanism in response perseveration learning sets. *Journal of Comparative and Physiological Psychology*, 1963, 56, 1032-1034. (b)
- MCDOWELL, A. A., & BROWN, W. L. Sex and radiation as factors in peripheral cue discrimination learning. *Journal of Genetic Psychology*, 1963, 102, 261-265. (c)
- MCDOWELL, A. A., & BROWN, W. L. Further evidence for excitatory properties of nonrewarded cues. *Journal of Genetic Psychology*, 1965, 106, 137-140. (a)
- MCDOWELL, A. A., & BROWN, W. L. Learning mechanisms in response shift learning set to nonrewarded cues. *Journal of Genetic Psychology*, 1965, 106, 173-176. (b)
- MCDOWELL, A. A., & BROWN, W. L. Perseveration learning set formation to nonrewarded cues by normal and previously irradiated rhesus monkeys. *Journal of Genetic Psychology*, 1965, 107, 309-311. (c)
- MCDOWELL, A. A., & BROWN, W. L. Response perseveration under constant stimulus-position conditions by normal and previously irradiated female rhesus monkeys. *Journal of Genetic Psychology*, 1965, 106, 81-84. (d)
- MCDOWELL, A. A., & BROWN, W. L. Response shift learning-set formation by normal and previously irradiated female rhesus monkeys. *Journal of General Psychology*, 1965, 72, 339-342. (e)
- MCDOWELL, A. A., GAYLORD, H. A., & BROWN, W. L. Learning set formation by naive rhesus monkeys. *Journal of Genetic Psychology*, 1965, 106, 253-257. (a)
- MCDOWELL, A. A., GAYLORD, H. A., & BROWN, W. L. Perseveration learning set formation by monkeys with previous discrimination training. *Journal of Genetic Psychology*, 1965, 106, 345-347. (b)
- MEYER, D. R. Intraproblem-interproblem relationships in learning by monkeys. *Journal of Comparative and Physiological Psychology*, 1951, 44, 162-167.
- MEYER, D. R., LoPOPOLO, M. H., & SINGH, D. Learning and transfer in the monkey as a function of differentiated levels of incentive. *Journal of Experimental Psychology*, 1966, 72, 284-286.
- MILES, R. C. Discrimination-learning sets. In A. M. Schrier, H. F. Harlow, & F. Stollnitz (Eds.), *Behavior of nonhuman primates: Modern research trends*. New York: Academic Press, 1965.
- REISE, H. W. Discrimination learning set in rhesus monkeys. *Psychological Bulletin*, 1964, 61, 321-340.
- RESTLE, F. Toward a quantitative description of learning set data. *Psychological Review*, 1958, 65, 77-91.
- RIOPELLE, A. J. Transfer suppression and learning sets. *Journal of Comparative and Physiological Psychology*, 1953, 46, 108-114.
- RIOPELLE, A. J. Learning sets from minimum stimuli. *Journal of Experimental Psychology*, 1955, 49, 28-32. (a)
- RIOPELLE, A. J. Rewards, preferences and learning sets. *Psychological Reports*, 1955, 1, 167-173. (b)
- RIOPELLE, A. J., CHRONHOLM, J. N., & ADDISON, R. G. Stimulus familiarity and multiple discrimination learning. *Journal of Comparative and Physiological Psychology*, 1962, 55, 274-278.
- RIOPELLE, A. J., & CHURUKIAN, G. A. The effect of varying the intertrial interval in discrimination learning by normal and brain-operated monkeys. *Journal of Comparative and Physiological Psychology*, 1958, 51, 119-125.
- RIOPELLE, A. J., & COPELAND, E. L. Discrimination reversal learning to a sign. *Journal of Experimental Psychology*, 1954, 48, 143-145.
- RIOPELLE, A. J., & FRANCISCO, E. W. Discrimination learning performance under different first-trial procedures. *Journal of Comparative and Physiological Psychology*, 1955, 48, 143-145.
- RIOPELLE, A. J., FRANCISCO, E. W., & ADES, H. E. Differential first-trial procedures and discrimination learning performance. *Journal of Comparative and Physiological Psychology*, 1954, 47, 293-297.
- RIOPELLE, A. J., & MOON, W. H. Problem diversity and familiarity in multiple discrimination learn-

- ing by monkeys. *Animal Behaviour*, 1968, **16**, 74-78.
- RUMBAUGH, D. M., & ENSMINGER, L. W. Discrimination reversal training with single and multiple stimulus pairs in the squirrel monkey. *Journal of Comparative and Physiological Psychology*, 1964, **57**, 304-306.
- RUMBAUGH, D. M., & PRIM, M. M. Temporary interference of insolvable discrimination reversal training upon learning set in the squirrel monkey. *Journal of Comparative and Physiological Psychology*, 1964, **57**, 302-304.
- RUMBAUGH, D. M., SAMMONS, M. E., PRIM, M. M., & PHILLIPS, S. Learning set in squirrel monkeys as affected by pretraining with differentially rewarded single objects. *Perceptual and Motor Skills*, 1965, **21**, 63-70.
- SCHRIER, A. M. Transfer by macaque monkeys between learning set and repeated reversal tasks. *Perceptual and Motor Skills*, 1966, **23**, 787-792.
- SCHRIER, A. M. Learning set without transfer suppression: A replication and extension. *Psychonomic Science*, 1969, **16**, 263-265.
- SCHUSTERMAN, R. J. Transfer effects of successive discrimination reversal training in chimpanzees. *Science*, 1962, **137**, 422-423.
- SCHUSTERMAN, R. J. Successive discrimination-reversal training and multiple discrimination training in one-trial learning by chimpanzees. *Journal of Comparative and Physiological Psychology*, 1964, **58**, 153-156.
- SCHWARTZBAUM, J. S., & POULAS, D. A. Discrimination behavior after amygdectomy in monkeys: Learning set and discrimination reversals. *Journal of Comparative and Physiological Psychology*, 1965, **60**, 320-328.
- SHELL, W. F., & RIOPELLE, A. J. Progressive discrimination learning in platyrrhine monkeys. *Journal of Comparative and Physiological Psychology*, 1958, **51**, 467-470.
- SHERIDAN, C. L., HOREL, J. A., & MEYER, D. R. Effects of response-induced stimulus change on primate discrimination learning. *Journal of Comparative and Physiological Psychology*, 1962, **55**, 511-514.
- SLEDJESKI, M., & FRENCH, G. M. Multiple transfer paradigms following discrimination problem solution in monkeys. *Journal of Comparative and Physiological Psychology*, 1968, **66**, 228-231.
- STOLLNITZ, F. Spatial variables, observing responses, and discrimination learning sets. *Psychological Review*, 1965, **72**, 247-261.
- STOLLNITZ, F., & SCHRIER, A. M. Learning set without transfer suppression. *Journal of Comparative and Physiological Psychology*, 1968, **66**, 780-783.
- STRONG, P. N., JR. Memory for object discrimination in the rhesus monkey. *Journal of Comparative and Physiological Psychology*, 1959, **52**, 333-335.
- TAKEMURA, K. Saru ni okeri benbetsu gakushu no kamae no jigenkav icho [Inter-categorical transfer of discrimination learning sets in monkeys.] *Annual Animal Psychology*, 1960, **10**, 55-63.
- THOMPSON, R. Approach vs. avoidance in an ambiguous-cue discrimination problem in chimpanzees. *Journal of Comparative and Physiological Psychology*, 1954, **47**, 133-135.
- TREICHLER, F. R. Transfer effects in monkey discrimination learning after extensive two-problem training. *Psychonomic Science*, 1966, **5**, 201-202.
- VON WRIGHT, J. M. Cross-modal transfer and sensory equivalence—A review. *Scandinavian Journal of Psychology*, 1970, **11**, 21-30.
- WARREN, J. M. Reversal learning and the formation of learning sets by cats and by rhesus monkeys. *Journal of Comparative and Physiological Psychology*, 1966, **61**, 421-428.
- WARREN, J. M., & SINHA, M. M. Interaction between learning sets in monkeys. *Journal of Genetic Psychology*, 1959, **95**, 19-25.
- WILSON, M., & WILSON, W. A., JR. Intersensory facilitation of learning sets in normal and brain-operated monkeys. *Journal of Comparative and Physiological Psychology*, 1962, **55**, 931-934.
- ZIMMERMANN, R. R. Effects of age, experience, and malnourishment on object retention in learning set. *Perceptual and Motor Skills*, 1969, **28**, 867-876.

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