

*CONDITIONAL DISCRIMINATION LEARNING:  
A CRITIQUE AND AMPLIFICATION*

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Carter and Werner recently reviewed the literature on conditional discrimination learning by pigeons, which consists of studies of matching-to-sample and oddity-from-sample. They also discussed three models of such learning: the "multiple-rule" model (learning of stimulus-specific relations), the "configuration" model, and the "single-rule" model (concept learning). Although their treatment of the multiple-rule model, which seems most applicable to the pigeon data, is generally excellent, their discussion of the other two models is incomplete and sometimes inaccurate. Potential problems of terminology are discussed in the present paper, as are additional lines of research that deserve consideration by those interested in further work in this area. The issue of response versus stimulus selection (configuration versus compound-cue learning) is discussed in connection with the configuration model. Particular attention is given to Carter and Werner's criticism of the application, in studies with other species, of the learning set procedure in testing for single-rule learning. Some of the important related issues are: the bias for improvement on new problems in a series, the adequacy of a multiple-rule model to explain learning set formation, and evidence in favor of the single-rule model, at least in primates. Consideration of these additional contributions to the study of conditional discrimination learning emphasizes the usefulness of this task in the comparative study of cognitive processes.

*Key words:* conditional discrimination, matching-to-sample, oddity-from-sample, concept learning, learning set formation

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Carter and Werner (1978) recently reviewed and analyzed research on conditional discrimination learning by pigeons. Although recognizing that there is an extensive literature on conditional discrimination learning by other species, they limit their review primarily to work with pigeons because of its "programmatic" nature; that is, because of the greater comparability of both the procedures used and problems attacked in the studies with pigeons than in the studies with other species.<sup>1</sup> We have no quarrel with this approach per se

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This paper was prepared with the aid of funds from NSF research grants BNS77-16242 and BNS79-06794. Reprints may be obtained from Allan M. Schrier, Psychology Dept., Brown University, Providence, RI 02912.

<sup>1</sup>Most of the work on conditional discrimination learning with other species has been done with non-human primates, though a great deal has also been done with human children. As we note later in the paper, there have also been an appreciable number of studies with rats, aside from the one early study by Lashley (1938) that is cited by Carter and Werner. Since the focus of the studies with children has often been different from that of studies with nonhuman species, we have restricted our discussion to studies done with these latter species.

and find many aspects of the review, particularly those sections that deal with the "multiple-rule model" and the "coding hypothesis," excellent. They have also performed a valuable service in calling attention to the fact that matching-to-sample, so heavily used in recent years in studies with pigeons, and oddity-from-sample are special cases of an important class of discrimination problems, namely conditional discriminations. However, it is in connection with the literature on other species that we do have some criticism of a number of aspects of their review. There is a difference between an approach that is intentionally restricted in scope and one which is basically insular. We think that the review can in many respects be described by the latter term. We are concerned that readers of Carter and Werner's review who might wish to broaden their perspectives by delving into the literature on other species are not given as much help by them as possible, and, indeed, in a number of instances may be hindered or misled by the review. In the first place, Carter and Werner sometimes create problems of terminology in this area by giving some terms differ-

ent meanings than those used before, introducing new terms where others already exist, or occasionally omitting terms that the reader will inevitably run into elsewhere. In addition, they often do not give references when making statements about what they assert is the current thinking with respect to data obtained with other species. When they do give such references, they do not always give the most important and most recent ones. Finally, on the occasions when they do make forays into the literature on other species, they make some serious mistakes.

As Carter and Werner note, one of the pioneering studies on conditional discrimination learning was carried out by Lashley (1938) using rats as the subjects. In the type of procedure used by Lashley, two stimuli (e.g., form A and form B) are presented on every trial, while only one of another pair of stimuli (e.g., color A and color B) is presented on any given trial. In later years, when a task of this type has been used, the former stimuli have often been referred to as the "simultaneous cues" and the latter as the "conditional" or "successive cues." Choice of one of the simultaneous stimuli (e.g., form A) is reinforced only when one of the conditional stimuli (e.g., color A) is present, whereas choice of the other simultaneous stimulus (form B) is reinforced only when the second conditional stimulus (color B) is present.

One potential source of confusion for someone searching beyond the pigeon literature is that the term "conditional discrimination" has sometimes referred to the type of problem used by Lashley and other times to the class of problems. Another source of confusion arises in connection with what has often been called the "successive" discrimination problem. This is another type of conditional problem, which along with the type that Lashley used, received considerable attention in the 1950's in a series of studies with rats. In a

successive discrimination, as carried out with rats in a T-maze for example, choice of the right arm is reinforced if both arms of the maze are white, whereas choice of the left arm is reinforced if both arms are black. Somewhat more accurate and consistent terms would be "two-choice spatial" conditional discrimination in place of successive discrimination, and "two-choice visual" or "non-spatial" conditional discrimination for the type of problem that Lashley used.<sup>2</sup>

We mention these studies with rats not only because of the possible confusion created by the terms in use, but also because one of the major concerns in carrying them out was a theoretical issue that should not be overlooked in any review of conditional discrimination learning. The issue we have in mind was whether discrimination learning involves "response selection" or "stimulus selection" (see Mackintosh, 1974, Chapter 10, for a good review of this issue and the related studies). Put another way, the question was whether, in the T-maze setting for example, the animals learn to go left in the presence of one stimulus configuration (black-black) and right in the presence of the other (white-white) or, alternatively, whether they learn to approach two of the four stimulus compounds (that is, black-left or white-right as opposed to black-right or white-left). Most of the evidence from the series of studies with rats favored a stimulus selection view. As we will mention later, the question of positional responding on the basis of the configuration of the entire set of discriminative stimuli presented on a given trial has also come up in connection with the learning of some types of conditional discriminations by nonhuman primates.

Perhaps because these issues have not arisen in connection with pigeon studies, Carter and Werner do not mention them or any of the studies concerned with them. However, near the beginning of their review, Carter and Werner do mention three hypotheses about the nature of conditional discrimination learning. They label these the "multiple-rule model," the "configuration model," and the "single-rule model." They do not devote a great amount of space to the configuration model, apparently because they do not feel that it accounts for conditional discrimination learning data. Unfortunately, what they do say about it is somewhat ambiguous in light

<sup>2</sup>As Carter and Werner also indicate, the term "sign" has sometimes been used to mean conditional cue. Thus, especially in some of the older literature on monkeys, the spatial task has been referred to as a "sign-differentiated spatial discrimination," and the type of task that Lashley used as a "sign-differentiated [form, color, object or whatever term describes the simultaneous cues] discrimination." Hence, also the occasional use of the term "multiple-sign" learning to designate conditional discriminations as a class.

of the distinction, drawn in the literature on other species, between configuration and compound-cue responding. Their description of the configuration model in the text of their paper can be taken to mean what is usually meant when the term is used, but, this becomes less clear when they call attention to a figure (Figure 1, p. 567) illustrating the differences between that model and the multiple-rule model. In the figure, what they describe as the configuration model is not clearly distinguishable from what would be used to illustrate a compound-cue model. Furthermore, they cite Gullikson and Wolffe (1938) and Spence (1952) as "Examples of theorists who have found the configuration model useful in the analysis of discrimination learning" (p. 566). Using the term as it is usually used elsewhere in the literature, they are correct in citing Gullikson and Wolffe, but not Spence. The main purpose of the article by Spence was to show how a compound-cue approach could account for both spatial and non-spatial conditional discrimination learning of the type considered in the studies with rats. This was consistent with the view Spence held of discrimination learning as first stated in his classic paper of 1936. In any event, careful attention must be paid to the distinction between the compound-cue and configuration models, since both have their applications in the area of conditional discrimination learning in addition to the multiple-rule and single-rule models. This is not simply a matter of pedantics, since as is so often the case in psychology, it is probably not a question of this or that model being correct, but of one model being appropriate under some circumstances and another under other circumstances.

We turn now to Carter and Werner's discussion of the single-rule model. By this they mean the learning of an abstract rule or concept that enables an animal to solve a new conditional discrimination problem more quickly than it did the original problem. The term "hypothesis formation" is also often used in this context. In order to conclude that such learning has occurred, it must be shown that the superior performance on the new problem is independent of stimulus generalization. Equally important, though Carter and Werner mention the point only in a footnote, it must also be shown that the superior performance does not represent non-specific transfer result-

ing simply from the additional experience gained in the test situation (that is, adaptation to testing). Such non-specific transfer has been shown to be important under some circumstances when testing for concept learning in monkeys (see Schrier, 1974, for discussion and references). Carter and Werner correctly point out that most of the studies with pigeons purporting to show oddity-from-sample or matching-to-sample concept learning can either be explained in terms of stimulus-specific rules or else are ambiguous.<sup>3</sup> Nevertheless, they assert that they are "unwilling to assume that pigeons cannot learn such concepts" (p. 596). The major reason, and certainly one which is well worth emphasizing, is that

the procedures normally used to establish matching and oddity learning sets with nonhuman primates and with human children (Harlow, 1949) differ from those used with pigeons. With Harlow's procedure, it is commonly believed that subjects could never learn a set of sample-specific rules, because every few trials a new set of stimuli replaces the old set. In other words, it is assumed that the learning set procedure differs from those [used in the pigeon studies] in that the matching or the oddity principle provides the only possible basis for learning. (p. 596).

Carter and Werner go on to describe an unpublished matching-to-sample experiment by Carter and Taten, which is apparently the only conditional discrimination learning study with pigeons in which the "Harlow procedure" has been used. However, Carter and Taten found no evidence for concept learning. That seems to leave only an experiment by Honig (1965), in which something like a matching procedure was used, as a possible demonstra-

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<sup>3</sup>As Carter and Werner point out, when a sampling procedure is used as in matching-to-sample, the oddity procedure is sometimes called "oddity-from-sample." Still other terms for it are "mismatching," and "non-matching." The oddity-from-sample procedure has been the only one used in studies of "oddity learning" with pigeons, but has been used only rarely in such studies with nonhuman primates and other species. Because, as we mention later, the difference in procedure can make a difference in the interpretation of the results, we use the term "oddity-from-sample" when talking only about studies with pigeons and "oddity" when the discussion concerns other species as well.

tion of conditional concept learning. Although they recognize that the basis for positive transfer to new problems in the Honig experiment is not entirely clear, the reader is left with the impression that it could well be an instance of concept learning. The circumspection with which they treat this study seems well justified, for Premack (1978) has also examined in detail several studies with pigeons, including Honig's, which might be considered as demonstrating concept learning, and has argued convincingly that all of them can be explained in terms of stimulus specific processes such as generalization.

Thus, there seems to be no specific empirical basis for assuming that pigeons can learn abstract conditional rules. From a comparative perspective, the chances of positive results seem problematical because the evidence for such concept learning is meager even for non-primate mammals. On the other hand, there is some evidence for abstract rule learning in at least some species of birds, although it is not of a conditional nature. In a series of studies, Kamil and co-workers (Kamil, Jones, Pietrewicz, & Mauldin, 1977) have shown that blue jays are able to perform at a reasonably high level on the standard discrimination learning set task, that is, a task involving a series of simple two-choice discrimination problems. Furthermore, the data suggest that the mechanism of learning set formation is the same as it is in monkeys and apes. There are still a number of textbook writers, apparently unaware of the learning set literature during the past decade or so, who assert that learning set formation is absent or very poor in non-primate mammals, not to speak of non-mammalian species (for the interested reader, a more informative review is provided by Warren, 1973).

There is a word of caution necessary should anyone decide to test for conditional discrimination concept learning in pigeons. This stems from Carter and Werner's statement, as quoted above, that it is assumed (although they do not say by whom) that the oddity or matching principle is the only basis for learning when oddity or matching problems are presented in a learning set procedure. Taking the statement at face value, it is simply not true. The learning set procedure typically refers only to the use of a series of problems in which each problem consists of a new set of

stimuli.<sup>4</sup> When the series of problems are all simple two-choice discriminations, any increase in rate of learning of the problems as a function of practice is presumptive evidence for concept learning. However, as others have pointed out (Strong & Hedges, 1966; Thomas & Boyd, 1973), only evidence of learning on the first trial of each new oddity or matching problem can be taken as evidence that the basis of solution is the oddity or matching principle, using the term in its strictest sense. Faster learning of later problems in a series of oddity or matching problems, while still demonstrating learning set formation, could be based on, among other things, a generalized response to stimulus configurations. Correct responding at levels considerably above chance on first trials of oddity problems, for example, has been found in several studies with monkeys (Levine & Harlow, 1959; Shaffer, 1967; Thomas & Boyd, 1973), but thus far, has not been demonstrated in any nonprimate species.

While emphasizing what would appear to be an important difference in the procedure of conditional concept experiments on non-human primates and on pigeons, Carter and Werner, at the same time, raise some very serious questions about the adequacy of the procedure used with nonhuman primates and, hence, the interpretation of the results. In their own words:

A careful analysis of the Harlow procedure reveals an error in logic. In most instances, research on matching and oddity learning sets involves the use of the Wisconsin General Test Apparatus. The stimuli most often used are common household or laboratory objects, which are

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<sup>4</sup>In some experiments, each problem has consisted of stimuli drawn repeatedly at random from a relatively small pool of stimuli. It is not clear how large the pool of stimuli has to be in order to get complete learning set formation. The question has come up in connection with experiments on transfer between the repeated-reversal and learning-set tasks (Schrier, 1974), which are mentioned later in this paper.

It should also be emphasized that the term "learning set formation" is sometimes used, as it seems to be by Carter and Werner, in a theoretical sense, implying concept or hypothesis formation, but, at other times, is used in a strictly empirical sense, implying only an increase in the rate of learning of problems over the course of a series of problems. Because the increase in rate can have different bases, we prefer to use the term in the latter manner.

displaced by the subject in order to obtain reinforcement. Each day a new pair of stimuli is chosen, and it is assumed that transfer from one session to another indicates that the subject is responding to a relationship between stimuli.

Several hundred stimulus objects may be needed for a single experiment, but while shape, size, and other stimulus characteristics vary from session to session, only a few distinct hues are available. A subject could solve a matching problem by learning a small number of  $S^D$  rules, because each hue is repeated many times during the experiment. All other information in the stimulus array may be disregarded. (p. 596)

The implication is clear that, using the "Harlow procedure," a subject, whether pigeon, monkey, human child or any other species, could solve each matching or oddity problem in a series by learning a small number of stimulus-specific rules rather than abstract concepts.<sup>5</sup> Though perhaps somewhat less direct, there is also the implication in their statements that the same criticism could be made of interpretations of standard discrimination learning set formation experiments. After all, the typical procedure in such experiments has been similar to that used in Harlow's 1949 experiment, which is the only one that Carter and Werner cite in connection with their discussion of the "Harlow procedure." Harlow's 1949 study is one of the most widely cited animal studies in the literature

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<sup>5</sup>One minor correction of Carter and Werner's description of the Harlow technique has to do with their statement that "Each day a new pair of stimuli is chosen." (p. 596). This is rarely the way it is done. Usually, several different problems are presented each day, as in fact is implied by a statement they make in the paragraph preceding the one in question. The point is minor in the present context, but is not when the major focus of concern is learning set formation. The number of trials per problem can be an important variable, such learning being poor in some instances when there are either too many or too few trials per problem (Miles, 1965, pp. 57-59; and an unpublished experiment by Colbert and Schrier, 1971, obtainable from Schrier). In fact, the unpublished manuscript describing the Carter and Taten study in detail indicates that their pigeons were given 120 trials per matching-to-sample problem. This is considerably more trials per problem than has usually been used in learning set studies, and one possible reason learning set performance in their experiment was so poor.

and has stimulated a huge volume of research (see Bessemer & Stollnitz, 1971; Medin, 1977; Miles, 1965; Warren, 1965, 1973 for reviews of the learning set literature). Perhaps some of these implications of Carter and Werner's statements were unintentional results of their preoccupation with pigeon studies. Nevertheless, it would be unfortunate if readers not familiar with the learning set literature were left with the impression that 30 years of research has had a basic flaw.

By way of answering Carter and Werner's criticism, we should say, first, that an "error of logic" hardly seems to be what is involved here. A more appropriate term, though less dramatic, would be a "methodological" error. It is possible that some case could be made for explaining conditional and standard learning set formation by monkeys and apes in terms of learning of a few stimulus-specific relations, if it can be assumed that they behave as did Carter and Taten's pigeons in their matching-to-sample learning set study (again, as described by Carter and Werner). Their data indicated that the pigeons used a very limited number of color categories and also did not attend to form cues when color cues were available. However, there is a great deal of direct and indirect information that indicates that the performance of monkeys and apes on oddity and standard discrimination learning set tasks cannot be explained in terms of stimulus-specific rules and that it is very unlikely that performance on matching-to-sample can be either. First, while nonhuman primates appear perceptually to divide the visible spectrum into four primary hues (Sandell, Gross, & Bornstein, 1979) as do humans, there is also evidence that, when given the opportunity, they can subdivide colors into as many secondary categories as humans do (Essock, 1977). Thus, it is quite possible that these animals use a larger number of color categories in the learning set situation than might appear to be the case on the basis of some kinds of tests. Second, a glance at almost any of the collections of junk objects used in learning set studies will suggest that, for many combinations of objects, a simple color categorization is not possible or is very unlikely. Many objects do not appear to be easily categorizable by color (reflective metal objects, for example). Many objects are multicolored, so that for some combinations, the animal would have to

choose the object that is, for example, not just red, but the most red, or the object that is red and blue, but not red and green. A number of combinations will inevitably involve objects that are the same color. While it may still be true that the majority of combinations can be distinguished on the basis of color, there are enough that are not that one would expect to see periodic sharp dips in performance to chance level, such as Carter and Taten found for the pigeon when the problem could occasionally be solved only on the basis of differences in form. However, once monkeys or apes have reached a high level of performance on matching-to-sample, oddity, or standard discrimination learning set tasks, they are much more consistent than one would expect if they were responding on the basis of only a limited set of cues. Third, although there is no doubt that color is a dominant visual dimension for monkeys, it has been shown that they make use of other cues as well, if they are available. For both conditional discrimination learning (Warren, 1964), and standard learning set formation (Warren, 1953), these animals do not perform as well when the discriminative stimuli differ only in color as they do when they also differ in other dimensions, such as form, size, or orientation.

Fourth, in the case of oddity learning in particular, we are not sure that a set of sample specific cues can be defined. With the oddity-from-sample procedure typically used with pigeons, a single problem is presented in which a response to a center key stimulus is followed by presentation of two side-key stimuli. In this case, learning can clearly be explained in terms of sample-specific response rules. But with the oddity learning procedure usually used with animals other than pigeons, no such initiating response to the center stimulus (or to any other stimulus) in an array is required. Thus there is no sample to speak of, and, hence, no sample-specific cues.<sup>6</sup>

<sup>6</sup>This is most clear in "three-position oddity" where the odd stimulus can appear in any of the positions in a three-stimulus array. Since the odd stimulus appears sometimes on the left, in the center, or on the right, there is no consistent location for a sample cue on which to base a sample-specific response (see French, 1965, for a detailed description and discussion of the different types of oddity procedures that have been used).

Fifth, we might also mention at this point that monkeys and apes have been trained on more complicated types of oddity and matching tasks, for which solution on the basis of stimulus-specific rules is even more unlikely than in the case of the types of problems considered by Carter and Werner. Examples of such tasks include "sameness-difference" (Smith et al., 1975) and "cross-modal" (Ettlinger, 1977) matching and "dimension-abstracted" and "Weigl-type" oddity (see French, 1965, for a discussion of these last two as well as other types of complex conditional discrimination tasks).

Lastly, there is a great deal of evidence from studies of standard discrimination learning set formation that has a bearing on the questions raised by Carter and Werner. On the basis of their analysis, one might expect that among the worst conditions for establishing concept learning would be extensive training using a very limited set of discriminative stimuli. Yet, it has been shown for apes (Schusterman, 1964), monkeys (Schrier, 1974), and blue jays (Kamil et al., 1977) that there is a large amount of positive transfer when these animals are first trained to a high level of performance on a task consisting of repeated reversals of a single pair of objects and then given a standard learning set task. The best explanation that has been offered for such positive transfer is that solution of both tasks involves development of the same abstract rule or hypothesis, usually referred to as "win-stay, lose-shift" (with respect to objects) (Levine, 1965). Another finding which seems to support this kind of interpretation of learning set formation is the high level of transfer that occurs when monkeys are first trained to a high level of performance on a series of form discrimination problems and then are given a series of color discrimination problems or the reverse (Schrier, 1971). For a discussion of evidence bearing on the hypothesis formation view of learning set formation see Bessemer and Stollnitz (1971), Levine (1965), and Medin (1977). Also see Premack (1978) and Thomas and Crosby (1977) for a discussion of related questions.

We can summarize our reading of Carter and Werner's review with the following main points. On the one hand, Carter and Werner correctly bring attention to the conditional discrimination task as having important po-

tential as a general paradigm for studying complex cognitive processes in animals. They also provide a very good discussion of Cumming and Berryman's coding hypothesis and the evidence in favor of multiple-rule learning in conditional discrimination learning by pigeons. On the other hand, we believe that certain aspects of Carter and Werner's analysis could result in serious misconceptions. One possibility is that the reader will incorrectly generalize the applicability of the multiple-rule learning model to other animals, when in fact evidence for other kinds of learning in rats and primates clearly exists. In addition, the reader might conclude on the basis of the information provided that a number of important theoretical issues to which the conditional discrimination problem has relevance have not been studied, although they have been in detail. Finally, because such reviews lead people in the way they think, an obligation exists to cite evidence supporting competing points of view, to make the reader aware of a number of reasonable accounts worth considering. We believe that by confining their attention to a single species and one specific set of procedures, Carter and Werner have thus increased the danger both of omitting substantial evidence in favor of alternative explanations and of overlooking important learning phenomena in pigeons.

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Received August 13, 1979

Final acceptance September 27, 1979