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DISCRIMINATION LEARNING AS A FUNCTION OF THE NUMBER OF RELEVANT CUES
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DISSERTATION
Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By
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*****

The Ohio State University
1963

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INTRODUCTION

All theories of discrimination learning must eventually deal with the variables which influence the way in which organisms sample from stimuli in their environment. Although crude qualitative statements can be made concerning certain properties of stimuli which affect their "attention-getting" value (intensity, size, etc.), in general learning theorists have not attempted to incorporate such variables into their theoretical structures. The trend of research in this area is clearly to minimize the extent to which such "selection" variables can operate. Thus, the discriminanda are frequently black vs. white, tone-on vs. tone-off, etc. The apparent assumption underlying the use of such stimuli is that their contrast to the rest of the environment is clearly sufficient to draw the organism's attention. However, that this is not necessarily the case is implied in a review paper by Restle (1957) in which he suggests, in reference to maze experiments, that under certain conditions extra-maze cues may be readily employed by Ss. An immediate implication of Restle's suggestion is that much of the variability in discrimination learning experiments can conceivably be attributed to the fact that different Ss are responding to different aspects of even the simple environment which the experimenter typically provides (cf. Reynolds, 1961). Presumably an understanding of stimulus sampling variables would make possible increased precision in psychological experiments (by providing the experimenter
with potential control over a present source of variability) and, correspondingly, such information would lead to improvement in the ability to predict in the individual case.

The experiment reported in this paper attempts to determine some of the characteristics of stimulus sampling during discrimination learning. Specifically, the experiment is designed to yield information on two points: (1) rate of learning as a function of the number of cues in the environment which are relevant to the discrimination, and (2) the number of cues to which lower organisms attend during the course of discrimination learning.

The major theoretical positions

Historically, learning theorists have adopted one of two extreme positions concerning stimulus selection during the formation of a discrimination. These two positions have become the center of a controversy which started in the early 1930's and has persisted, though with less fervor, to the present. This issue is called the continuity-noncontinuity controversy and the review of recent literature on stimulus sampling included in this paper will be organized with respect to this issue and the implications of the data for the issue.

The continuity position, as originally formulated by Spence (1936), rests upon two independent assumptions. The first of these is that a reinforcement strengthens the response tendency to approach all stimuli striking the organism's "sensorium." The second assumption is that learning is continuous and gradual, proceeding in increments resulting from the consequence (reinforcement) of the act. Thus, the first assumption relates to the range of cues which are affected
by reinforcement while the second assumption deals with the way in which learning progresses.

According to the writer's version of this type of continuity theory, discrimination learning is conceived of as a cumulative process of building up the excitatory tendency or association between the positive stimulus cue and the response of approaching it, as compared with the excitatory tendency of the negative stimulus cue, which receives only nonreinforcement, to evoke the response of approaching it. This process continues until the difference between the excitatory strengths of the two stimulus cues is sufficiently great to overshadow always any differences in excitatory strength that may exist between other aspects of the situation which happen on a particular trial to be allied in their response evoking action with one or the other of the cue stimuli. For example, the difference in the excitatory strengths of the cue stimuli to their responses must, for learning to be complete, become greater than the difference between the excitatory strengths of the position cues, e.g., the left and right alleys or food boxes. (Spence, 1945, p. 254)

The assumptions beneath the noncontinuity position are a perfect complement to those of the continuity position. Here it is assumed that the organism attends to a single stimulus dimension (assumption 1); i.e., the organism tests a "hypothesis" concerning the importance of that dimension in his environment, that hypothesis being discarded if it fails to be confirmed by the consequence of the act. According to this position, when S discovers the correct hypothesis performance in selective learning situations abruptly shifts to asymptote; i.e., learning is discontinuous (assumption 2) with the shift occurring when S discovers the relevant stimulus.

... once an animal is immersed in a given problem-situation the animal selects out of a welter of possible stimuli certain sets of discriminanda to which he reacts. Each time (while "paying attention to" this particular set of discriminanda) he makes what proves to be a "correct" response, he learns (wrongly perhaps) something about the significance of this particular stimulus; each time he makes a "wrong"
response, he learns something else, but he does not learn anything about the "correctness" or "wrongness" of the to-be-finally-learned set of discriminanda. Eventually he gives up responding to his first set of discriminanda and responds to another set, and another set, etc., until he begins to respond to the relevant set. From then on, and from then on only is he learning anything about the discrimination involved, or, from then on only are his "bonds" being strengthened, etc. (Krochevsky, 1938, pp. 111-112)

Of the two pairs of assumptions which are the basis of this controversy, the difference with respect to assumption 1 in each position appears to be the most amenable to experimental attack. Krochevsky has stated that Ss attend to a single cue at a time, turning their attention to another cue only when the former leads to errors. Sponse, on the other hand, has stated that all stimuli striking S's "sensorium" will be strengthened (or weakened) as a consequence of reward (or non-reward). Thus, it would appear that one could differentiate between the adequacy of these two assumptions if (a) one could provide an environment composed of numerous stimuli, and (b) one could devise a test which would essentially "ask" the organism how many of those stimuli he was attending to. This is in essence what the experiment reported in this paper attempts to do.

Review of relevant literature

Blum and Blum (1949) have categorized the kinds of data and experimental paradigms employed by researchers investigating the continuity-noncontinuity controversy prior to 1950 as follows: (1) "By gross observation of the day-to-day behavior of animals in problem situations". (2) "By analysis of performance curves in soluble and insoluble problems" (Krochevsky, 1932a, 1932b). (3) "By tests for positive or negative transfer after reversal of the reward relations
of a stimulus or stimulus pair at some point in the learning process" (Krechevsky, 1938; McCulloch & Pratt, 1934; Spence, 1940). (4) "By correlations of the error scores in particular problems with the differential excitatory strengths of the discriminanda, as measured by the times one had been rewarded more than the other in previous training" (Lashley, 1942; Spence, 1937, 1938). (5) "By giving the animal a preliminary 'set' to respond to one aspect or organization of the stimulus elements, and then testing for association of other aspects or organizations with the response" (Blum & Blum, 1949; Bruner, Matter, & Papanek, 1955; Lashley, 1942; Spence, 1945).

There appears to be no basic disagreement over the data bearing on the first two categories although there is disagreement over their interpretation. In the last three categories the status of the data in relation to the controversy is not clear; different experimental situations appear to produce results supporting either position. The purpose of this section is to summarize the Blum and Blum conclusions concerning the controversial data in their classification scheme, and to extend the scheme to include some new approaches to the controversy.

Category 3: The reversal experiment

With respect to the reversal experiment, Blum and Blum conclude that the paradigm does not "offer an adequate test of the postulate unless experimental conditions, particularly as they relate to possible differential treatment of experimental and control groups, are specified." This conclusion emerges from a consideration of the interaction of different training procedures upon discriminanda of differing difficulty. Employing Hullian concepts of excitatory and
inhibitory generalization gradients they are able to relate the effectiveness of pre-reversal training to the difficulty of the discrimination asked of S, and they have integrated this relationship with various training procedures (e.g., correction vs. non-correction method, etc.). Since there is always the question of when the shift occurs in relation to the hypotheses being tested by various Ss, this paradigm would appear to be unable to resolve the issue unequivocally.

**Category 4: Correlational analyses**

The rationale underlying the correlational analysis rests upon the continuity assumption that the effect of each reinforcement or nonreinforcement is to strengthen or weaken, respectively, the habits involved. Thus, one would expect to find fairly high correlations between reinforcement history and choice behavior. Spence (1937) and Lashley (1942) have obtained such correlations but they disagree as to their meaning. Blum and Blum have re-evaluated this correlation data and conclude that it is more in line with continuity expectations.

**Category 5: Preliminary "set" experiments**

The fifth category, the one in which S is given a preliminary "set" to respond to one aspect of a stimulus complex and is then tested to other aspects of the same complex, is the conceptual model for the great majority of recent experiments bearing on the issue. For purposes of comparison it will be useful to subdivide this category in reviewing more recent experiments.
a. Partial correlations between a "critical" cue and an "irrelevant" cue.---The procedure in this line of experiments is to train Ss to discriminate between complex environments in which one stimulus dimension is consistently related to reinforcement while a second stimulus dimension is related to reinforcement only part of the time (Babb, 1956; Bitterman & Coate, 1950; Hughes & North, 1959; Jeeves & North, 1956). The critical stimulus is then removed from the stimulus complex and S learns to discriminate between partially correlated stimuli. These experiments unanimously support the predictions from continuity theory; i.e., the differential reinforcement of the partially correlated stimuli leads to differential response strengths to approach these stimuli.

An experiment by Babb (1956) will serve to illustrate the general procedure. Four groups of rats learned two discrimination problems. The training problem consisted of a discrimination between two alleys in which the critical cue was the presence or absence of chain curtains hanging in the alleys. Three experimental groups learned the chain-no chain discrimination in alleys which were white or black; the control group learned the discrimination in grey alleys. The three experimental groups differed in that the positive cue (chains) was paired with the white alley 30%, 50%, or 70% of the time over the 60 training trials.

Following training all Ss learned the black-white discrimination with white positive. Transfer effects from the training condition were in the direction predicted by continuity theory; i.e., the 70%
group showed positive transfer, the 50% group showed zero transfer, and the 30% group showed negative transfer.

Jeeves and North (1956) obtained similar results in a situation in which form was the critical cue and brightness a partially correlated cue (75% or 25% of the time). Hughes and North (1959) obtained evidence for the continuity position although, in this case, the partial correlation was not introduced until after 150% over-learning trials were given.

b. Changes in habit strength resulting from a change in cue-reward relations.—Lawrence and Mason (1955) and Goodwin and Lawrence (1955) provided still another approach to the continuity issue. Their general procedure was to train Ss in a discrimination situation where two stimulus dimensions were randomly paired. The Ss were first trained with one dimension relevant and, after reaching criterion, the reward relations were changed so that the other dimension was relevant and the first was irrelevant. Finally, Ss were required to relearn the relevance of the original dimension by again systematically reinforcing or nonreinforcing stimuli within that dimension. The rationale behind this procedure follows:

According to the continuity hypothesis as outlined by Spence, each time the Ss are responding to a cue on one dimension, e.g., white, the two cues on the other dimension, e.g., high and low hurdles, tend to become equal in habit strength, for each is reinforced and nonreinforced an equal number of times. Thus, during the learning of the second discrimination the first discrimination is lost or nullified. If this is true, however, then, when the Ss reach the third discrimination involving the same two brightness cues as the first discrimination, it should be immaterial in terms of rate of learning as to which of these two cues is made positive and which is made negative. (Goodwin & Lawrence, 1955, p. 437)
The results of these experiments are not in line with the above interpretation of continuity theory.

It is not clear to the writer that the equalization of habit strengths to black and white necessarily follows from continuity theory while S is responding to another stimulus dimension. The equal reinforcement and nonreinforcement procedure which results with respect to black and white during the learning of the second discrimination problem might more reasonably be expected to maintain the relative strengths of these habits. Goodrich, Ross and Wagner (1961) attempted to analyze these experiments and concluded that the complicated nature of the reinforcement and nonreinforcement procedures with respect to the stimuli involved did not provide a definitive test of the continuity position. Ross (1962a, 1962b) has subsequently shown that earlier learned habits are not, in fact, equalized when Ss learn a new discrimination with the stimuli from the old habits present.

c. Preliminary set experiments in which the environment is abruptly changed after the set is established.—Spence (1945) reported an experiment in which Ss were trained to respond on the basis of position in a T-maze (i.e., right or left). After the habit was well established, a black-white difference was superimposed upon the position habit; i.e., black was always on the right and white on the left. After 20 trials of this double relevant cuo training, Ss were returned to the original grey apparatus and the position habit was broken (a control group received no double cuo training). The Ss were then required to learn the black-white discrimination where black and white appeared equally often on the right and left and their position on a
given trial was assigned randomly. In this test phase the brightness-reward relations which existed for the experimental group during the twenty trials of double cue training were reversed; i.e., if black was correct (B+) and white incorrect (W-) during double cue training, testing was conducted with B- and W+. A statistically significant difference in trials to the learning criterion was obtained with the control group learning the problem more rapidly than the experimental group as predicted by continuity theory. Ritchie, Ebling and Roth (1950) replicated this experiment in its essentials in the jumping stand apparatus and obtained similar results.

d. Preliminary set experiments employing subtle changes in the environment during the double cue period.—The general procedure in experiments belonging in this category is to train organisms in the presence of a complex environment with only one cue in that environment relevant to the discrimination. Then, after S is responding consistently to that one relevant cue (as evidenced by the fact that he is discriminating between these complex stimuli), a previously irrelevant cue is now consistently paired with the previously critical cue for a fixed number of trials. Then the previously critical cue is removed and Ss are tested for transfer by being required to learn a discrimination based on the stimuli which were briefly paired with the critical cue in the double cue training period. It is important to note that this double cue procedure demands no abrupt change in the environment presented to S since during the training period those irrelevant stimuli, by definition, have appeared equally often and randomly with both of the stimuli to be discriminated. Thus, this
category is differentiated from the previous category solely on the basis of the nature of the change in the environment; in Category 5c something is either added to or subtracted from the stimulus complex which is presented to S. In this category, Category 5d, the only change in the environment is with respect to the randomness of appearance of irrelevant cues with the critical cue. An experiment by Bruner, et al. (1955), which will be discussed in detail in a subsequent section of this paper, employed this subtle double cue procedure with groups of Ss differing with respect to degree of overlearning before the double cue pairing was introduced. They reported obtaining a reduction in the number of cues attended to as a function of this variable.

While these two categories of experiments are extremely similar in principle, it seems to the writer that there is an important difference between them which should not be overlooked. Noncontinuity theorists would have us believe that while an organism is responding with reference to a correct hypothesis he remains essentially oblivious to other events in his environment (or if he recognizes these events he is unable to observe their relationship to reward). This arbitrary assumption, while important in forcing a difference between the positions, seems to the writer to be most unreasonable. Abrupt changes in the environment typically produce dramatic alterations in ongoing behavior (e.g., Fink & Patton, 1953) although such alterations apparently do not disturb choice behavior (see Blum & Blum, 1949; Lashley, 1942; Spence, 1945). These behaviors may be generally described as hesitations and investigative behaviors which one would expect to be
accompanied by what Wyckoff (1952) has called "observing responses." Berlyne (1950) has, in fact, shown that such environmental changes have the effect of drawing the organism's attention to them. It is only the one-hypothesis-at-a-time assumption that makes experiments in Category 5c difficult for noncontinuity theory to handle. A more reasonable assumption (although one which essentially dissolves the controversy) would be that organisms are capable of evaluating more than one hypothesis under certain circumstances.¹

From the standpoint of either the continuity position or the more liberal version of noncontinuity theory, it is interesting to speculate about the possible effects of the procedural difference between the experimental paradigms represented by Categories 5c and 5d. In the case of the former category, the example was an experiment cited by Spence (1945). It will be recalled that a position habit was trained in phase 1, a black-white difference was superimposed on the position habit in phase 2, the position habit was broken in phase 3, and Ss learned the black-white discrimination in the final phase. From the results of Berlyne's experiment we would expect the introduction of black and white (phase 2) to have the effect of initiating observing responses toward those stimuli. Under those circumstances the prediction of the obtained results follows very readily from continuity theory. Once the stimuli have fallen upon the

¹The problem then becomes one of specifying the circumstances (variables) which determine the number of cues attended to. While this approach assumes that neither of the extreme positions represented by the continuity-noncontinuity controversy is adequate by itself, it would not appear to be an unwarranted assumption in view of the experiments reviewed in this paper.
sensorium, the subsequent reinforcement or nonreinforcement of the response to the phase 1 critical cue will affect the response tendency to approach the novel stimuli introduced in phase 2.

While the one-hypothesis-at-a-time version of noncontinuity theory cannot handle the results of Spence's experiment, the more liberal version certainly can. If one is willing to assume that any stimulus event which is capable of disrupting a well-learned behavior will be retained by the organism for at least short periods of time and, further, that the organism is capable of simultaneously storing two pieces of information (at least "under special circumstances"), the Spence results come as no surprise. Stated differently, this form of noncontinuity theory would simply say that organisms ordinarily respond on the basis of a single cue but (by granting them a capacity beyond the arbitrary single channel) under certain conditions they may be able to effectively learn about more than one cue. The point will become clearer from a consideration of the paradigm from Category 5d.

If novelty is a condition which favors attending to and learning about other cues, adaptation (resulting from continual exposure) would seem to favor "ignoring." The effect of overtraining employed in the Brunor, et al. experiment before the critical double cue pairing might, therefore, be expected to result in retarded learning (relative to the animals trained only to criterion before double cue pairing) in the final phase of the experiment. This is the result reported in this experiment although, as will be shown, there is some question about the validity of the conclusion. Before concluding this discussion, one piece of evidence which seems to support the
role of adaptation to irrelevant cues should be mentioned. Elam and Bitterman (1953) were able to show in two experiments that a group of animals pre-trained with a stimulus dimension irrelevant subsequently learned the relevance of that dimension (in a new situation where it was the basis for the discrimination) more slowly than a group of Ss which did not receive such pre-training (i.e., did not have the irrelevant dimension present in pre-training). This result, incidentally, would not be predicted by continuity theory.

Category 6: Training to a stimulus complex and testing for response strength accruing to components of that complex

In addition to the expansion of Category 5 of the Blum and Blum classification scheme it is necessary to create an additional category to handle the final set of experiments related to the problem. An experiment by Warren (1954) will illustrate the general procedure. Rhesus monkeys were trained to discriminate between complex stimulus cards presented in the standard WGT setting. These stimulus cards differed in color (C), form (F) and size (S). Ninety-six 15 trial problems were run in the course of the experiment; the first six trials were run to the compound stimulus and in the remaining trials Ss were tested to cards differing in C, F, S, C and F, C and S, and F and S. While color was found to be a strongly prepotent cue, there was some evidence for additivity of cues in the sense that performance in the presence of F and S differences was better than performance with either F or S differences by themselves.

Fink and Patton (1953) reported a conceptually similar experiment in which they showed that altering stimulus dimensions of a complex
environment had the effect of disrupting the performance of a learned response in the rat, and that the greater the number of dimensions altered, the greater was the disruption of behavior.

These experiments and many others (Brown & Carr, 1958; Cole, 1953; Hammer, 1955; Riopelle & Chinn, 1961; Warren, 1953, 1956) provide data supporting the continuity position; they support it because the data suggest that an organism learns about more than one aspect of a stimulus compound during the course of discrimination learning. However, for reasons to be discussed in a subsequent section of this paper in relation to an experiment by Reynolds (1961), many of these experiments may report pro-continuity findings as the result of an artifact produced by certain statistical procedures.

A compromise position

It is somewhat surprising that a compromise between the continuity and noncontinuity hypotheses did not appear until 1955. Bruner, et al. (1955) reported an experiment which presumably established the validity of the first assumption of both the continuity and noncontinuity positions. These authors suggested that the number of effective cues in the environment is a function of at least two variables (motivation and amount of training), and that increases in either of these two variables results in a "funneling" or narrowing of attention. Thus, at low levels of motivation and/or early in training the cue selection assumption of continuity theory is most adequate while high levels of motivation and/or extended training favors a marked narrowing of attention (like the noncontinuity assumption). Their experiment was a 2 x 2 factorial in which level of hunger (12 or 36 hrs.)
and degree of learning (to criterion or 100 trials beyond) were manipulated. The procedure consisted of training rats to discriminate between black and white doors which appeared in a four unit discrimination apparatus, door brightness being assigned randomly to the right or left in each of the four units. After reaching the learning criterion or 100 trials beyond, experimental Ss continued to run to the black and white doors but they were arranged in an alternation pattern (e.g., RLRL) for 20 trials while control Ss ran to these same doors with brightness cues within a unit still assigned randomly. After the 20 double cue trials, the black and white doors were painted grey and control and experimental Ss were required to learn the alternation pattern. The conclusions drawn from the data were that both the motivation variable and the degree of learning variable had a significant narrowing effect upon "breadth of learning." However, it should be noted that these conclusions are not clearly supported by the data. To demonstrate, for example, that overlearning influences the number of cues attended to, it would appear to be necessary to demonstrate a difference between the group trained to criterion before the 20 double cue trials and the Ss given 100 trials beyond criterion before the 20 double cue trials. This difference was apparently not even tested in this experiment (and it was very small). Rather, the conclusions concerning narrowing of attention were drawn from a significant difference between experimental and control Ss learning to criterion, and a failure to find a difference between the groups given extended training. The failure to find a difference in this latter comparison, incidentally, appears to be due to an unexpected shift in
the control group in the direction of the experimental group (a shift attributed to "maze brightness" by the authors). Thus, while there was a very slight increase in the number of trials required to learn the alternation problem after extended training, the failure to obtain a statistically reliable difference in a comparison involving a control group which behaved in an unexpected fashion (coupled with the fact that there were only six to eight animals per group), leaves the writer somewhat uneasy about the validity of the conclusions. This uneasiness appears to be justified when one considers other experiments in the literature which, when combined, amount to a replication of the principles Bruner, et al. were attempting to evaluate. In fairness to these authors, it should be recognized, however, that there are many differences between the following experiments and their study; different problems were involved, different apparatus were used, etc.

Hughes and North (1959) trained rats to discriminate between transverse and longitudinal stripes on the floor of a simultaneous discrimination apparatus. Black and white doors which S was forced to pass through on the way to the goal served as an irrelevant cue. After meeting the learning criterion on the transverse vs. longitudinal stripe discrimination (72 trials), Ss were given 108 overlearning trials on this discrimination with brightness partially correlated with reinforcement (i.e., one stimulus door followed by reinforcement 75% of the time and the other door 25% of the time). In the last phase of the experiment, the transverse and longitudinal stripes were removed and Ss were required to discriminate between the partially correlated stimuli; i.e., one group had the 75% stimulus correct and the other
had the 25% stimulus correct. Highly significant differences in rate of learning were reported in line with continuity expectations. In principle, this experiment is very similar to the extended training procedure in the Bruner, et al. study, yet opposite conclusions for continuity theory are drawn from the data. The evidence for the continuity position reported by Bruner, et al. with respect to their Ss trained to criterion seems to be a well substantiated finding in the literature. Bitterman and Coate (1950) and Jeeves and North (1956) report similar results using the partial correlation technique, while Spence's (1945) experiment yielded the same results using the paradigm described in Category 5c.

Although the Bruner, et al. study does not provide clear support for a "funneling" of attention as a function of training, there does appear to be some general evidence for such a phenomenon. It is not uncommon for psychologists, confronted with the problem of accounting for the fact that organisms are able to survive in a world where they are continually bombarded by an infinite number of stimuli, to talk about the organism learning to "select," and subsequently respond to, the important aspects of that environment. There are two ways in which such selection could presumably operate: (1) it could occur through changes in the organism's "observing responses" (Wyckoff, 1952); i.e., orienting acts which alter the stimulus configuration striking the organism's receptor surfaces, or (2) it could operate within the configuration which strikes S's sensorium. The former idea allows for selection factors compatible with a continuity theory while the latter is more in line with traditional noncontinuity theory.
The Reynolds experiment

An experiment by Reynolds (1961) suggests that the latter notion is more adequate. The Ss were two pigeons trained in the standard free operant apparatus. In the first of two experiments reported, the key which S was required to peck was illuminated with either a white triangle on a red background or a white circle on a green background. When the triangle-red combination was present, responding was reinforced on a VI 3 schedule; when the circle-green combination was present, responses were never reinforced. In the test sessions the triangle, the circle, or the red or green backgrounds illuminated the key separately. An analysis of the responding which occurred during the test period showed that only one of the four components was determining the discrimination - for one bird it was the presence of the triangle and for the other it was the presence of the red ground; response rate to the three ineffective components was approximately equal and very low.

This experiment represents one of the most powerful arguments for the validity of the first assumption of noncontinuity theory. Because of its importance to the issue, and the small number of Ss involved, it should certainly be replicated. The reason Reynolds should obtain such striking support for the noncontinuity position, while many others have obtained support for the continuity position is not clear; his apparatus (the free operant Skinner box), species of S, and procedure are all considerably different from others employed in investigating this problem.

From a methodological point of view Reynolds' experiment is
interesting in that it represents the only study reviewed which treats an individual across all conditions and uses each individual as his own control. This may be an important consideration for the studies dealt with in Category 5. In view of Reynolds' results, many of the studies in this category which report results in line with continuity expectations may have obtained these results as an artifact produced by the procedure of grouping together the data of individual Ss; Reynolds' study would also support the continuity position if the data of his two pigeons was combined.

To illustrate, suppose that each bird was responding at the rate of 20 responses per minute to the positive compound (triangle on red) and zero responses to the negative compound (circle on green). Now, according to the continuity position response strength should have accrued to both triangle and red and, since they are but components of the compound, one would expect that the response strength to each of these elements would be less than that to the compound. Reynolds found, it will be recalled, that one bird responded solely to the triangle and the other bird solely to the red color. The result of combining the data of both birds is in line with continuity expectations; i.e., while both birds' average rate of response to the compounded stimulus is 20 responses per minute, the average rate to each of the components is 10 responses per minute. Thus, the data grouping procedure may mask the fact that individual Ss are responding to only a single aspect of their environments.¹

¹This point is applicable to Brown & Carr, 1956; Fink & Patton, 1956; Warren, 1953, 1954, 1958.
A limitation imposed upon tests of the continuity-noncontinuity hypotheses

Before turning to the experiment which is the main topic of this paper, one further point should be made. The continuity-noncontinuity controversy is one which deals with discrimination learning, not necessarily with performance after learning. Thus, it could be argued that the narrowing of attention which Bruner, et al. have suggested as a function of overlearning, and the Reynolds study where Ss are trained and tested for long periods of time (only after relatively stable behavior has developed; i.e., after learning has definitely occurred) are not tests of the issue, but rather are simply interesting empirical findings concerning stimulus sampling occurring during the execution of an overlearned task.

The rationale and general procedure of the present experiment

The experiment which follows is one which attempts to evaluate stimulus selection during discrimination learning. It does not fit neatly into any of the categories discussed earlier in this paper, but it is most closely related to experiments belonging in Category 6. Unlike the Reynolds' experiment it employed independent groups of Ss while, at the same time, circumventing the problems of data combining discussed previously. The experiment utilized three groups of Ss - a control group and two experimental groups. All Ss were trained in an environment containing two distinct cues - a brightness cue (black or white) and a chain curtain cue (presence or absence of such curtains). This training was done in two runways with both cues represented in
each runway; e.g., black with chain curtains vs. white and chain curtains absent. The three groups of animals differed in terms of the number of cues in this environment which were relevant to the runway discrimination (reflected in a difference in latencies). To illustrate: some Ss in the two-cue group were always reinforced in an alley which was black (B) with chain curtains present (C) and never reinforced in the other alley condition which was white (W) and contained no chains (NC). Thus, this group of Ss could form an effective discrimination on the basis of either brightness or chain cues. The Ss in the one-cue group were trained with only one relevant cue; e.g., B+ and W- with C and NC conditions appearing equally often and randomly with both B and W (hence, an irrelevant cue). All Ss in the control group were run in alley conditions where brightness and chain stimuli appeared together equally often and at random. Further, reinforcement and non-reinforcement occurred equally often to each of the possible cue combinations. The control group, then, had no basis for discriminating between the training alleys. After all Ss in the experimental groups had indicated an obvious discrimination in the training apparatus they were tested in a complex maze which required, for an errorless run, a discrimination between brightness and the chain cue used in the runways. The stimulus-reward relations which were present during training for the one- and two-cue groups remained the same during the test condition. The Ss which had one or more irrelevant cues during training were assigned a correct and incorrect stimulus from that dimension for use in the test apparatus on a quasi-random basis.

The rationale behind this procedure is as follows: If Ss in the
two-cue group learned about only one feature of their environment (e.g., B+ and W-) they should transfer to the test apparatus the same information as the Ss trained to only one relevant dimension. Thus, these groups should perform at the same level in a situation which requires knowledge about two cues. If, on the other hand, the two-cue group, in line with continuity expectations, learns about both of the relevant cues in their environment they should perform at a level superior to either of the other two groups. The control group, of course, with no relevant cue training should learn the test apparatus with considerably more difficulty than either the one- or two-cue groups. It will be noted that this experiment is so designed that the data grouping problems discussed earlier are avoided.

As a test of the continuity position the stimulus compound employed in the training phase of the present experiment should be more readily acceptable than the stimuli employed in many other experiments. Spence has intentionally avoided form stimuli because of the problems encountered in assuring the reception of the entire configuration (see Ehrenfreund, 1948). The present experiment employed blatant stimuli which would seem to insure that they impinged upon the organism's "sensorium" (substantiated by the fact that equal numbers of Ss in each group learned to approach each of the four stimuli).

In addition to the stimulus selection data, the initial training phase of the experiment permits an evaluation of rate of learning as a function of the number of relevant stimuli in the environment. This phase of the experiment does not provide a test of the hypotheses at issue. The continuity position would predict more rapid learning for
the two-cue group because the two habits related to the relevant cues summate in determining performance (Zinger, 1952); the noncontinuity position would seem to predict more rapid learning for the two-cue group because, in the hypothesis testing process, as the number of "correct" hypotheses increases the probability of selecting a correct hypothesis early in training also increases.
METHOD

Subjects

The Ss were 48 male hooded rats of the Long-Evans strain approximately 100-110 days of age at the start of the experiment. All Ss were experimentally naive and they were housed in groups of four per cage. Water was available on an ad lib. basis throughout the experiment. One S died shortly after the training phase of the experiment started.

Apparatus

Two apparatuses were employed in the experiment; two runways served as the training apparatus and a complex maze served as the test apparatus. Each of the 4 foot training runways separated a grey 10 inch start box from a grey 14 inch goal box. The runways were identical in all respects except brightness; one was painted flat white and the other flat black. Each runway was 4 inches wide, 5 inches high and constructed with a guillotine door at each end. Raising the first guillotine door tripped a microswitch which started a Standard Electric timer. This clock continued to run until S interrupted a photocell beam which crossed the alley at the mouth of the goal box. In this way latencies in the training alleys were obtained.

Each runway was made to accommodate five chain curtains which could be inserted on appropriate trials. The curtains were constructed by connecting three lengths of beaded chain (like that used on bath tub stoppers) to a 1/4 inch threaded steel bar; nuts kept the chains
appropriately spaced along the bar. Each length of chain was just long enough to touch the floor of the apparatus, and they were spaced 1 inch apart and 1 inch from each wall. The first curtain was 2 inches from the start box and the last curtain was 2 inches from the goal box. Both runways were covered by 3/16 inch plexiglass.

The test apparatus was a 4-unit complex maze. Figure 1 summarizes the essential characteristics of a maze unit. Each unit was independent of the others so that the units could be randomly placed in the sequence leading to the goal by simply interchanging their positions. The width and depth of the test apparatus was identical to the training apparatus. The stem leading to the choice region of all units was flat grey; one choice region was painted flat white throughout, a second was flat black throughout, and the two remaining units were half white and half black (see Figure 1). The latter two units were painted with black on the right side of one, and on the left in the other.

All units were constructed so that they would accommodate the chain curtains used in the training apparatus. Thus, in the two units painted uniformly black or white, the chain curtains could be placed in one of the two alloys formed by the diamond shaped "island" in the middle of the choice region making chains a relevant cue for discriminating between alleys while brightness, since it is the same in both alleys, is an irrelevant cue. In brightness discrimination units (where one alley was white and the other black), chains were either present in both alleys or absent in both alleys. The series of four units terminated in a goal box which was identical to the goal boxes in the training apparatus. A guillotine door at the beginning of the
Top View of Four-unit Test Maze

Chain Curtains
Guillotining Door
Barrier

Top View of A Brightness Unit -- Chain Curtains Irrelevant Cue

Fig. 1. -- Test Apparatus
stem of each unit, and at the mouth of the goal box prevented S from re-tracing once he had passed by the door.

**Procedure**

**Pre-training**

One week prior to the start of the experiment Ss were placed on a 23 hour food deprivation schedule; simultaneously E began taming Ss by handling them regularly. On each of the two days preceding the start of the experiment groups of four Ss were placed in each of the training alleys for 10 minute periods during which they could explore the apparatus. No chain curtains were present in either alley on the first habituation day but they were present in both alleys on the second day. No food was available to Ss during these sessions. On the last day of pre-training Ss were allowed to eat 97 mg. J. P. Noyes pellets ad lib. for 15 minutes and the remainder of their one hour feeding was on the standard laboratory diet (Rockland Rat Diet). The Ss were then assigned randomly to one of three groups; 16 Ss per group.

**Training**

The treatments imposed upon the Ss in each of the groups are given in Table 1. Here it may be seen that the group treatment differences are based upon the number of cues present in the alleys which are treated differentially with respect to reinforcement. The two cues which E manipulated were brightness - black (B) or white (W) - and chain curtains which were either present (C) or absent (NC). Both of these cues were represented in each alley on every trial for all groups (see Table 1).

On each of the first three days of training each S was given four
### TABLE 1

REINFORCED AND NONREINFORCED STIMULUS ASSIGNMENTS DURING TRAINING FOR EACH SUBJECT

<table>
<thead>
<tr>
<th>Ss</th>
<th>Control Group</th>
<th>One-cue Group</th>
<th>Two-cue Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4</td>
<td>B-C</td>
<td>B-C</td>
<td>B-C</td>
</tr>
<tr>
<td></td>
<td>B-NC</td>
<td>B-NC</td>
<td>B-NC</td>
</tr>
<tr>
<td></td>
<td>W-C</td>
<td>W-C</td>
<td>W-C</td>
</tr>
<tr>
<td>5-8</td>
<td>B-C</td>
<td>B-C</td>
<td>W-C</td>
</tr>
<tr>
<td></td>
<td>B-NC</td>
<td>B-NC</td>
<td>W-C</td>
</tr>
<tr>
<td></td>
<td>W-C</td>
<td>W-C</td>
<td>W-C</td>
</tr>
<tr>
<td>9-12</td>
<td>B-C</td>
<td>B-C</td>
<td>C-B</td>
</tr>
<tr>
<td></td>
<td>B-NC</td>
<td>B-NC</td>
<td>C-W</td>
</tr>
<tr>
<td></td>
<td>W-C</td>
<td>W-C</td>
<td>W-C</td>
</tr>
<tr>
<td>13-16</td>
<td>B-C</td>
<td>B-C</td>
<td>NC-B</td>
</tr>
<tr>
<td></td>
<td>B-NC</td>
<td>B-NC</td>
<td>NC-W</td>
</tr>
<tr>
<td></td>
<td>W-C</td>
<td>W-C</td>
<td>W-C</td>
</tr>
</tbody>
</table>

B = Black  
C = Chain curtains present  
W = White  
NC = Chain curtains absent
trials per day; throughout the rest of training Ss were given six trials per day. Within a series of 12 trials Ss received equal numbers of reinforced and nonreinforced trials, and each stimulus appeared equally often. Within a series of 24 trials Ss in the zero-cue (control) group had equal numbers of reinforced and nonreinforced trials to each of the four possible stimulus combinations. Three independent quasi-random orders of 12 reinforced and nonreinforced trials were constructed and the selection of a particular order for a 12 trial block was on a random basis; the only restriction on randomness within each block was that there be no more than three consecutive reinforced or nonreinforced trials. The particular cue combinations appearing in the alleys on a given trial was completely determined by the reinforcement series for the two-cue group; i.e., if B and C were correct for a S, that combination appeared on every reinforced trial and W-NC appeared on every nonreinforced trial. The cue combinations appearing in the alleys for the one-cue Ss were only partially determined by the reinforcement schedule; i.e., if B+ and W- for an animal, on reinforced trials B could appear with C or NC. The stimulus from the chain dimension was assigned to the alleys in these cases on a random basis with the restriction that C and NC appear equally often over a series of 12 trials, and the same combination was not present on more than two successive trials. Cue combinations for the control group were assigned to each trial on a random basis with the restriction that each stimulus combination appeared and was reinforced and nonreinforced equally often within a 24 trial series.

On a reinforced trial S was given three 97 mg. J. P. Noyes pellets
in a glass furniture coaster placed at the far end of the goal box and painted grey. On these trials S remained in the goal box for 15 seconds or until he had consumed the pellets - whichever occurred last. On nonreinforced trials S simply remained in the goal box for 15 seconds. All Ss were run during the training period until every S, except those in the control group, had three latencies in the negative alley within a twelve trial block which were at least 10 seconds longer than the average of the latencies in the positive alley in this same block of trials. If S did not complete a run within 60 seconds he was gently removed from the apparatus. The Ss were run under 21 ± 1 hour of food deprivation for 168 trials, with an inter-trial interval of at least five minutes.

Testing

During testing each S was run four trials per day in the complex maze described previously. The Ss were run to the same reward and under the same deprivation conditions they experienced during training. Relationships between stimuli and reinforcement established during training were maintained during the test period; i.e., if B+ and W- was established during training, B was correct and W incorrect at each choice point in the test apparatus where they were opposed. The Ss trained with one (one-cue group) or two (control) stimulus dimensions randomly paired with reinforcement during training were assigned a correct stimulus from that dimension on a random basis with the restriction that equal numbers of such Ss have each stimulus positive (see Table 2). The two cues appearing in the training apparatus were separated in the four units of the test apparatus; the stimuli
<table>
<thead>
<tr>
<th>Subject</th>
<th>Control Group</th>
<th>One-cue Group</th>
<th>Two-cue Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B-C</td>
<td>B-C</td>
<td>B-C</td>
</tr>
<tr>
<td>2</td>
<td>B-C</td>
<td>B-C</td>
<td>B-C</td>
</tr>
<tr>
<td>3</td>
<td>B-C</td>
<td>B-NC</td>
<td>B-C</td>
</tr>
<tr>
<td>4</td>
<td>B-C</td>
<td>B-NC</td>
<td>B-C</td>
</tr>
<tr>
<td>5</td>
<td>B-NC</td>
<td>W-C</td>
<td>B-NC</td>
</tr>
<tr>
<td>6</td>
<td>B-NC</td>
<td>W-C</td>
<td>B-NC</td>
</tr>
<tr>
<td>7</td>
<td>B-NC</td>
<td>W-NC</td>
<td>B-NC</td>
</tr>
<tr>
<td>8</td>
<td>B-NC</td>
<td>W-NC</td>
<td>B-NC</td>
</tr>
<tr>
<td>9</td>
<td>W-C</td>
<td>B-C</td>
<td>W-C</td>
</tr>
<tr>
<td>10</td>
<td>W-C</td>
<td>B-C</td>
<td>W-C</td>
</tr>
<tr>
<td>11</td>
<td>W-C</td>
<td>W-C</td>
<td>W-C</td>
</tr>
<tr>
<td>12</td>
<td>W-C</td>
<td>W-C</td>
<td>W-C</td>
</tr>
<tr>
<td>13</td>
<td>W-NC</td>
<td>B-NC</td>
<td>W-NC</td>
</tr>
<tr>
<td>14</td>
<td>W-NC</td>
<td>B-NC</td>
<td>W-NC</td>
</tr>
<tr>
<td>15</td>
<td>W-NC</td>
<td>W-NC</td>
<td>W-NC</td>
</tr>
<tr>
<td>16</td>
<td>W-NC</td>
<td>W-NC</td>
<td>W-NC</td>
</tr>
</tbody>
</table>

B = Black  C = Chain curtains present
W = White  NC = Chain curtains absent
of each dimension being opposed twice at choice points in the complex maze. For example, the first unit might oppose B-T, the second C-NC, the third W-B and the fourth NC-C. Only one dimension was relevant at each choice point, the irrelevant dimension being represented identically in both alleys. Each unit of the test maze was arbitrarily assigned a number (1-4) and the 24 possible orders of these numbers were generated. The particular maze-unit order employed on any trial was selected from this list of possible orders on a random basis with the restriction that no order would be repeated until the entire list was exhausted. The maze-unit order changed every two trials. As an additional counterbalancing precaution E arbitrarily decided to reverse the position of the chains in the test maze units every 12 trials; e.g., if chains were in the left alley of the unit having a uniformly black choice region (chain discrimination unit) they would now be placed in the right alley; all chains which were present in the one brightness unit were removed and they were placed in the other brightness unit. For reasons which will become apparent in the discussion section, chains were switched daily after trial 12 (day 3). A correct run through the maze required equal numbers of right and left choices.

The Ss were run to a criterion of eight successive errorless trials. An error occurred when S placed both forefeet in the negative alley. Attempts to pass through the negative alley were thwarted by a sheet metal barrier hinged to the far end of the diamond and held in place by the subsequent unit. These metal barriers were painted grey and they could not be seen by S until he had committed himself in
accordance with S's criterion. An incorrect response necessitated a re-tracing before a correct response could be made - thus, the correction method was employed at each choice point although S could not re-trace between choice points.
RESULTS

Training data

Figure 2 shows the mean running latencies for the three groups under reinforced and nonreinforced alley conditions. These means were obtained by averaging separately the six reinforced and nonreinforced trials for each group within successive sets of twelve training trials. A groups (3) x blocks (3) x reinforcement condition (2) analysis of variance of this data was attempted using as a score for each S his mean latency in blocks 1-2, 7-8, and 13-14 under each condition. In this and subsequent analyses of variance a score was assigned to the S that died; this score was determined by averaging the scores of other Ss in his subgroup. This analysis was abandoned when an F-max test (Häner, 1963) revealed that the cell variances were strikingly heterogeneous (p < .01).

Table 3 shows the results of an analysis of variance conducted over the combined block 1-2 data. As the table shows, the group differences are not statistically reliable at this point (the obtained F is less than 1.00). The only significant difference obtained in this analysis is a group x reinforcement condition interaction (p < .01). A profile of this interaction appears in Figure 3. An analysis of the individual components of this interaction using Tukey's studentized range statistic (Häner, 1963) showed the only significant difference to be between the reinforcement-nonreinforcement condition within the
Fig. 2.—Performance in training runways: Mean latency for each group on reinforced and nonreinforced trials.
### TABLE 3

**SUMMARY TABLE: ANALYSIS OF VARIANCE OF COMBINED BLOCK 1 AND 2 TRAINING DATA**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Between Subjects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groups</td>
<td>2</td>
<td>35.56</td>
<td>17.78</td>
<td>0.28</td>
</tr>
<tr>
<td>Ss/Groups</td>
<td>45</td>
<td>2849.53</td>
<td>63.32</td>
<td></td>
</tr>
<tr>
<td><strong>Within Subjects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reinf. condition</td>
<td>1</td>
<td>21.08</td>
<td>21.08</td>
<td>2.06</td>
</tr>
<tr>
<td>Groups x Reinf. condition</td>
<td>2</td>
<td>142.21</td>
<td>71.10</td>
<td>6.94**</td>
</tr>
<tr>
<td>Reinf. condition x Ss/Groups</td>
<td>45</td>
<td>461.47</td>
<td>10.25</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>95</td>
<td>3509.85</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**p < .01**
Fig. 3. Block 1 training data: Profile of significant Group x Reinforcement condition interaction.
two-cue group (p < .01), reflecting the fact that this group had started to discriminate by the second block of trials (see Figure 2).

At the end of training (blocks 13-14) the mean latency under the negative alley condition was greater than the mean latency in the positive alley condition for each S in the one- and two-cue groups. A sign-test (Siegel, 1956) showed this effect to be highly significant (p < .001). However, there was no significant difference in mean latency on reinforced and nonreinforced trials for the control (zero-cue) group using this same test. Thus, the statistically reliable difference in the reinforced and nonreinforced alley conditions for the experimental groups suggests that they had discriminated between these conditions; the failure to find a reliable difference between these conditions for the control group suggests that any existing latency differences may be attributed to chance.

It will be recalled that the learning criterion employed in the training phase of the experiment was very stringent (three of six trials in the negative alley condition with latencies at least 10 seconds greater than the mean of the six latencies in the positive alley condition during this same block of 12 trials). Two animals in the two-cue group failed to meet this criterion when training was terminated (168 trials) although other behavior suggested that they had discriminated (e.g., occasional removals from the negative alley for failing to complete a run in 60 seconds, frequent investigative behavior mid-way down the negative alley, etc. -- none of which occurred after block 1 in the positive alley condition). For purposes of analysis a slightly less stringent criterion was used which demanded that
only two latencies under the negative alley condition in a block of 12 trials be at least 10 seconds greater than the mean of the latencies under the positive condition in this same block of trials. All Ss in the one- and two-cue groups met this criterion, while none of the Ss in the control group met the criterion. A Mann-Whitney U test showed the superiority of the two-cue group over the one-cue group with respect to this criterion to be statistically reliable (p < .05).

Test data

The results of the test phase of the experiment appear in Figure 4 where percentage correct choice is plotted over successive days for each group. An analysis of variance was conducted over day 1 performance. A score for each S was obtained by cumulating the number of correct choices out of a possible 16 (four choices per trial, four trials per day) and assigning that number as his score. The results of this analysis appear in Table 4. No statistically reliable differences were found.

Because a change in experimental procedure introduced on day 4 appears to have eliminated group differences on that and subsequent days, a second analysis of variance was carried out over the data collected on days 1, 2, and 3. A score for each S on each day was obtained as in the preceding analysis. The results of this analysis appear in Table 5. A t-test of the difference between the two experimental groups was not significant (p > .05). The Newman-Keuls method for making multiple comparisons showed the difference between the control and each of the experimental groups to be significant (p < .01 in each case). This same multiple comparison procedure was used to test
Fig. 4.--Performance in test apparatus: Mean percentage of correct choices for each group as a function of training.
**TABLE 4**

**SUMMARY TABLE: ANALYSIS OF VARIANCE OF CHOICE PERFORMANCE ON THE FIRST DAY OF TESTING**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cue combinations</td>
<td>3</td>
<td>54.2</td>
<td>18.07</td>
<td>1.82</td>
</tr>
<tr>
<td>Groups</td>
<td>2</td>
<td>43.3</td>
<td>21.65</td>
<td>2.18</td>
</tr>
<tr>
<td>Cue combinations x Groups</td>
<td>6</td>
<td>117.7</td>
<td>19.62</td>
<td>1.97</td>
</tr>
<tr>
<td>Within cells</td>
<td>36</td>
<td>358.5</td>
<td>9.95</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>47</td>
<td>573.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 5

**SUMMARY TABLE: ANALYSIS OF VARIANCE OF DAY 1, 2, AND 3 CHOICE BEHAVIOR DURING TESTING**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
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</tr>
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<tbody>
<tr>
<td>Between Subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cue combinations</td>
<td>47</td>
<td>316.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groups</td>
<td>3</td>
<td>83.4</td>
<td>27.80</td>
<td>7.47**</td>
</tr>
<tr>
<td>Cues x Groups</td>
<td>2</td>
<td>58.8</td>
<td>29.40</td>
<td>7.90**</td>
</tr>
<tr>
<td>Subjects/Cues</td>
<td>6</td>
<td>39.8</td>
<td>6.63</td>
<td>1.78</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>134.0</td>
<td>3.72</td>
<td></td>
</tr>
<tr>
<td>Within Subjects</td>
<td>96</td>
<td>545.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blocks</td>
<td>2</td>
<td>318.7</td>
<td>159.35</td>
<td>65.06**</td>
</tr>
<tr>
<td>Blocks x Groups</td>
<td>4</td>
<td>19.9</td>
<td>4.98</td>
<td>2.03</td>
</tr>
<tr>
<td>Blocks x Cues</td>
<td>6</td>
<td>23.0</td>
<td>3.83</td>
<td>1.56</td>
</tr>
<tr>
<td>Blocks x Cues x Groups</td>
<td>12</td>
<td>7.4</td>
<td>0.61</td>
<td>0.25</td>
</tr>
<tr>
<td>Blocks x Subjects/Cues</td>
<td>72</td>
<td>176.3</td>
<td>2.45</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>143</td>
<td>861.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**p < .01
the components of the significant cue combinations effect and blocks effect. In the former case the performance on cue combinations B-C+ and B-NC+ was significantly better than performance on W-C+ and W-NC+ (p < .01 for each of the four comparisons), but the comparisons between cue combinations within each of these two pairs were not significant (p > .05). Multiple comparisons of performance on individual days showed performance on day 1 was significantly different from performance on days 2 and 3 (p < .01 for both comparisons), but the difference in performance on days 2 and 3 was not statistically significant.

The results of an analysis of variance of the number of trials required to meet the test phase criterion appears in Table 6. Newman-Keuls multiple comparisons were made to evaluate the significant groups effect and, as in previous analyses, the only significant differences (p < .01) were between the control and two experimental groups.
TABLE 6

SUMMARY TABLE: ANALYSIS OF VARIANCE OF THE NUMBER OF TRIALS REQUIRED TO REACH THE TESTING CRITERION

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td>2</td>
<td>5786</td>
<td>2893</td>
<td>5.52**</td>
</tr>
<tr>
<td>Cue combinations</td>
<td>3</td>
<td>2877</td>
<td>959</td>
<td>1.83</td>
</tr>
<tr>
<td>Cue combinations x Groups</td>
<td>6</td>
<td>3344</td>
<td>557</td>
<td>1.06</td>
</tr>
<tr>
<td>Ss/Cue combinations</td>
<td>36</td>
<td>18857</td>
<td>524</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>47</td>
<td>30864</td>
<td></td>
<td>**p &lt; .01</td>
</tr>
</tbody>
</table>
As inspection of Figure 2 and the results of the statistical analysis of the training data indicate, the experimental groups had successfully discriminated between positive and negative alley conditions by the end of training. The heterogeneity of variance which appeared in the first analysis attempted is readily understandable and was expected on the basis of the effects of reinforcement and nonreinforcement on running latencies. As a function of training, latencies in the presence of the positive cue(s) (or on each trial for the control group) asymptoted and varied only slightly from trial to trial. The Ss' reactions to the frustrating character of the negative cue(s), on the other hand, varied considerably. Some Ss consistently refused to leave the start box and were removed after 60 seconds; others would turn their back to the alley, sniff at the end of the start box, then suddenly turn and run to the goal box at a rate which approached their speed in the presence of the positive cue(s). After moderate amounts of training some Ss which had been removed from the negative alley many times for failing to run, again began to leave the start box and enter the goal box. In the case of several of those Ss, latencies in the presence of the negative condition continued to decrease until, near the end of training, they were only slightly greater than the latencies in the positive condition. The result of such diverse reactions to the negative cue(s), coupled
with the relatively homogenous behavior in the presence of the positive cue(s), resulted in the heterogeneity of variance obtained. This condition, incidentally, was not altered by a reciprocal transformation of the data.

As stated earlier in this paper, identical predictions emerge from both the continuity and noncontinuity positions with respect to rate of learning as a function of the number of cues in the environment which are relevant to the discrimination. Eninger (1952) has already confirmed the validity of this prediction. However, Eninger's study and several others in the literature (e.g., Babb, 1956; Jooves & North, 1956) differ from the present experiment in that the groups to be compared differ in terms of the sheer number of different stimuli presented to them -- in addition to the relationship of these stimuli to reinforcement. The present experiment has the former condition constant for all groups; the groups differ only in terms of the number of stimuli which are consistently related to reinforcement.

In view of certain empirical findings related to the present experiment it would be very surprising if a difference in rate of learning between the one- and two-cue groups was not obtained. Eninger's experiment shows that animals will learn a discrimination more quickly when two stimulus dimensions are simultaneously present and are relevant to the discrimination than when either of these dimensions is relevant by itself. Further, while subtle irrelevant stimulus dimensions do not retard learning (Slam & Bitterman, 1953), retardation will result if more prominent irrelevant stimuli are present (Wortz & Bitterman, 1953). In the present experiment, then,
there should be two factors operating which would produce differences between the one- and two-cue groups. As in Eninger's experiment, the two-cue group in the present experiment has more stimuli relevant to the discrimination than the one-cue group (a condition which should favor more rapid learning for the two-cue Ss) and, simultaneously, the one-cue group has an irrelevant relation to contend with which the two-cue group does not have (a condition which should retard rate of learning for one-cue Ss according to Wortz and Bitterman). Although the present experiment does not permit one to assess whether one or both of these factors is (are) operating, the expected difference in trials to the revised criterion was obtained.

Before attempting an interpretation of the group differences in the test phase of this experiment a comment is in order concerning the irregular nature of the group performance curves in Figure 4. It will be recalled from the test procedure that the original plan was to move the chain curtains in each of the test units every twelve trials; i.e., with respect to the chain units the chains were placed in the opposite alley, all chains were removed from the brightness unit containing chains in both alleys and they were placed in the brightness unit which contained no chain curtains. Since a marked drop in performance accompanied this change (day 4), E decided to change the positions of the curtains before each day's run. Progressively smaller decrements in performance under the "unfavorable" chain condition occurred over days 4, 6, and 8. Because it was not clear that the decrement in performance on day 4 was due solely to the change in chain condition (i.e., Ss also ran to a new combination
of maze units) a subsidiary experiment was run and is reported in the Appendix. The results of this experiment suggest that the change in chain condition was the factor responsible for the observed decrement in performance.

The comparisons between groups in the test situation provide the most important results for the empirical question which prompted this experiment -- the number of cues "attended to" by an organism during the course of discrimination learning. Because the change in chain curtains previously described conceivably "washed out" differences between the experimental groups, two analyses were conducted over that portion of choice performance in which differences between these groups were the largest. Even this somewhat questionable procedure failed to reveal a difference between the one- and two-cue groups, although the control group was found to be significantly inferior to each of the experimental groups. The relative order of the groups on the first day of testing, it will be noted, is as predicted by the continuity position. However, the fact that the order of the one- and two-cue groups reversed on the second day of testing, as well as the consistent failure to find significant differences between these groups, suggests that any such differences are a result of chance factors and the groups did not benefit differentially from the different experimental treatments. Thus, the present experiment must be interpreted as favoring the first assumption of the noncontinuity position.

That transfer from the training to test situations occurred is apparent from the fact that the control group performed at a level
consistently below the experimental groups. However, one could argue that the change in the environment for two-cue Ss from training to test situations was greater than that for one-cue Ss; i.e., two-cue Ss had no pre-test experience with irrelevant brightness or chain stimuli. Conceivably, then, the additional benefits of two-cue over one-cue training were offset by the confusion resulting from the introduction of the "irrelevance" of a previously relevant cue. However, such a line of reasoning would lead one to expect the greatest disruptions in performance to occur on early trials. The results of the present experiment clearly do not confirm this prediction; i.e., the two-cue group performed at a level considerably higher (though not significant) than the one-cue group on the first four test trials. Such an objection does not, therefore, seem relevant to the present experiment.
SUMMARY

The experiment contained in this paper attempted to determine (1) the rate of discrimination learning as a function of the number of relevant cues in an environment containing a constant number of cues, and (2) the extent to which animals trained in the presence of two relevant cues will transfer information about these cues to an environment where a knowledge of the relevance of each is required for successful performance.

Three groups of 16 male hooded rats were trained to discriminate between two runways which contained two stimuli (black or white and chain curtains or no chain curtains). For a control group none of these stimuli were systematically related to reinforcement or nonreinforcement. A one-cue group was trained with one stimulus dimension relevant to the discrimination; e.g., black correct and white incorrect, with chain curtains appearing equally often and randomly with the brightness stimuli. A two-cue group was trained with both the brightness and chain stimulus dimensions simultaneously present and relevant to the discrimination; e.g., black and chain curtains positive, white and no chain curtains negative. The experiment was completely counterbalanced with respect to cues or cue combinations for the one- and two-cue groups, respectively, in the training phase. The number of exposures to each stimulus was constant for all animals (84 exposures).
The two-cue group learned the discrimination more rapidly than the one-cue group; the control group, of course, was unable to discriminate between alloys.

At the completion of training all SSs were run in a test maze composed of four interchangeable simultaneous discrimination units. Each unit required of S that he learn a discrimination based upon one of the stimulus dimensions present in the training alleys, the other stimulus dimension being uniformly represented in that unit (hence, irrelevant). Each stimulus dimension was relevant to the discrimination of two of the four units in the test maze and irrelevant for the other two units. An equal number of right and left choices was demanded for a correct run through the maze; incorrect choices resulted in S encountering a barrier which forced him to re-trace and make a correct choice before entering the next unit. The assignment of correct cue combinations was completely counterbalanced for all groups, with any stimulus-reward relation established in the training phase of the experiment maintained in the test phase.

An analysis of variance of day 1 choice performance in the test maze revealed no significant differences between groups. A second analysis of variance conducted over day 1, 2, and 3 choice performance (because a procedural change eliminated differences between all groups on day 4) showed a significant cue combination effect, group effect, and day effect. Multiple comparisons showed that each cue combination containing black (i.e., black-chains and black-no chains) was significantly easier to learn than cue combinations containing white. An analysis of group differences showed the one- and two-cue groups to be
significantly superior to the control but not significantly different from each other. The significant day effect simply reflected the fact that learning had occurred for all groups. An analysis of variance of the number of trials required to reach criterion in the test maze (8 consecutive errorless trials) revealed the same significant group differences obtained in the preceding analysis.

Although mean group choice performance was ordered as predicted by continuity theory (i.e., two-cue, one-cue, control group -- from highest to lowest) on day 1 and over days 1, 2, and 3, the failure to obtain significant differences between the one- and two-cue groups was interpreted as favoring the noncontinuity position.
The following experiment was prompted by the marked decrement in choice performance of the three groups of Ss in the previous experiment on the fourth test day. This decrement could have resulted from either of two simultaneous changes in the experiment. In addition to the change in placement of the chain curtains, all Ss encountered two new maze sequences (as they did each day). Since either of these factors could be responsible for the observed decline, the following experiment was carried out in an attempt to determine which factor was responsible.

Procedure

Sixteen male hooded rats approximately 200–250 days of age which had been used in a partial reinforcement experiment were the Ss in the present study. Because a period of approximately two weeks had lapsed from the termination of the partial reinforcement experiment to the start of this experiment, Ss were returned to the apparatus used in their original experiment (a uniformly grey runway approximately six feet long) and they were re-trained to asymptotic latencies on a 50% reinforcement schedule. Training trials were given at the rate of eight per day for three consecutive days. Running latencies were relatively stable during days 2 and 3 of this training. On the following day training was started in the test apparatus. The procedure was identical to the procedure in the main experiment until day 4.
At this point Ss were subdivided to form two matched groups, the matching being done on the basis of choice performance on the two preceding days. For the Ss in this experiment the chains were not switched on day 4 but were left in their original positions. For one of the subgroups (RS) the correct response pattern was the same as the correct response turn pattern for Ss in the major experiment at this stage of testing. This was accomplished with the chains in their old positions by interchanging the two chain units and the two brightness units with respect to their positions for Ss in the major experiment on these same trials. For the other group (iNS) the maze unit sequence was the same as in the original experiment although now, with the chain curtains in their original positions, a new response turn sequence was demanded.

Results and Discussion

Figure 5 shows the results of choice performance for the two subgroups as well as the performance for the control group in the main experiment on days 1-4. It may be seen that no decrement in performance was observed for either of the subgroups under either of the preceding conditions. These results indicate that the decrement in performance on day 4 in the main experiment may be attributed to the change in chain condition only; that it was not produced by either a difficult response turn pattern or by a peculiar effect of the maze unit sequences on that day.
Fig. 5.—Mean percentage of correct choices as a function of response sequence, maze-unit sequence, or chain condition.
BIBLIOGRAPHY


I, David Gilbert Born, was born in Kalamazoo, Michigan on December 23, 1936. My pre-college training was in the public schools in Kalamazoo. In September, 1953, I enrolled as a full time student at Western Michigan University where I received the following degrees: Bachelor of Science and Bachelor of Business Administration, 1958; Bachelor of Arts and Master of Arts, 1959. From September, 1959 to the present I have been a graduate student at The Ohio State University where I have specialized in Experimental Psychology.

I have accepted a position as Assistant Professor of Psychology at the University of Utah for the 1963-1964 academic year.