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ABSTRACT

Research was conducted on two selective attention systems in learning situations. The theoretical and experimental approaches are presented in a set of six papers. One paper considered directions in attention theory and five papers report experiments with pigeon and children subjects. The two attention systems are (1) coding response, which mediate selections from multidimensional stimulus arrays, and (2) managing responses which are precurrent behaviors essential for stimulus reception and organization. These experiments used the conditional discrimination with multidimensional stimuli. One experiment studied the effects of discrimination histories on selective stimulus control in a conditional discrimination, a second experiment attempted to establish superordinate stimuls control of conditional discrimination performance, and a third, with human children subjects, examined the distracting effects of an irrelevant second dimension upon learning a conditional discrimination with one dimensional stimuli. A fourth experiment, derived from findings in two experiments above, measured stimulus control exercised by the negative stimulus in a simple discrimination acquired without errors. (Author)

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Attentional Factors In Learning

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Virginia Polytechnic Institute
and State University

Blacksburg, Virginia

SEPTEMBER, 1970

U. S. DEPARTMENT OF
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CONTENTS

SUMMARY

Research was conducted on two selective attention systems in learning situations. The theoretical and experimental approaches are presented in a set of six papers. One paper considered directions in attention theory and five papers report experiments with pigeon and children subjects.

The two attention systems are (1) coding responses, which mediate selections from multidimensional stimulus arrays, and (2) managing responses which are precurrent behaviors essential for stimulus reception and organization. The paradigm in which managing behaviors were relevant was a concurrent discrimination schedule. One concurrent discrimination experiment was concerned with the conditions in which two discriminations were independent of one another. The paradigm in which coding responses were relevant was the conditional discrimination. Three experiments used the conditional discrimination with multidimensional stimuli. One experiment studied the effects of discrimination histories on selective stimulus control in a conditional discrimination, a second experiment attempted to establish superordinate stimulus control of conditional discrimination performance, and a third, with human children subjects, examined the distracting effects of an irrelevant second dimension upon learning a conditional discrimination with one dimensional stimuli. A fourth experiment, derived from findings in two experiments above, measured stimulus control exercised by the negative stimulus in a simple discrimination acquired without errors.

Implications from the data for the design of learning programs were explicated.

INTRODUCTION

Attention, as it is used in this research context, is defined merely by the observation of stimulus control, that antecedant stimulus changes produce behavioral changes. However, attention usually refers to something more specific, namely observations of control at different levels by, or of different responses in, a multidimensional stimulus situation. But, such usages are only special cases of the more general definition. In fact, all stimulus situations are multidimensional, where dimensions may be specified within a modality, for different modalities, and importantly, in reference to different response systems. Consider that even uniform illumination may vary in wavelength, purity, intensity, position, and extent. So, all stimulus control research sets the occasion for an attention concept, and it is not surprising that many notions about the nature and specification of attention have arisen.

While attention in its various forms has been a source of confusion, and while attention is completely redundant to more precise terminology, great value of the several attention concepts has been rendered to force study of multiple stimulus determinants of behavior. That is, control by one stimulus dimension must be studied in the context of stimulus control by other dimensions. For example, questions concerning the necessary conditions to establish stimulus control (Terrace, 1966) are better stated to ask about the conditions necessary to establish control by m specified dimensions but not by n-m specified dimensions (Johnson & Cumming, 1968). It is only by considering functional relations between behavior and multiple stimulus variables that a complete account of antecedant stimulus control will be possible.

Attention concepts, by their frequency and ubiquity, have rendered a second service in insisting that researchers pay attention to the selectivity of stimulus control. It is quite clear that persons are not equally influenced by all conditions of stimulation, indeed that is an impossible state of affairs given basic response incompatibilities. But while selective stimulus control is an obvious fact of behavior, the types of selection and the responsible systems are not. It has required the many attention theories to convince us of profound ignorance. The papers of this report cover promising theoretical and experimental directions. The first paper reviews some outstanding, early attempts at attention theory and offers a rationale for future direction. The experimental papers which follow operate within this rationale and examine types of stimulus selection.

Each paper is presented in publication style; since their purposes differ, they are presented separately, with the theoretical and experimental contexts, methods, findings, and research and programmatic suggestions discussed in each. A summary abstract precedes each paper.

NARRATIVE

Theoretical context

The first paper in this report is a theoretical review of the two outstanding variants of attention theory, one deriving from Spence (1937) and the other from Sutherland (1959) and Mackintosh (1965). Spence's theory was elegantly simple and it stood a long period of time until incongruous instances were demonstrated in the laboratory. The Sutherland-Mackintosh theory has essentially replaced the Spence theory in currency, and the paper "Stimulus selection and attention in stimulus control" took special interest in this theory, examining its postulates and physical reference. Since as a result, the Sutherland-Mackintosh theory appeared inadequate, a new theoretical direction was recommended. In particular, a behavioral, stimulus-selection system, similar enough to Lawrence's (1963) "coding response" notion that the name was freely used, was suggested. The first paper develops some of the implications of these ideas for stimulus-selection data.

In so doing, the theory paper provides part of the theoretical context for the research presented here. In addition, other considerations of stimulus control data led to the suggestion that a second behavioral system plays an important role in determining stimulus selection. A discussion of this second system completes the theoretical context for this research.

In general, a second behavioral system, besides coding, is said to occur within the chain of stimulus-controlled behavior. This system functions primarily to manage other behaviors, later in the chain in a gross characterization, these responses are responsible for "getting the subject into position" for stimulation. But managing responses, as they may be called, are not trivial, physically necessary parts of the reinforced response chain. Rather, they are precurrent to, and mediate the occurrence of particular coding responses and indicating responses, and they are themselves controlled by general characteristics situation which have been historically associated with reinforcement contingencies. For example, a pigeon must maintain orientation to the key in order to peck at appropriate stimuli, or the pigeon exposed to an extensive stimulus array must move back and forth, scanning the array, in order to select a part of the array at high accuracy. In these examples, the maintenance of position and the scanning movement would be managing responses while the coding response and pecking response would occur later in the chain. (These considerations are, perhaps, best exemplified by the switching response appearing in the concurrent discrimination procedure below.) These managing responses would be controlled by position and extent dimensions of the discriminative situation rather than, say, by wavelength, intensity, etc.

The notion, as it stands, obviously needs even more specification to distinguish it from coding and indicating responses in certain situations. Thus, it is necessary to distinguish the managing functions from the coding functions that may occur upon scanning a brightness contour, for example. However, a complete characterization is only in preparation and relevant research is only in planning stages, at this point.

The managing response notion is reminiscent of Spence's (1937) "preparatory response" and Wyckoff's (1952) "observing response," and it may, indeed, be similar in many respects. This writer would only argue for a distinction between coding and managing functions, and for a more general character for the managing response than Wyckoff gives to the observing response.

So, it is probably easy to consider the present experiments within the context of the coding response and managing response notions.

Nearly all the present experiments were conducted using one of two paradigms, the conditional discrimination and the concurrent discrimination. In a concurrent discrimination, there are two operanda with members of a particular stimulus dimension signalling changes in reinforcement contingencies for each operandum. In this way, responses on one operandum refer to one discrimination and responses on the other operandum refer to the second discrimination. The subject must switch between operanda to benefit from both discriminations, and pecking performances appear to depend upon patterns of switching.

In a conditional discrimination, the significance of any stimulus (to which a response is reinforced or not) varies with another, superordinate stimulus. In such a situation, it may be necessary for the subject to "code" each stimulus uniquely before he can behave in a consistent relation to the superordinate stimulus.

Experimental research

The original research proposal recommended four experiments, two with the concurrent discrimination procedure and two with the conditional discrimination procedure.

A. Concurrent discrimination

One experiment was to examine the effect of training one stimulus discrimination, for different periods of time for different groups, on the subsequent acquisition of a second discrimination present concurrent with the first. This experiment was designed to test a postulate in the Sutherland-Mackintosh theory that stimulus control by one dimension was reciprocally related to the control exercised by any other concurrent stimulus dimension. If it happened that greater control was acquired by the first discrimination before the second was added, and consequently less was acquired by the second, then the postulate would be supported. Whereas, if control by the two dimensions was unrelated, then that postulate would want revision. However, for reasons clarified in the initial theoretical paper, this postulate is indeterminate, a characteristic which renders vacuous, as applied to this postulate, any empirical research.

Therefore, it was felt that a simple demonstration of discrimination performance independence would amply make the same point and provide a more positive contribution. Consequently, the one concurrent discrimination experiment, the original experiment B, was designed to obtain performance independence and to discover whether independence could be maintained as the opportunity to engage in either discrimination varied. Here, subjects were successively exposed to conditions in which the ratio of single to compound stimuli, with two stimulus dimensions, was altered. This experiment is presented in "Independence of concurrent discriminations with variation in the ratio of component discriminations."

It was during the conduct of this experiment that a management response function was suggested by the occurrence of switching between response keys. The data which led to this interpretation was presented in the September, 1969, Progress Report of this research. As it happens, the design of the concurrent discrimination experiment presented here did not permit deliberate manipulation of the switching operant, and deliberate manipulation is demanded in order to observe directly and control exercised by patterns of switching responses. A concurrent schedule procedure designed by Findley (1958) does meet this requirement.

In the present procedure, two pecking keys were employed with a different discrimination contingency programmed on each, and a pigeon made either key available by moving from one to the other; switching was indirectly observed when pecks succeeded one another on different keys. In the Findley procedure, both schedules were also continuously available, but they were presented successively on a single key as the result of pecks on a second key. That is, in order to change from one schedule to another the pigeon pecked a "switching key" rather than moving from one schedule key to the other schedule key. Switching is, thus, made explicit and independently available for manipulation.

B. Conditional discriminations

Two conditional discrimination research problems were proposed; four experiments bear on these problems. The first of these, titled "Multidimensional conditional stimulus control: Some data of two-dimensional matching-to-sample," was called experiment C in the proposal. This experiment examined the conditional stimulus control exercised by a redundant stimulus dimension, which was added to discriminative stimuli after matching had been acquired with respect to one dimension. That is, some subjects initially acquired matching based only upon colors, and other subjects, based only upon line forms. After initially matching was acquired, lines were added to colors for the first group, and colors were added to lines for the second group. Stimulus control tests consisted of sessions in which the members of the original dimension were removed. In general, earlier findings were replicated; selective, conditional stimulus control was exercised by the dimension learned initially, according to the behavior governing rate of acquisition. Transfer effects were observed on another aspect of performance, however. In addition, the line and color dimensions were scaled relative to one another in behavioral terms, and this value was constant over some conditions.

By the time of writing, it was not possible to report on selection effects that may have been peculiar to ST or to CO stimuli, and an analysis relevant to the coding response interpretation had not been completed. Publication of these data should await this information.

In this experiment, the second dimension was redundant, in that the same information about reinforcement contingencies was carried by the second as was available from the first dimension, and relevant, in that members of the second dimension were informative of reinforcement. Although colors were redundant to lines, it appeared that colors distracted subjects, since accuracies were disrupted upon the introduction of colors to acquire lines. If a relevant, additional dimension was disruptive, it was wondered what an irrelevant, additional dimension might do.

Along these lines, an experiment was designed to examine the effect of different ways in which an irrelevant dimension might distract from the acquisition of a conditional discrimination based on a relevant dimension. This experiment appears in "Effect of irrelevant color upon the acquisition of form oddity."

Since one object of this research is to develop techniques useful to instructional programs, for children in particular, the irrelevant dimension experiment was designed to use children as subjects. Later research will use children exclusively, and it was necessary to develop research technology and experienced personnel, as well as engender good working relationships with the principals of the local elementary schools, the only large populations of school-age children in the area.

In sum, cooperation and mutual respect was obtained. Experimenters worked at the conveniences of both principals, and care was taken to see that both parents and students were aware of the general program objectives and did not object to participation. As it happened, parents occasionally called to request that their children be allowed to participate in the study. (A permission form is attached to the paper.) It remains essential to render some service to both principals for their cooperation.

Experiment D in the proposal suggested that an "extended conditional discrimination" might be trained in pigeons. In the extended conditional discrimination, the conditional rule behavior itself is placed on a conditional relationship with a further superordinate stimulus. For esample, with a single stimulus set such as lines, one superordinate stimulus, such green, would signify line matching, while red superordinate stimulus would signify line oddity (in which responses to the non-matching CO would produce reinforcement). The attractions to the extended conditional discrimination are (1) that it is paradigmatic of the most complex forms of conceptual abstraction, and (2) that neither adult humans nor pigeons can acquire an arbitrary example during long exposure, although humans can accurately perform according to the rules once instructed. The initial effort simply attempted to train some suggestion of extended conditional stimulus control in pigeons, and the procedure consisted of signalled, conditional discrimination reversals.

The idea was to train the extended conditional discrimination by "brute force" to assure its feasibility. Pigeons acquired line matching until some criterion performance was attained and then placed on line oddity to criterion before returning to matching, and so forth. Whenever matching was in effect ST stimuli appeared on a green background and during oddity sessions ST stimuli appeared on a red background. As it was mentioned in the paper, "Successive conditional discrimination reversals," control by the colored background was obtained. This experiment should continue until line matching and line oddity trials are accurately performed when mixed into a single session.

As soon as it was obvious that extended conditional discriminative stimulus control could be acquired, thinking began on developing more efficient training techniques. One promising direction is Terrace's (1963) errorless discrimination training procedures. A second direction would be to "guide" or "prompt" the development of one discrimination with a discrimination based on a second, independent dimension, previously established. Touchette (1970) has presented a technique which may fit this description.

Terrace's (1963) errorless training procedure was attempted first, and to develop the necessary technical skills, as well as to probe some limits of this procedure, the experiment, "Generalization gradients around S^{Δ} following errorless discrimination learning," was conducted. The central theme of this experiment involved a question somewhat beside the primary objectives of this research program. Its relevance here is primarily technical in nature; we wanted to train a discrimination in an errorless fashion, under rather difficult conditions.

Terrace (1963) trained an errorless red-green discrimination by shaping the key-peck to red, and soon thereafter, introducing the green, negative stimulus. Green was presented initially for very brief durations a low intensity (a dark key) in successive time periods, and over three, daily, 30-min sessions, the green stimulus was gradually incremented in duration and intensity until it was present for equal durations at equal brightness to the red. No incomprehensible responding essentially zero, ever occurred to the green stimulus while responding to red was maintained at a high rate. Thousands of responses would ordinarily have occurred to green with the usual discrimination learning procedure.

We wished to train a discrimination between a positive stimulus of a completely darkened key and a negative stimulus of a key brightly lit by 576 nm light. In the laboratory lore about pigeons it is said that pigeons will not peck a dark key without considerable training effort, but will display a pecking operant level to a brightly lit spot. Further, gradual introduction of the negative stimulus could only be made on the basis of stimulus duration since a very dim 576 nm light is perfectly generalized with a dark key, here, the positive stimulus. In spite of these conditions, the discrimination was trained successfully without errors.

Clearly, the next steps include developing techniques for training a conditional discrimination without errors (an interesting case since a single stimulus may at different times signal pecking and non-pecking) and developing "prompting" techniques.

Information dissemination

Two of the papers in this report have already appeared publicly. "Stimulus selection and attention in stimulus control" was presented in a symposium at the Eastern Psychological Association convention in Atlantic City, N. J., April 3, 1970.

"Generalization gradients around S^{Δ} following errorless discrimination learning" is in press, having been accepted by Psychonomic Science.

The other papers will appear when data analyses have been completed.

Grant Personnel information

Four undergraduate students associated with this research were admitted in graduate psychology programs.

Mr. John M. Kane was admitted into McMaster University for a research program in stimulus control. Mr. Kane was, nonetheless, drafted into national service before the end of his first semester.

Miss Natalia M. Hoenigmann was admitted into a child psychology program at the University of North Carolina at Greensboro, with an emphasis on discrimination and concept learning in children.

Mrs. Ellan S. Dodson was admitted into a school psychology program at Radford College.

Mr. William H. Anderson was admitted into a clinical psychology program at the State University of New York at Stong Brook.

STIMULUS SELECTION AND ATTENTION IN STIMULUS CONTROL

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The concept of attention, as it has been quite frequently used recently, often appears gratuitously; we know about attention by its reverse, inattention i.e., failures of stimulus control. When attention is demonstrated, the reference is to selective stimulus control, i.e., those cases in which some, but not all stimulus features control behavior.

Real progress could be made if we held to Skinner's suggestion that attention simply be identified with the fact of stimulus control. Then we could return to the old question, "What are the necessary and sufficient conditions to establish stimulus control?," understanding, as we have learned from some recent research, that we mean stimulus control by dimension S and not by dimensions X, Y, and Z, and also demanding a multidimensional test. Such an attitude would not be satisfied with the spate of experiments using one value of the independent variable; it would encourage the discovery of functional relations between behavior and its determining variables. Not only is this virtuous, but it is essential, if we are to make sense of stimulus control data.

If attention is used in one way to label the fact of stimulus control, it has also been used to denote an event, or a mechanism which has been invoked to explain stimulus control.

The least satisfying of these attention theories refers to an absolutely dimensionless system. These theories do no more than profess the importance of an attention concept and recognize that the behavior is complex.

More adequate attention theories refer to a two-stage contingency, or process, which is necessary to understand stimulus control as a coherent body of data. In these theories, the second stage consists of reinforcing responding in the presence of stimulus features; the first, prior, stage determines which features will thus acquire control, and on occasion, this stage or event is called attention.

There is no special problem here except a semantic one· the theorists could have chosen a more descriptive term and had not used attention. In this sense, the phrase, "The effect of attention on generalization" is barely comprehensible. Spence's receptor-exposure-act is certainly more descriptive of the proposal that the working or non-working condition of the mechanism makes a difference in stimulus control.

Theories in animal discrimination learning have been divided into continuity and non-continuity types and follow Spence, on the one hand, and Lashley and Krechevsky, on the other. Modified or neo-continuity and neo-non-continuity theorists see themselves differing primarily on the basis of attention, i.e., whether selective stimulus control occurs. However, it is exactly on this basis that the Spence and Lashley-Krechevsky theories are identical. Both recognize selective stimulus control and propose a two-stage contingency to account for it. The theories differ with respect to the character of the attention stage, and Spence's theory was the more determinate.

Spence proposed that "preparatory responses," later called "receptor-exposure-acts," were responsible for stimulus selection, i.e., the subject determined what stimulus features gained control by what he "looked at." Thus, if a subject in a jumping box looked at the stimulus card rather than the wall beside it, the discrimination problem was soluable. All one has to do is reduce the size of the "gaze," as it were, to understand how one of Reynolds' pigeons was controlled by the white outline triangle and the other pigeon by the red background. In fact, a great deal of selective stimulus control data can be understood by the character of this attention stage. This theory is prototypic of many similar theories in which the selection-determining event is specified in behavior.

This formulation is troublesome, however, if one considers a discrimination between a red outline triangle and a green outline circle. There, orientation differences do not separate stimulus features.

The attention stage in the Lashley-Krechevsky theory was nev er dimensionalized; rather, processes were presented as essential to describe and understand certain stimulus control findings. Their theory was more a listing of characteristics which a completely dimensionalized theory should have. For that matter, more recent attention theories using a non-continuity label specify outcome functions of the attention stage but few details concerning its determiners or its organic reference.

Sutherland (1958) and Mackintosh (1965) have developed a theory along these lines and I would like to examine it briefly. Sutherland and Mackintosh have been as explicit as any in describing outcome functions, determiners and organic reference, and they are frequently cited.

In this theory, Sutherland (1958) views the brain as consisting of three boxes: (1) a number of different stimulus-analyzing mechanisms (mechanisms each of which accepts stimulus input and each operates, to the extent of producing outputs, on a different, single dimension of the stimulus), (2) a control center which determines which analyzing mechanism will be "switched in," or used, at any time, and (3) a center selecting which response is attached to analyzing mechanism output.

Sutherland is quite anxious to make behavioral predictions based entirely on the system so a set of operation rules were established to produce outcome functions. Let us look at them.

The main feature is the set of stimulus - analyzing mechanisms. Stimulus input goes into a number of analyzing mechanisms but each operates by producing outputs only with variations in a single stimulus dimension. In vision, for example, one analyzer may detect only brightness differences, and another, the ratio of horizontal and vertical extents, and so forth. Responses are attached to analyzer outputs as a result of learning. So, discrimination learning involves two stages - first, the learning of which analyzer must be switched in, and second, the learning of analyzer output to response attachments.

One rule states that reinforcement and non-reinforcement consequences work as usual, but specifically on the analyzer output to response attachments.

A second rule states, however, that changes in response attachments occur only to outputs of the analyzer which is currently switched in. An early version of the theory (Sutherland, 1958) had a third rule stating that only one analyzer could be switched in at any time.

Thus, it is assumed, plainly, that strict stimulus selection is the case - in the third rule - and non-continuity results are understood, by assumption, in the second rule stating that responses are attached only to the operative analyzer.

One feature, - the rule stating that only one analyzer may be switched in at any time - is determinate and may be tested. However, several experiments, e.g., Butter (1963) and Johnson & Cumming (1968) have shown that more than one aspect of a stimulus may acquire control. Mathematical theories solve this dilemma by the device N number of "looks," where only one dimension is analyzed on any "look" but a subject may make N "looks." A more current version of the Sutherland-Mackintosh theory changes the third rule to one saying that analyzer switching is not an all-or-none affair but that the more strongly one analyzer is switched in the less strongly are others switched in. While, on the face, this rule is tested by finding negative correlations between degrees of control exercised by different dimensions of compound training stimuli, no operation change is required to accept evidence of equal control, should one be able to recognize equality.

With these characterizations and rules, demonstrations of non-continuity effects, incidental cue learning, single stimulus pretraining and selective stimulus control results are easily accommodated in a way unlikely or impossible with Spence's theory. Simultaneously, continuity effects and equal component control are also happily understood.

Note that the change in the third rule renders the system indeterminate (in exactly the same way for which Spence criticized Krechevsky's choice of hypotheses). That is, there is no way to predict which analyzers, the number of analyzers which are operative, or the conditions in which they are operative. Neither is there further specification of the analyzer control center.

Thus far, we are left with a profession of faith that a two-stage contingency is necessary, because simply training with a compound stimulus does not guarantee that control will be exercised equally by all dimensions of the stimulus. We have, further, a suggestion that subjects deal in units of stimulus dimensions independent of their size and position in space. But, we are unable to determine which dimensions will acquire stimulus control (or that any will not acquire control) based merely on the Sutherland-Mackintosh theory.

If determiners of stimulus control are not evident in the operation rules, there may be suggestions from the organic reference of the Sutherland-Mackintosh theory. Characteristic of non-continuity theories which attempt an organic reference, Sutherland and Mackintosh choose neurological terminology. However, no neurological information that is not inferred from behavior is introduced to suggest ways in which subjects classify stimuli, so there is no gain here.

At this point, one might ask, "Why not assume that a behavioral system is responsible for stimulus selections?" The reasons for choosing a neurological reference are not obvious; there are no data either to suggest that a neurological model is necessary or that a behavioral model is insufficient.

On the other hand, all the evidence considered is behavioral and the degrees of freedom for presumed neural action are intolerably numerous. There are further considerations from the fact that two additional rules in the Sutherland-Mackintosh theory (Sutherland, 1964, p. 150) describe how training affects the stimulus analyzing mechanisms, and in the absence of suggestions about how any portion of the nervous system is altered by training, a behavioral attention stage seems all the more reasonable. There may even be advantages to behavioral specifications: (1) we may be able to see one *in vivo*, that is, specify its topography, and (2) there are behavioral laws to be obeyed, consequentially providing determining variables and experimental tests. The problem lies only in the character of the behavior, and Spence's preparing and orienting functions do not exhaust the possibilities.

In 1963, Schoenfeld and Cumming presented a behavioral analysis of perception using an advanced paradigm $S \rightarrow R_1$ thence R_2, where R_2, a "reporting response" is a conjunctive function of S and R_1 such that $R_1 = f(S)$ and $R_2 = f(R_1)$. Clearly, the idea is a two-stage contingency in which stimulus control of R_2 reporting responses depends upon, or is mediated by, in a general sense, the R_1 "instruction response," as it was called. While the Schoenfeld & Cumming paper was primarily concerned with the resolution of perceptual phenomena, its operation in generalization and discrimination learning phenomena was also suggested.

Cumming and Berryman (1965) further developed the concept of R_1 and delineated its operation. In so far as a general characterization is called for, Lawrence's (1963) treatment of the "coding response" is a likely candidate. By coding, Lawrence referred merely to the assignment of a different label to each event, i.e., the occurrence of a particular response peculiar to each stimulus event.

As the result of R_1, or a coding response, a new event occurs or a new potential exists. This event is the "stimulus-as-coded" of Lawrence, or the "stimulus as responded to," or "...dealt with" or "...operated on," to which R_2 responses may be associated; it is sufficient to say, now, that $R_2 = f(R_1)$. Theoretically, R_1 may code or refer to any specific feature, or any combination of features of S.

The application of this formulation to stimulus selection and attention should be obvious. The R_2 reporting responses are equivalent to key-pecking by pigeons in an operant chamber and turning left or right by a rat in a T-Maze. The R_1 is then equivalent to the prior attention stage in operation, although it should not be called an "attention response." Its function is coding or instructing, and whatever stimulus selection occurs is a function of the "code" or "instruction." Johnson (1970) has demonstrated the plausibility of this account for several unusual details (in stimulus control literature) concerning the determining variables of stimulus selection.

The remaining problem is to reduce the degrees of freedom available with the concept, so that predictions will be practical. Since we are dealing not with cognitive inventions but explicit pieces of behavior, there are constraints, and the functions are discoverable. The fact that responses are shaped by training seems to multiply complexities. But, the behavior to be explained is complex, and one would almost be disappointed with a simple explanation.

Lawrence (1963) has thoroughly discussed the interpretations of many stimulus control findings with this type of concept; his is an excellent review. I will not review them here, except for one last point.

In evaluating and comparing theories as I have briefly done, one may deal rigidly with the terminologies provided by the theorists, or one may seek conceptual similarities, regardless of language. Thus, I may have given the impression that a mechanism like that which Sutherland and Mackintosh present would be quite adequate if only it were specified in behavior rather than neurology. On the other hand, one may also consider whether the list of mechanism specifications is sufficiently rich to understand a wide range of stimulus control phenomena. Rather than extend the discussion at this time, it should be quickly noted that the Sutherland-Mackintosh theory, in any form that I have seen, is unable to account for the mere fact that several conditional discriminations may be acquired. Lawrence (1963) has discussed the problem applicable to them, and I refer you to that discussion.

In summary, it has been the main point to discuss shortcomings of some current attention theories and to suggest some directions for fruitful further thinking.

INDEPENDENCE OF CONCURRENT DISCRIMINATIONS WITH VARIATION IN THE RATIO OF COMPONENT DISCRIMINATIONS

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ABSTRACT

Three, White Carneau cock pigeons were exposed to three varieties of a CONC MULT RI EXT schedult in which colored backgrounds and white line orientations appeared on both response keys in color-line compounds or as single stimuli. A vertical white line indicated reinforcement on an RI 2-min schedule and a white horizontal line indicated extinction for responses to the left key whenever these stimuli appeared. A green and red background, respectively, indicated equivalent, independent contingencies whenever they appeared, for right key responding. In three conditions, the ratio of single to compound stimulus components and the ratio of line to color components were varied. Response, position and stimulus discrimination independence was established and was not altered by changes in concurrent discrimination context conditions.

One question posed in various forms about animal information processing capabilities concerns the absolute amount of information which may be processed at any time. In the animal discrimination learning literature this question has appeared in a form asking how many stimulus aspects may effectively control behavior at any time. Researchers have suggested various numbers of depending upon the species of subjects tested. The inference usually drawn from the data is that the respective nervous systems define the limits, but suggestions about specific characteristics which impose the limits are either vague and ill-defined or beyond current technology.

There is, at least, one idea which may be tested. It may be suggested that as many aspects may acquire control as there are independent response systems available to the subject. This suggestion has strategic implications different from current practice, which is the place subjects in a situation, count the number of aspects which do exercise control and consider the result to express a limit. The present suggestion, for one thing, recognizes that any estimate of limits may be a function of existing measurement operations. Experiments conducted with this attitude which confirm situational determiners of information processing would, besides dispeling restrictive theory, indicate manipulable variables for obtaining more or less processing.

This view becomes practical to test only when an animal of limited capacity is placed in a situation which is said to exhaust that capacity. Several investigators are convinced that pigeons in two-dimensional stimulus discrimination situations fulfill these conditions. Sutherland (1959) and Mackintosh (1965) were willing to assume that rats, octopuses, and pigeons could attend to changes in no more than one stimulus dimension at a time, i.e. that only one information-processing channel was available for stimulus dimensions. It was said that, to the extent that precision was gained about any other aspect in a stimulus situation, precision must be sacrificed about an originally learned aspect of that situation.

The present experiment exposed pigeons to a two-dimensional stimulus discrimination where responses to values of both dimensions was identifiable and available at any time. The procedure is a concurrent discrimination.

A concurrent discrimination is a free-operant, simultaneous discrimination. That is, at least two operanda and two stimulus conditions are present and available for durations sufficient to allow all responses to occur in all stimulus conditions. The usual simultaneous discrimination is a trial procedure which permits one response to only one stimulus condition, confounding the preference for one stimulus with the rejection of the other. In the concurrent discrimination, while a response to one key is strictly incompatible with a simultaneous response on the second key, pigeons could switch freely from key to key over time, and Catania (1965) has outlined features of procedures which insure independence with respect to overall rates of responding. Response independence is essential before discrimination independence may be recognized.

The present experiment examined concurrently maintained discriminations with variation of the context within which each appeared. That is, the effects on the dimension A discrimination of changes in the context provided by the other, dimension B discrimination, was observed. Specifically, rates of responding in the presence of values from each of two stimulus dimensions, background color and angular orientation of a white line, were monitored and the ratio of color or line, single stimulus components to color-line compound stimulus components varied. Reinforcement schedules maintaining the two discriminations were equivalent, so that discrimination independence was evidenced by high response rates to the appropriate operandum during all positive stimulus components from each dimension.

Thus, the experiment attempted to establish independent discriminations and discover whether discriminations remained independent over a range within which the opportunities to engage in either discrimination, varied.

Method

Subjects: Three, 5-6 yr old, White Carneau cock pigeons were maintained at 80% of their free-feeding weights and were run daily provided weights were within 15 g of 80% weights. All subjects had each received approximately 255 sessions during which several procedural variables were evaluated to insure response independence. The data and operations during these sessions are outlined in the September, 1969, Progress Report.

Apparatus: A standard operant chamber for pigeons (LVE 1519C) was outfitted with three pecking keys, 2.54 cm in diameter, aligned horizontally 8.3 cm apart and 15.2 cm from the floor. A 5.1 cm square hole provided access to a magazine at which grain (50% Kaffir, 40% vetch, 10% hempseed) was occasionally available for 3-sec periods. This opening was below the center key 9.5 cm from the floor. A speaker mounted on the left side of the front panel provided white masking noise (86 db re: SPL) and a fan on the chamber wall provided ventilation continuously. A 3-w lamp located above the center key provided general, houselight illumination.

Light stimuli transilluminating the pecking keys were provided by IEE display units with 313X lamps. Stimuli consisted of red (R) or green (G) hues which filled the key area or vertical (V) or horizontal (H) white lines which were approximately .47 cm wide and 2.5 cm long on dark achromatic backgrounds. At times hues and lines appeared alone and at times a white line was superimposed on a chromatic background.

Automatic programming and recording apparatus was housed in a separate room from that housing experimental chambers.

Procedure: All three pigeons served in preliminary experimentation with the concurrent discrimination for approximately 255 sessions. During this time stimulus conditions and features of the reinforcement contingencies were varied to obtain a procedure in which reliable responding and stimulus control was observed.

The basic experimental situation was an 8-ply concurrent schedule applied to responding on the two side keys in the 3-key chamber. Eight different stimulus conditions were arranged by presenting four stimuli, V, H, G, and R, alone and in line-color combinations. That is, there were V, H, G, and R periods in which each stimulus appeared alone for the entire period and periods of the combinations GV, GH, RV, and RH. Stimuli appeared alone or in combination on both side keys; the center key was always dark. Whenever V appeared, responding to the left key was reinforced, and whenever G appeared, responding to the right key was reinforced. Non-reinforcement of left or right key responding was indicated by H or R, or the absence of a line or color, respectively. Thus, line changes referred to reinforcement changes for left-key responding and color changes referred to reinforcement changes for right-key responding. These rules are summarized in table 1 below.

TABLE 1

Reinforcement contingencies in the basic concurrent procedure

Left Key	Stimulus	Right Key
EXT	G	RI 2 min
RI 2 min	V	EXT
EXT	R	EXT
EXT	H	EXT
RI 2 min	GV	RI 2 min
EXT	RH	EXT
EXT	GH	RI 2 min
RI 2 min	RV	EXT

Responding on the two keys was reinforced on independent, random-interval 2-min schedules of reinforcement, except that during V, G, RV, and GH periods responding to the appropriate key received reinforcements programmed on both schedule devices. This feature equated all stimulus periods for which any reinforcement was scheduled at an overall rate of 60 reinforcements per hr. Catania (1961) indicated that this consistent reinforcement rate feature eliminated contrast effects (Reynolds, 1958) that may otherwise appear in concurrent, multiple schedule performances. In both cases, RI intervals were timed from the preceding reinforcement. Thus, the mean probability of reinforcement increases over time from zero to certainty and holds at certainty until reinforcement is delivered.

Another contingency was placed on switching responses, between keys; this feature, called "changeover delay" (COD), specified a minimum amount of time since a response on key B which must pass before a key A response would produce a programmed reinforcement. In practice, the first key A response after a key B response initiated a 2-sec COD interval during which no key A response was reinforced. Throughout, center key responses were ineffective except to provide for the initiation of CODs by subsequent side key responses. The COD feature appears to eliminate superstitiously maintained switching responses.

Sessions consisted of 40 components, each 1 min in duration and separated by a 5 sec timeout when all lights except the general chamber illumination was off and no response was ever reinforced.

Besides the basic, 8-ply concurrent schedule there were two variations in which the number of single stimulus components from one dimension was three times the number of compound stimulus components. Thus, in one form (3:1 Color) there were 15 periods each of G and R and 5 periods each of GV and RH. In the second form (1:3 Line) there were 15 periods each of V and H and 5 periods each of GV and RH. In both of these variations, the opportunity for one discrimination was dominant and the second dimension appeared only concurrent with the first.

Table 2 lists the sequence and length of exposure the three conditions for the three birds. In general, all subjects were exposed to each condition

TABLE 2

Session in which subjects were exposed to experimental conditions

	Subject		
Condition	80	81	82
3:1 Color	258 to 281	257 to 279	257 to 276
1:3 Line	282 to 335	280 to 336	277 to 329
Basic 8-ply	336 to 382	337 to 385	330 to 380 406 to 436
Special Training			381 to 405

for 15 daily sessions and continued until five successive days of relatively stable responding had occurred. Judgements of stability were made from daily rate charts and fit the criterion that component rate changes over two successive days was no greater than 15%.

Bird 82, during initial exposure to the basic concurrent schedule, failed to respond during RV. Therefore, this bird was given training which included 5 sessions of exposure to GV, GH, and RV components, 12 sessions of exposure to RV only, and 8 sessions of exposure to GV, GH, and RV components again, before final return to the basic concurrent schedule procedure.

RESULTS

The main questions of the experiment are answered by referring to the distribution of responses to the two keys in the various stimulus conditions and to relative response rates, according to three features of the procedure. First, there is discrimination performance, and for precise discriminations, rates should be high in those stimulus components for which reinforcement is programmed and low, essentially zero, in those stimulus components for which extinction is programmed. Second, since position codes stimulus dimensions, responses should occur to the left key for line stimuli and to the right for color stimuli. Third, judgements of response independence rely upon a match between the ratio of left key response rate relative to responding on both keys and the ratio of left key reinforcement rate relative to the total reinforcement rate for responses to both keys (Catania, 1965), for each type of stimulus component.

Response rates to keys and stimuli from the final five sessions of each context condition were analyzed to determine whether performance independence was established.

Of primary interest for judging independence of stimulus discriminations and response position are those components in which a particular stimulus value, or the absence of a dimension member, is correlated with extinction. There were 10 such components in the 8-ply schedule and 5 in each of the 3:1 Color and 1:3 Line Conditions, totalling 60 such observations for all subjects. With one exception, no mean rates greater than 4 responses per min and only 5 instances of rates higher than 2 responses per min were observed within the 60 extinction components. The single, high-rate exception occurred as bird 82 responded at 10 responses per min to the left key during G in the 3:1 Color condition. So long as all other rates in components correlated with reinforcement are reasonably high, such low rates indicate that responding was precisely controlled according to position and stimulus rules and that response distributions were independent of changes in context.

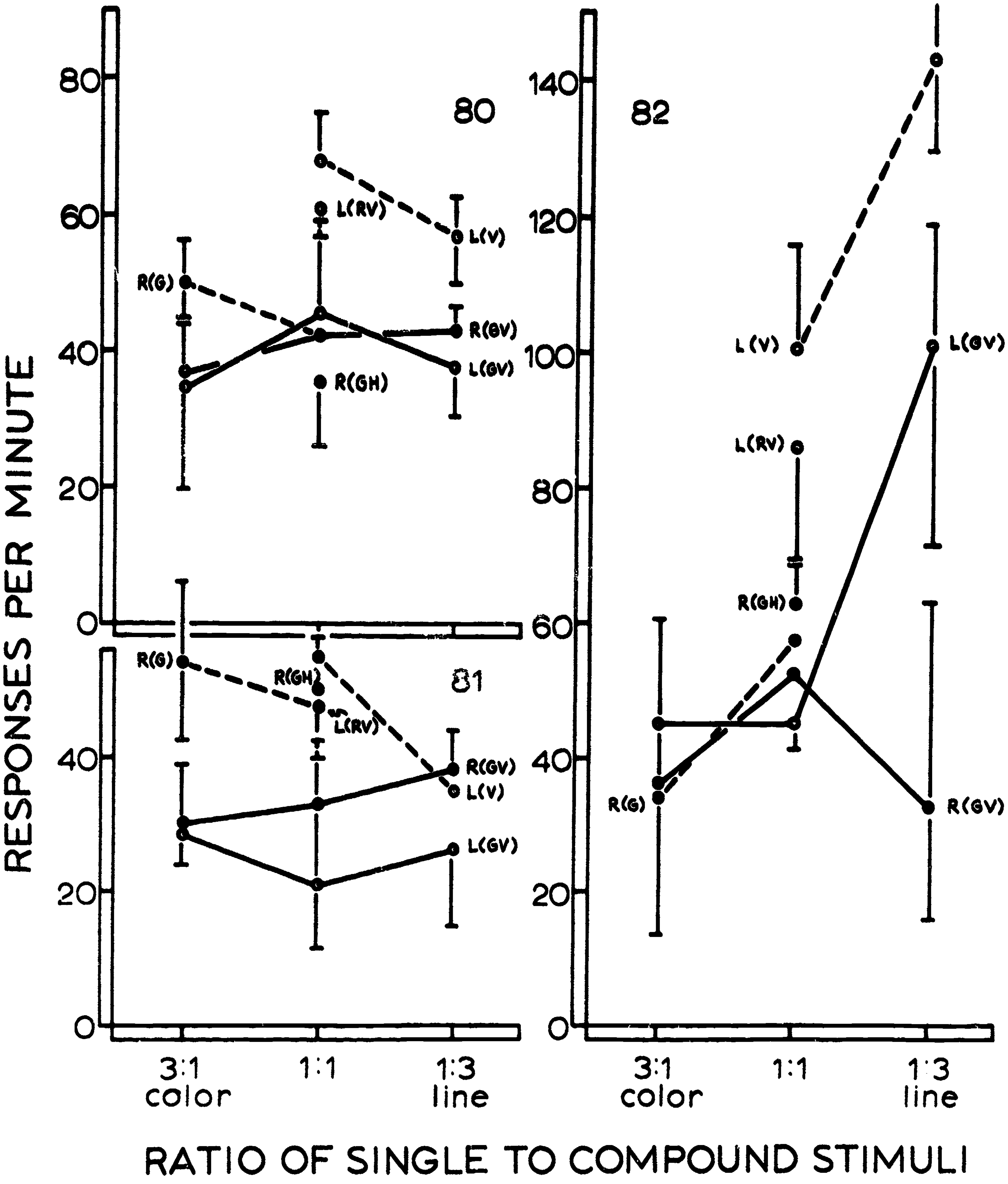
Response independence would be most easily identified if all rates to components correlated with reinforcement were equal. This might be expected since the two independent reinforcement schedules were equivalent RI 2 min schedules. However, observations of multiple schedule performance have shown response interaction effects called behavior contrast (Reynolds, 1958) and since the present procedure is a concurrent multiple schedule, one might expect responding on the right key to GH, for example, to be greater than the right key rate during GV, due to response interaction. Catania (1961) observed no contrast effects, that rates during reinforcement components were equal, in a CONC VI, MULT VI EXT so long as the reinforcement rate during components when responses to only one key was reinforced was equal to the reinforcement rate obtained during concurrently reinforced components. That is, in CONC VI EXT components, reinforcements could be obtained at a 1 per min rate for responses on the VI key, while during CONC VI VI components, responses to each key obtained a .5 per min reinforcement rate, or a total rate of 1 per min. Since this procedural feature was employed in the present experiment, contrast effects should be eliminated, but it would be expected that response rates would reflect the relative reinforcement rates. Therefore, rates during G, V, GH, and RV would be higher than comparable key rates in GV, as related to the reinforcement rate function. According to these suggestions, for performance independence, response rates should not differ across context conditions but should differ in level between component types.

Absolute rates of responding to stimulus components correlated with reinforcement, for the three subjects, were calculated from the 5 terminal sessions of each context condition, and are presented in fig. 1. Since rates during extinction components were quite low, they do not appear here. Brackets indicating the range of variation for each value, or in some cases for overlapping clusters of values, display the consistently large variance around means. High between-session variability with, nonetheless, low standard errors of the means over blocks of sessions was characteristic of performance under all three experimental conditions following the dissolution of transitions between conditions. Large variance with small standard errors may represent a sort of compensatory rate change between sessions similar to that which Catania (1965) observed within sessions.

The side key to which responding occurs is indicated by L and R for left and right keys, respectively, and component types are given in parentheses.

For the most part, rates on left and right keys in the concurrent GV component were similar; there is extensive overlap between the distributions of these rates. But, there was no consistent relation between rates and experimental conditions. Except for performance by 82 during 1:3 Line, it would be difficult to argue for rate changes greater than zero as a function of context changes.

Figure 1. Absolute rates of responding to stimulus components correlated with reinforcement for three subjects. L and R refer to rates on left and right keys, respectively and letters within parentheses indicate stimulus components.


RESPONSES PER MINUTE
80
60
40
20
0
40
20
0
140
120
100
80
60
40
20
0
80
81
82
L(RV)
L(V)
R(G)
R(GV)
L(GV)
R(GH)
R(G)
R(GH)
L(RV)
R(GV)
L(V)
L(GV)
L(V)
L(RV)
R(GH)
L(GV)
R(G)
R(GV)
3:1 color
1:1
1:3 line
3:1 color
1:1
1:3 line
RATIO OF SINGLE TO COMPOUND STIMULI

Several other component rates are within the range of GV values but most of these are significantly higher than GV rates. In general, as was expected, rates on the reinforced key in components when responding was reinforced on only one side key was higher than rates on either key in the concurrent GV. None is significantly lower. It is not clear, however, which variables produce, for example, equality of left key rates in V and GV during one condition and a much higher left key V rate in another condition, as for 81. Either case is acceptable for judgments of independence but such events occur frequently enough to recommend closer analyses of concurrent discrimination situations.

Overall, it appears that response and discrimination performances during terminal sessions were independent of changes in the ratio of single to compound stimulus components and the ratio of line to color components.

Of nearly equal interest for judgments of discrimination independence is information about performance changes from one context condition to another. In particular, if discriminations established with respect to each dimension are independent of one another, then changes to a discrimination situation involving greater use of a second dimension should display no serious disruption of discriminative performance. There are only two transitions between experimental conditions so that regular transition effects due to conditions may not be assessed. Nonetheless certain regularities which appeared between subjects may be described.

In the transition from 3:1 Color to 1:3 Line, all subjects shifted the key to which the majority of responding was made, within the first 1:3 Line session. This involves a change from responding primarily to the right key during 3:1 Color to the left key during 1:3 Line. For 80 and 81 performances on 1:3 Line was similar to the terminal performances on that condition after 7 sessions. Bird 82 required approximately 15 sessions before performance similar to terminal performance was observed. During these transition sessions bird 81 did not respond significantly to either H or RH components. Inappropriate responding did occur to V on the right key and only low rate responding occurred on the left key to the concurrent GV condition. Bird 80 responded to H on both keys but was otherwise similar to 81. Changes to terminal performance by these subjects then involved equalizing left and right key rates during GV and decreasing the rate of inappropriate responding. Initially, Bird 82 simply shifted nearly all responding to the left key. Its response distribution then changed until it was similar to that of Bird 80, although concurrent GV responding was maintained once right key responding reappeared at reasonable rates. From that point, right key responding to V was long in extinguishing, and a marked dominance of left key responding continued.

The transition from 1:3 Line to the basic, 8-ply concurrent schedule again occurred rapidly with respect to response distribution to the two keys; within the first session on the 8-ply schedule total responses to the two keys were approximately equal, within 18% of one another. In general, response distributions between keys to particular stimulus components were maintained for those components previously exposed. Two components, GH and RV, in the 8-ply schedule were not presented in either 3:1 Color or 1:3 Line. All three birds initially failed to respond during RV, although appropriate GH performance appeared immediately. Bird 80, in addition, failed to respond at a high rate to G. So, changes to terminal performances for two subjects consisted exclusively of raising left key rates to RV and, in the case of 80 alone, raising right key rates to G. Bird 82, however, failed to respond to RV over 50 sessions of the 8-ply schedule and, thus, was given the special training described above, before being returned to the 8-ply schedule with appropriate RV behavior.

Thus, it appears that stimulus discriminations once established were easily maintained over conditions, that subjects were quite sensitive to overall changes in reinforcement rate between the two keys, and that transition effects consisted mainly of correlating appropriate position to particular stimulus component. While only two transitions are described it may not be unreasonable to expect that subsequent presentation of any combination of previously exposed components would reveal no transition effects.

DISCUSSION

In both terminal performances and transitions between conditions, response independence and independence of stimulus and position discriminations were noted in individual subjects. Of these, stimulus discrimination independence is most notable, since independence was maintained as discriminations on two dimensions were required under relatively sparse "reminder" rates.

Discrimination independence has been noted before, e.g., Goodwin & Lawrence, 1955; Coate & Gardner, 1965; Liu & Zeiler, 1968, but none of these demonstrated independence in either compound stimuli or for individual subjects. Only in the present case is it possible to state that subjects can process information from two stimulus dimensions concurrently. One can confidently refute earlier (Sutherland, 1959) estimates of information processing capacities in pigeons. In addition, there is support for the notion that limits of discrimination performance is set by the numbers of independent responses systems available and permitted by the measurement operations.

However, the importance of the study lies not in theory refutation or support as in its directions for techniques of obtaining multidimensional stimulus processing. In this line, it appears that more attention should be directed toward behaviors which seem to "manage" information processing. Preliminary work identified the switching response as a potential manager and the present study provides a useful procedure for its analysis.

MULTIDIMENSIONAL CONDITIONAL STIMULUS CONTROL:

SOME DATA ON TWO-DIMENSIONAL MATCHING-TO-SAMPLE

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ABSTRACT

One group of four White King cock pigeons were trained on 3-ST matching-to-sample with line stimuli (L-matching). Following L-matching acquisition they were transferred to matching compound lines and colors (C + L-matching) and were then exposed to colors alone (C-matching) and recovered on L-matching. A second group of three pigeons were initially trained on C-matching and later received C + L matching and L-matching. At least two independent aspects of matching performance were identified, performance about chance level and a learning transition to high accuracy performance asymptotes. Determining a coefficient of discriminability between lines and colors, such that lines were 2.5 times more difficult to learn than colors, and correcting for this value, both original matching acquisition and subsequent transfer on lines or colors alone were learned at identical rates. Further, pretraining on one dimension determined selective control by that dimension during C + L training, although some color discriminative control was acquired and exercised its influence primarily on performances about chance level in the transfer phases.

Several experiments (cf. Lawrence, 1949; Mackintosh, 1965; Miles & Jenkins, 1965) have investigated the effects of training a single stimulus discrimination on later training when these single stimuli were components of compound discriminative stimuli and were consistent with earlier training. Johnson & Cumming (1968) and Johnson (1970) has examined the effects in both sequences, single to compound stimuli and compound to single stimuli. All studies found that so long as the significances of the single stimuli were consistent throughout both training phases, little or no stimulus control was exercised by other components of the compounds and that this relation held for both sequences. Thus, selective stimulus control, attention, by parts of multidimensional stimuli was easily obtained by manipulating the subjects' discrimination histories. All these experiments employed simple discriminations in which the significance of each stimulus is invariant. The present study extends the analysis of attention relations to a conditional discrimination, matching-to-sample.

Here, matching was trained first to a set of three stimuli from one dimension. Later a redundant set of three stimuli from a second dimension was added to the original set to form compound stimuli. Stimulus control by components of the compounds was assessed by returning to one dimensional stimuli, taking each dimension in succession.

METHOD

Subjects: Seven White King cock pigeons, 5-6 yrs old, were run daily provided weights were within 15 g of 80% free-feeding weights. Rations of maple peas were fed daily in home cages as needed to maintain 80% weights.

Apparatus: A standard operant chamber for pigeons (LVE 1519C) was outfitted with three pecking keys, 2.54 cm in diameter, aligned horizontally 8.3 cm apart and 15.2 cm from the floor. A 5.1 cm square hole provided access to a magazine at which grain (50% kaffir, 40% vetch, 10% hempseed) was occasionally available for 3-sec periods; this opening was below the center key, 9.5 cm from the floor. A speaker mounted on the left side of this panel provided white masking noise (86 db re: SPL) and a fan provided ventilation continuously. A 3-w lamp located above the center key provided general, houselight illumination.

Light stimuli which transilluminated pecking keys were provided by IEE display units with 313 X lamps. Stimuli consisted of red (R), green (G), or blue (B) lights which filled the key area or white line forms approximately .47 cm wide and 2.5 cm long on dark achromatic backgrounds. These forms were a vertical line, (V), a horizontal line, (H), and a cross with perpendicular arms ariented 45^{o} from horizontal, (X).

Automatic programming and recording apparatus was housed in a separate room from that housing experimental chambers.

Procedure: All pigeons were fed their daily rations at the chamber grain magazine location on three, successive days. Then, all were trained to peck the three stimuli to which they were exposed initially with a modified "autoshaping" procedure (Brown & Jenkins, 1968). Thirty pecks were reinforced in the presence of each of the three stimuli before experimental treatment began. On the session following completion of key-peck training, all pigeons were placed on a matching-to-sample procedure.

A matching trial was started by presenting a standard (ST) stimulus on the center key. A peck to that key immediately produced presentation of comparison (CO) stimuli on the side keys. At this time, additional pecks to the center key had no further effect but a peck to either CO stimuli on the side keys darkened all keys. In addition, a peck to the matching CO produced 3-sec reinforcement while a peck to the non-matching CO produced a 3-sec blackout, in which all chamber illumination was extinguished. After either reinforcement or blackout, a 22.5 sec intertrial interval followed with house light on and all keys dark. Any peck during intertrial interval re-started timing of the intertrial interval.

In matching three STs with two COs on any trial, there are 12 possible stimulus combinations assuring that each stimulus appears equally often as ST and CO and on left and right side keys. Each session consisted of 120 trials, 10 blocks of random permutations of the 12 trial types.

Four pigeons were initially trained to peck and to match with the three line stimuli and three pigeons were initially trained to peck and to match the three color stimuli. Exposure to consistent matching rules continued throughout, but the stimuli to which subjects were exposed were changed for blocks of sessions. Usually, stimuli were changed when accuracies had stabilized at asymptotic high values over five successive sessions according to judgments considering trends and accuracy values from visual inspection of acquisition functions. Discriminative stimuli for session blocks for each pigeon are listed in table 1. Exposures included initial acquisition of line (L) matching or color (C) matching, color-line (C + L) matching in which a particular line was superimposed on a particular color, such that V was on R, H on G, and X on B, and matching of dimensions not acquired initially, L-matching for birds 44, 45, and 46, and C-matching for birds 27, 28, 37, and 38.

TABLE 1

SEQUENCE OF STIMULUS CONDITIONS

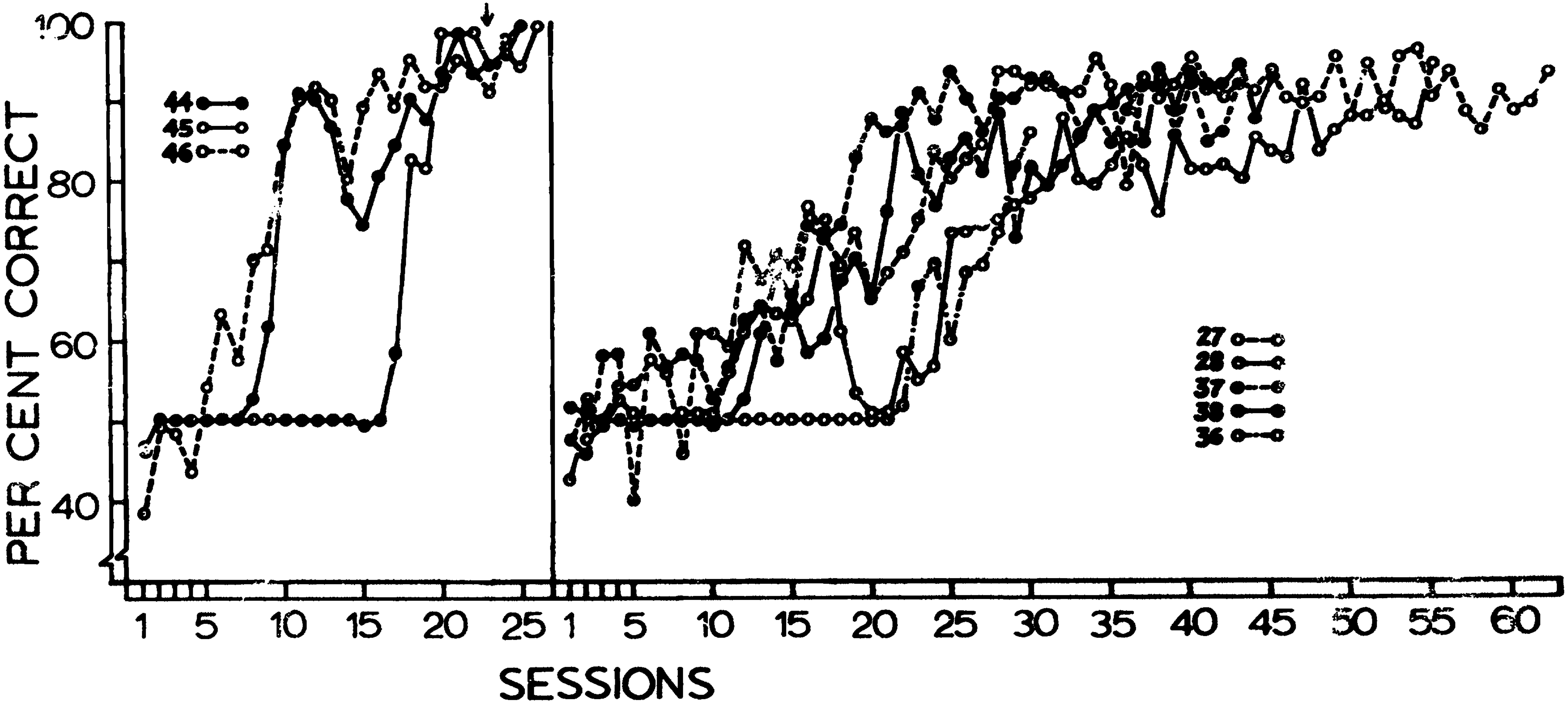
Subjects/Sessions			Subjects/Sessions			Subjects/Sessions			
27	28	- Condition	37	38	- Condition	44	45	46	- Condition
1 to 62	1 to 56	L-Matching	1 to 43	1 to 45	L-Matching	1 to 25	1 to 26	1 to 25	C-Matching
63 to 72	57 to 66	C + L-Matching	44 to 54	46 to 57	C + L-Matching	26 to 39	27 to 40	26 to 42	C + L-Matching
73 to 83	67 to 77	L-Matching	55 to 64	58 to 67	C-Matching	40 to 80	41 to 120	43 to 122	L-Matching
84 to 93	78 to 87	C + L-Matching	65 to 70	68 to 72	C + L-Matching				
94 to 106	88 to 107	C-Matching	71 to 76	73 to 77	L-Matching				

RESULTS AND DISCUSSION

Functions for the acquisition of matching by individual subjects are presented in fig. 1; C-matching subjects are in the left panel and L-matching subjects are in the right panel. The percentage of trials matched correctly are plotted over sessions.

C-matching functions are similar in form to those obtained in comparable experiments with color stimuli (Cumming & Berryman, 1965). In the general form, accuracies are just below the 50% chance level (here about 43% correct), on session 1, and they move rather quickly, within 3-4 sessions after leaving 50%, to accuracies of 85% correct or higher. Individual subjects differ primarily with respect to the length of the period that performance is about chance level. In the present experiment Bird 45 remained an exceptionally long period, 16 sessions, about 50%.

Figure 1. Acquisition of color matching by three subjects in the left panel and acquisition of line matching by five subjects in the right panel. Plotted is the per cent of 120 trials which were correctly discriminated over daily sessions.


PER CENT CORRECT
100
80
60
40
SESSIONS
1
5
10
15
20
25
1
5
10
15
20
25
30
35
40
45
50
55
60
44
45
46
27
28
37
38
36

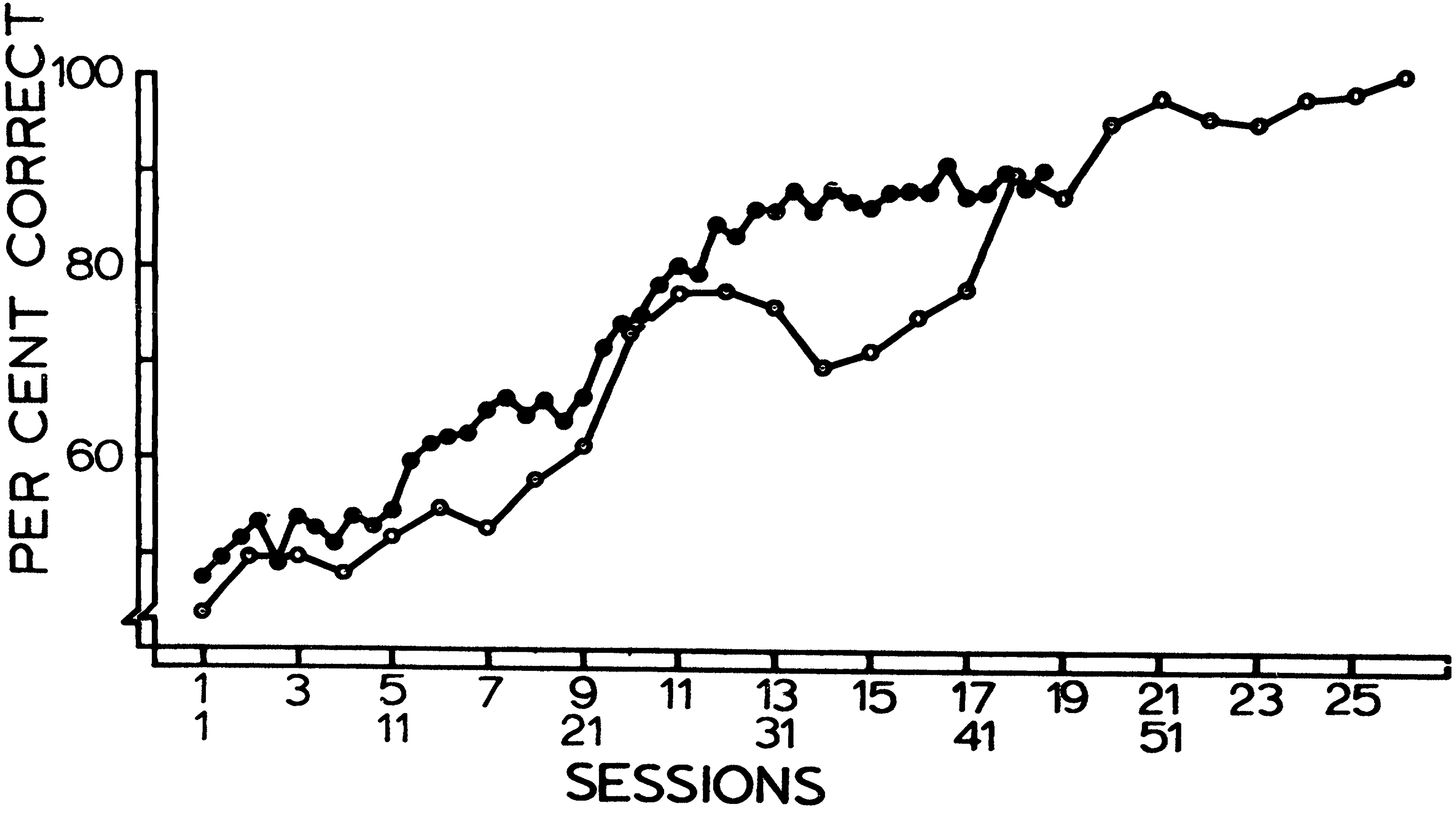
L-matching acquisition functions differed considerably from C-matching acquisition. Session 1 accuracies averaged below chance, about 47% correct, but this was not reliable across pigeons. Further, only two subjects, Bird 36, which was subsequently discarded due to treatment error, and Bird 38 remained at chance level for any appreciable period. In general, the trend to high accuracies occurred at a slower rate than observed in C-matching and it contained many large trend reversals. In addition, C-matching functions stabilized at accuracies about 96% correct while L-matching functions reached an asymptote about 88% correct. These differences are reminiscent of the effect of making C-matching more difficult by a zero-delay procedure in which the response to the ST illuminates the CO stimuli but extinguishes the ST stimulus, so that stimuli are unavailable for simultaneous comparison (Cumming, Berryman, & Cohen, 1965).

The frequent observation of choosing the non-matching CO in session 1, while a small effect, may be due to stimulus-specific extinction characteristic only of early acquisition of the response chain used in this procedure. That is, the initial pecks to ST_V were never reinforced with grain presentation. Thus, when pecking to ST had ceased and the subject was confronted with the choice between CO_V and CO_H, or CO_X, extinction to ST_V would generalize to CO_V and the likelihood of choosing CO_V would be lessened, thereby increasing the likelihood of pecking CO_H or CO_X. Such relationships would likely disappear as responses to CO_H or CO_X, given ST_V, were also extinguished, and a few reinforcements for a matching CO had occurred. This argument depends upon some intial discriminative precision with the line or color dimensions. If lines are generally more difficult discriminanda than colors, for pigeons, the less reliable oddity performance on session 1 by L-matching subjects is understandable.

Differences in discriminative precision with the two stimulus dimensions were reflected in the slopes of acquisition functions and asymptotic accuracies. Carter, Cumming & Eckerman (1968) compared the acquisition of simple and conditional discriminations with two lines and two colors and found a simple transformation of color acquisition functions to match the form of line acquisition functions. In particular all cases of line discriminations required 2.5 times as many sessions to learn as color discriminations.

Mean acquisition functions were calculated from the four L-matching subjects and the three C-matching subjects and these functions are presented in fig. 2; the abscissa scale for C-matching is stretched 2.5 fold that for L-matching. The coicidence is striking considering the small number of subjects compared. Close agreement was obtained with an additive constant, yielding the expression $L = 2.5C + K$ for the relative difficulty of 3-ST matching with L and C stimuli. In the equation, L and C are numbers of sessions with line and color stimuli and K is an additive constant about -1.0.

Figure 2. Average acquisition functions for original L-matching (solid points) and original C-matching (open points). One session on upper abscissa scale is equal to 2.5 sessions on the lower abscissa scale, and scales were adjusted horizontally (see text).


PER CENT CORRECT
100
80
60
1
1
3
5
11
7
9
21
11
13
31
15
17
41
19
21
51
23
25
SESSIONS

The match was on the basis of learning rate once performances changed from a relatively stable period about chance level. The additive constant, in this case, indicates that the stable period around chance level was relatively longer in the case of C-matching.

Figure 3 presents the accuracy functions for the four L-matching subjects during the blocks of transfer sessions. Following stabilization on L-matching, all four subjects received redundant, color and line compound stimuli to match; that is, a color appeared with each line. Two subjects, 27 and 28 then recovered L-matching while 37 and 38 were changed to C-matching. After these assignments, all subjects were again given C + L matching before 27 and 28 received C-matching and 37 and 38 recovered L-matching.

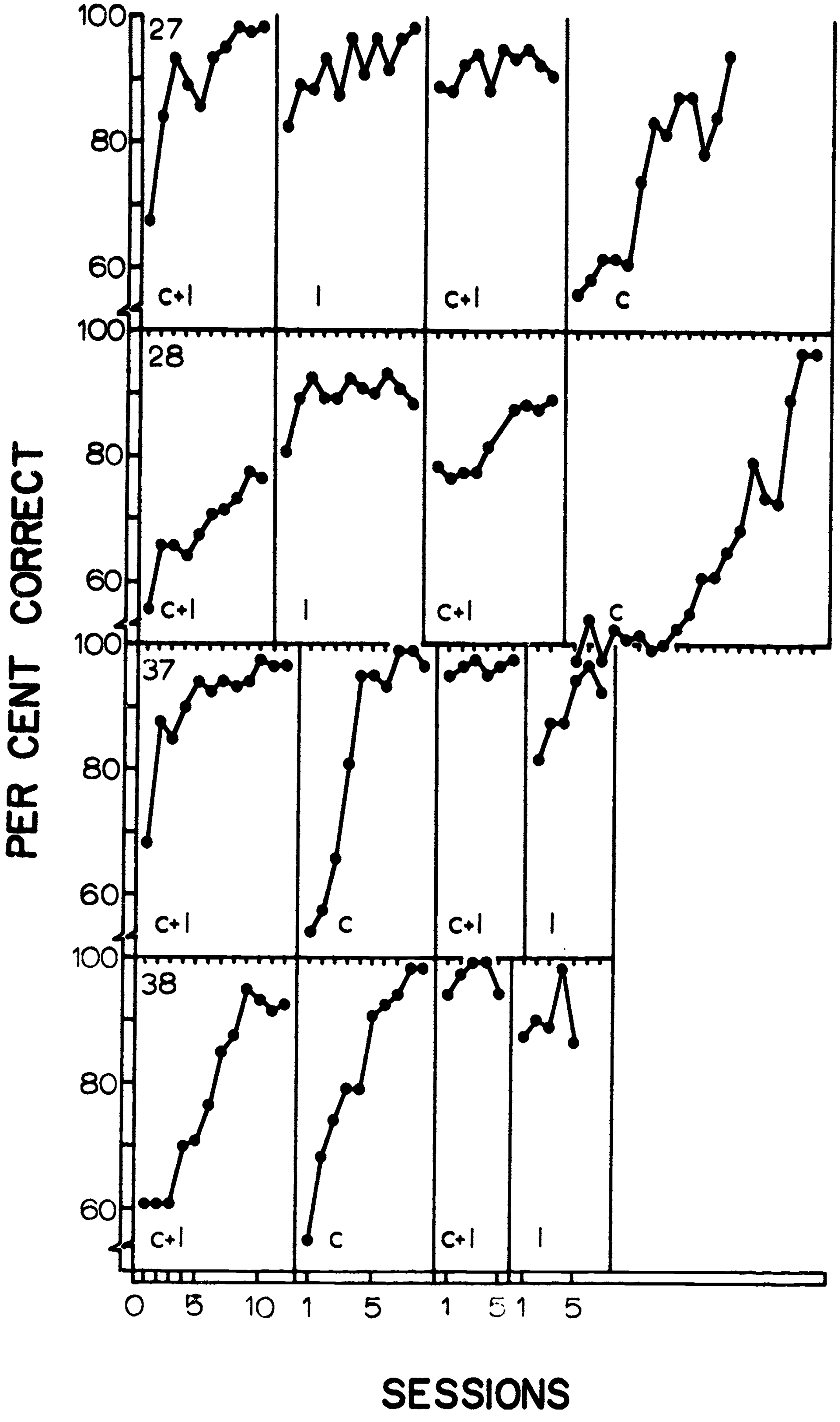
It appeared that all subjects recovered rather quickly any performance which had been previously acquired. Thus, there were no large disruptions of L-matching as seen whenever L-matching was recovered, whether before or after C-matching was acquired. In addition, second exposures to C + L-matching displayed accuracies from the outset which were attained in the initial exposure to C + L-matching

All subjects were disrupted upon initial exposure to C + L-matching although not to chance level; accuracies on the first C + L session ranged from 56-68% correct. Performances returned to high accuracies more quickly than occurred with either original L-matching or C-matching. An exception was Bird 28 which was placed on recovery of L-matching before performance had stablized at high accuracy on C + L. These slopes undoubtedly reflect generalization between lines of L-matching to C + L-matching and it may be speculated that initial disruption was due to decreased line discriminability on "noisy" colored backgrounds, which afforded somewhat less figure-ground contrast.

It is impossible to ascertain whether any color matching was acquired during C + L-matching. However, it may be suggested that those subjects which displayed C + L-matching accuracies greater than 92%, an accuracy level seldom attained in original L-matching, did acquire some color matching precision. Those subjects would be expected to display rapid acquisition of C-matching. Subjects 27, 37, and 38 consistently performed at 92% correct or better during C + L-matching, and they also acquired C-matching more rapidly than those subjects which acquired C-matching initially. At the same time, subject 28 never performed at 90% correct during C + L-matching and C-matching acquisition for that subject was well within the range of acquisition rates for original C-matching subjects.

Having initially acquired line matching appeared, at least, to have no deleterious effect upon the acquisition of matching color discriminations

Figure 3. Performance on transfer phases for four subjects. Lower case c's and l's indicate color and line stimuli, respectively.


PER CENT CORRECT
100
80
60
27
C+I
I
C+I
C
28
C+I
I
C+I
C
37
C+I
C
C+I
I
38
C+I
C
C+I
I
0
5
10
1
5
1
5
1
5
SESSIONS

during the time that colors appear as redundant components of compound, line-color matching stimuli.

Figure 4 presents the performance for the three, original C-matching subjects during their blocks of transfer sessions. After these birds had stabilized on C-matching, all were placed on C + L-matching. Then, all subjects received L-matching. Bird 44 had also completed a second exposure to C + L-matching and a recovery of C-matching at the time of writing.

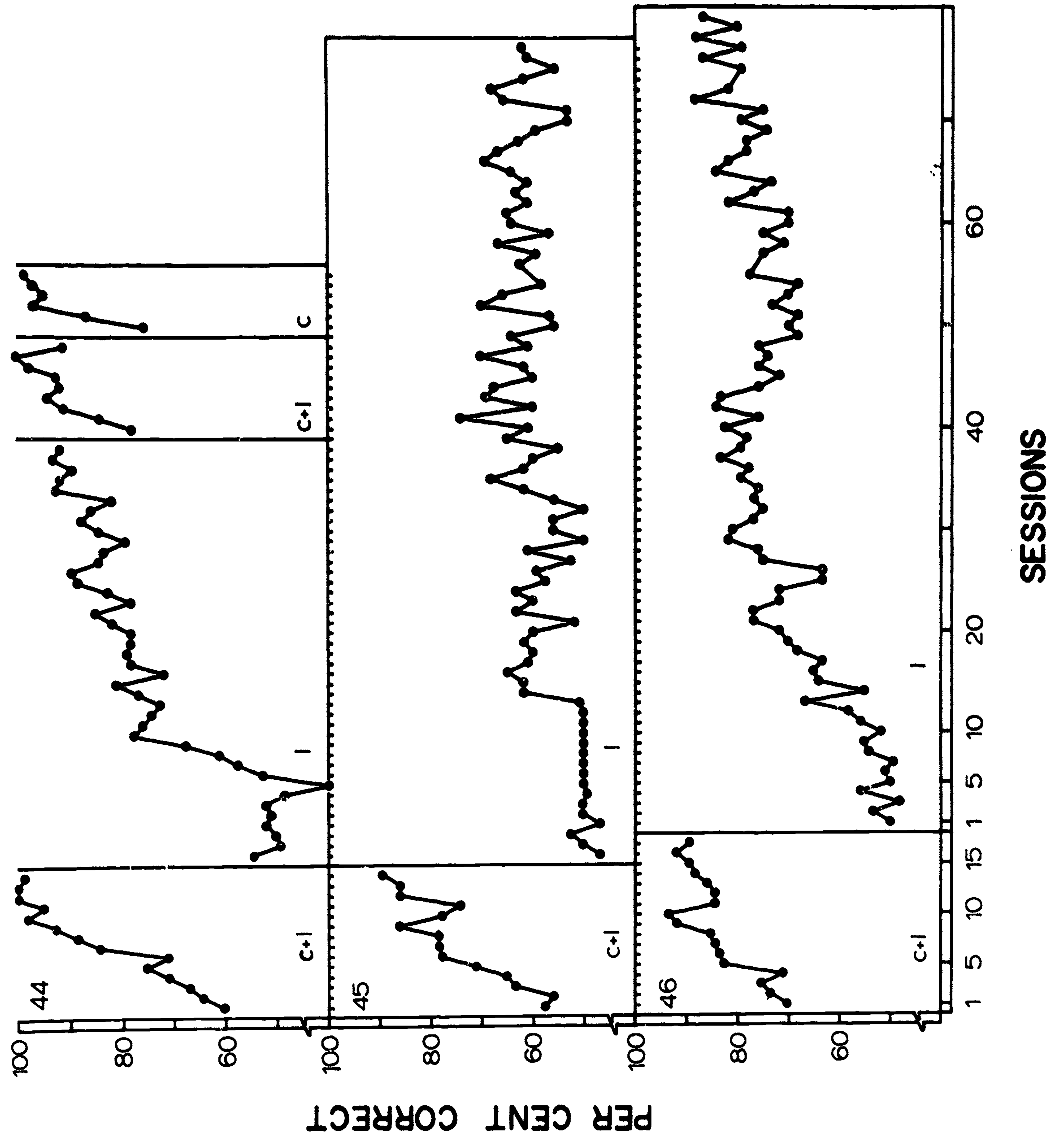
All three subjects stabilized at accuracies above 90% correct on original C-matching and the introduction of C + L-matching disrupted these performances. Accuracies on session 1 with compound stimuli ranged from 58 to 70%. These first day values are about equal to L-matching subjects on their first exposure to compounds, but C + L acquisition functions for 44, 45, and 46 appear more slightly sloped than for L-matching subjects, and they required more sessions before performances were reasonably high and stable. Only 44 attained an accuracy equal to its earlier C-matching asymptote. Again, disruption may be related to color discrimination difficulty with superimposed lines.

L-matching acquisition functions are different for the three subjects. Bird 44 acquired at a rate equal to the most rapid subject receiving L-matching originally and attained asymptotic performance generally characteristic of L-matching. Bird 46 left chance level within the range of sessions shown by original L-matching subjects but once an 80% correct level was attained, further improvement was quite slow and asymptote was about 83% correct. Bird 45 also left chance within the usual range of sessions, but moved to an accuracy about 60% correct and failed to improve over approximately 65 sessions.

On the average, L-matching acquisition following C and C + L-matching is identical, for 25 sessions, to the mean acquisition function from original L-matching subjects. These two mean functions differ in that performance by subject 45 forces a lower asymptotic accuracy level. In the present case, L-matching stabilizes about 78% correct whereas accuracies for original L-matching subjects were stable about 88% correct. Thus, it would also appear here that initial exposure to C and C + L-matching has no deleterious effect upon subsequent acquisition of matching lines alone. Such a statement, however, minimizes the obviously important effects on individual subjects of individual discrimination experiences, and, so, means that a more detailed analysis of experimental conditions is necessary to understand the effects.[1]

It is possible to compare the acquisition of transfers to L and C-matching following original training and C + L-matching in the same manner as was done for original training. There it was found that lines required

Figure 4. Performance on transfer phases for three subjects.


PER CENT CORRECT
100
80
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44
45
46
C+I
I
C
SESSIONS
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2.5 times as long to acquire as colors once performances changed from chance level. While the plot is not presented for the transfer phases, multiplying C-matching sessions by 2.5 produced an acquisition function slope identical to L-matching acquisition. The mean functions differ with respect to asymptotic values, as they did in original training, and with respect to the value of the additive constant needed before sloped portions of the functions overlapped exactly. In this case the expression is $L = 2.5 C + 7$. The K value here indicates that the chance level performance continued for a relatively longer time for L-matching subjects.

These transformations recognize two independent aspects of matching performance: performance about chance level, and learning rates once subjects perform differently from chance level. It seems reasonable to consider the multiplying factor as a coefficient of discriminability between lines and colors for pigeons since Carter, Cumming, & Eckerman (1968) found an identical value, 2.5, for line and color stimuli with pigeons in both simple and conditional discriminations. Then, correcting for discriminability, the learning rates for lines and colors were identical and they did not differ as a function of pretraining experiences. On the other hand, since K values differed, it appears that the principal effect of prior discriminations was on performance resulting in chance level accuracy. In particular, since L-matching in the transfer phase was identical to original L-matching functions by other subjects, the duration of chance level performance was reduced by pretraining for C-matching subjects, on the average.

It is clear from these data that color stimuli acquired incomplete but measurable discriminative control during C + L-matching after original L-matching and that line stimuli acquired on control during C + L-matching after original C-matching. Thus, it appears that pretrained stimuli selectively controlled performances with compound stimuli. The discriminative control which color acquired was exercised on a particular aspect of matching performance.

This finding is similar to that from simple, successive discriminations where selective control was established for pretrained stimuli, before other stimuli were added to form compounds, such that little or no control was exercised by added compound stimulus components (Johnson & Cumming, 1968). However, until a comparison group exposed first to C + L-matching and then shifted to C-matching or to L-matching is available, it is impossible to assure that the selective stimulus control observed here is a result of the uni-dimensional matching pretraining rather than existing stimulus propensities. While it was shown that any existing stimulus propensities were profoundly modified by experimental conditions in the Johnson & Cumming (1968) study, and while there are numerous similarities between simple and conditional discriminations, complete confidence in the conclusions of the present experiment must await further research.

NOTE

[1] The necessary, detailed analysis is a within-session analysis of hypotheses, or stereotyped stimulus-response correlations, which include performances with respect to ST stimuli alone, choices with respect to CO stimuli alone, choices with respect to CO position, particular ST-CO combinations, and consequence-dependent sequential patterns. A computer program for the description of 3-ST matching has been developed but the analysis of results was incomplete at the time of writing.

EFFECT OF IRRELEVANT COLOR UPON THE ACQUISITION OF FORM ODDITY

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ABSTRACT

Thirty-four students, 7-9 yr old, from Gilbert Linkous and Margaret Beeks elementary schools acquired the oddity problem with three geometric forms, a circle, square, and triangle. A series of trials began with a standard, (ST), form to which a response was required to produce a matching comparison, (CO), form and a non-matching CO. A response to the odd CO form produced reinforcement and students continued working trials until a criterion of 12 successive correct trials was met. Students were assigned to one of three groups which differed in the way a second, irrelevant color dimension appeared. In the Identical within-identical between, (IW-IB), group, all forms were always red. In the Identical within-different between, (IW-DB), group, the forms had the same color on any trial but varied randomly among red, green and blue from trial to trial. In the Different within-different between, (DW-DB), group, the color of any ST or CO form on any trial was randomly determined from red, green, and blue. Color was never consistently correlated with reinforcement. The groups were ordered, in terms of number of trials to criterion and numbers of students requiring more than 150 trials to meet criterion, according to the amount of color variation. Suggestions for learning programs considering these effects were made.

Studies of problem solving based on multidimensional stimulus arrays have been frequently concerned with the "attention values" of the various stimulus dimensions, according to their identity and according to whether they were relevant or irrelevant to solution (cf. Trabasso & Bower, 1968; Lovejoy, 1968). Irrelevant stimulus dimensions, unlike the relevant class which is always present and has a fixed relation with solution rules or reinforcement contingencies, are defined by negation. Irrelevant stimuli have an inconsistent or random relation with reinforcement contingencies, and as a logical result, there are many ways for stimuli to be inconsistent with reinforcements. Further, that number is multiplied by problem complexity. Since the attention values of stimuli are used to predict the degree to which irrelevant features distract a student from solution, it is important to describe and understand the effects of types of irrelevancy.

The present experiment used a common problem paradigm, the conditional discrimination. In the conditional discrimination, the appropriateness of choosing one among several comparison (CO) stimuli varies with the value of an additional superordinate, standard (ST) stimulus. Thus, at least two, and usually more ST-CO configurations are defined with at least three stimuli, one ST and two COs, compose any configuration. Usual protocals employ a trial procedure, and so, stimuli may vary both within a trial and between trials. Consequently, additional stimuli may be irrelevant on both within-trial and between-trial bases. The present study examined, in particular, the effect on learning form oddity by children, of an extra, irrelevant color dimension. Color was invariant for one group, varied only between trials for a second group, and varied both between and within trials for a third group. It might be expected, in relation to the amount of color variation, that distraction by color would be minimal in the invariant group, and maximal in the within-trial, between-trial variation group.

METHOD

Subjects: The subjects were 34 students within the ages of 7-9 yr from Gilbert Linkous and Margaret Beeks elementary schools in Blacksburg, Virginia. Preliminary work identified that children about 10 yr and older solved the form oddity problem within 24 trials, indicating that solution and problem management strategies were established behaviors in their repetories. The children were randomly selected from those students arriving on early bus loads at Gilbert Linkous and those students who walked home at Margaret Beeks. In addition, the students were randomly assigned to one of three experimental groups. Eight other students' performances were eliminated from the analysis either because the problem contingencies were reported to them during the experiment, in the cases of five, or because, in the cases of seven, solution occurred within 24 trials.

Apparatus: Stimulus materials were brightly painted, red, blue, or green circles, squares, or triangles. These forms were cut from ¼ in. plywood in a size which could be inscribed in a 2.5 in. square. They were mounted on a black painted ¼ in. plywood base, 3.5 in. square. Three stimuli on each trial covered three muffin tins, each 3 in. in diameter and 1.5 in. deep, which were mounted in a 7.5 in. X 15 in. styrofoam tray. Two stimulus locations to the student's right were divided from one location to the student's left by black tape, .75 in. wide, fixed to the tray surface. A 12 in. X 21 in. styrofoam rectangle was used to screen the students' view of stimuli. Reinforcements of candied, fruit-flavored dry cereal for responses to ST stimuli and reinforcements of one-cent vending machine charms for correct CO responses were placed in corresponding tins and covered by stimulus forms.

Procedure: A form oddity trial began with ST stimulus presentation (in the tray position to the student's left), by placing the screen over CO stimuli. The experimenter waited until the student moved the form aside the muffin tin reservoir. This response was reinforced, every third trial on the average (VR3 schedule), with a candied cereal morsel. When the ST response occurred, the experimenter moved the screen aside to expose simultaneously two CO stimulus forms with the ST. One CO always matched the ST, and one CO (the "odd" CO) never matched the ST, and one response of moving a single CO aside the reservoir was allowed on any trial. If the student moved the odd CO, a reinforcement charm was made available, and the experimenter said, "Very good, let's try it again," after which the screen was placed to obstruct the student's view of the tray, and forms for the next trial were positioned during the intertrial interval. Moving the matching CO form aside revealed an empty reservoir, led the experimenter to say, "Let's try it again," and to obstruct the student's view during intertrial interval. The intertrial interval varied around a mean duration of 13 sec.

With three STs, and two COs on any trial, there are 12 possible trial combinations assuring that each form appears equally often as ST and CO and in the two CO positions. Runs with any student consisted of blocks of random permutations of the 12 trial types determined for 120 trials. Runs continued with any student until a criterion of 12 successive correct trials was attained. If 120 trials were exceeded, the program of 120 trials was repeated.

When any student exceeded 150 trials before reaching criterion, two procedural variations were employed. In one variation, the correction procedure, trials on which an error occurred were rerun until the student chose the correct CO. In the second variation, the student was merely asked, "What do you see?" After the ST response resulted in exposing all three trial stimuli. On occasion both variations were employed simultaneously. Details on each procedure are discussed with the results.

Each student was invited to sit at a table in the experimental room, assigned to an experimental group, asked for name, age, and grade, and guided through the first two trials. On the first trial, the student was asked to move the ST stimulus aside, and then to choose to move one of the two CO stimuli. On the second trial, the student was asked only to choose one of the two CO stimuli. After the second trial no further unspecified talking was initiated by the experimenter and student talking was discouraged with polite but terse answers to questions with an injunction to continue working.

Students were assigned to one of three experimental groups. In the Identical within-identical between (IW-IB) group, oddity choices were reinforced with respect to constantly red forms. In the Identical within-different between (IW-DB) group, the single ST and two CO forms were the same color on any trial but varied randomly among red, blue, and green, from trial to trial. The color of each ST and CO stimulus on any trial in the Different within-different between (DW-DB) group was randomly determined with the restriction that each color appeared equally often in each position over 120 trials.

Students were run for a varying number of sessions, ranging from 1 to 4, each for varying durations, although maximum session duration was 45 min. The schedule of sessions depended upon a number of eventualities, but occurred insofar as possible on successive school days for any student. In general, session schedules were reasonably regular and the maximum period between a first and fourth session was six calendar days.

RESULTS AND DISCUSSION

Figure 1 presents individual performance functions for the IW-IB group, fig. 2 presents the functions for the DW-DB group, and fig. 3 presents performance functions. The functions are plots of net correct responses over trials. That is, each correct trial is indicated by an upward diagonal deflection and each error trial is indicated by a downward diagonal deflection. So oddity performance is indicated by long, uninterrupted upward deflection as seen in the criterion performance which terminates each function. The reverse of oddity, matching, would be indicated by a long, uninterrupted downward deflection, while performance around chance level would be indicated by an average slope of zero. No other conditional rules are directly indicated by this plot.

No general form appears in the functions. That is, there are periods of average zero slopes and of both low positive and negative slopes scattered throughout at different points. All students, except students J. Ba. and [illegible]. F. from group DW-DB who were terminated after approximately 280 trials, display the terminal criterion performance.

Figure 1. Performance functions for student in group IW-IB learning oddity with respect to forms. Each correct trial is indicated by an upward diagonal deflection and each error by a downward diagonal deflection. The CP and SRR procedures are indicated by a solid and dashed line, respectively, intersecting the functions.

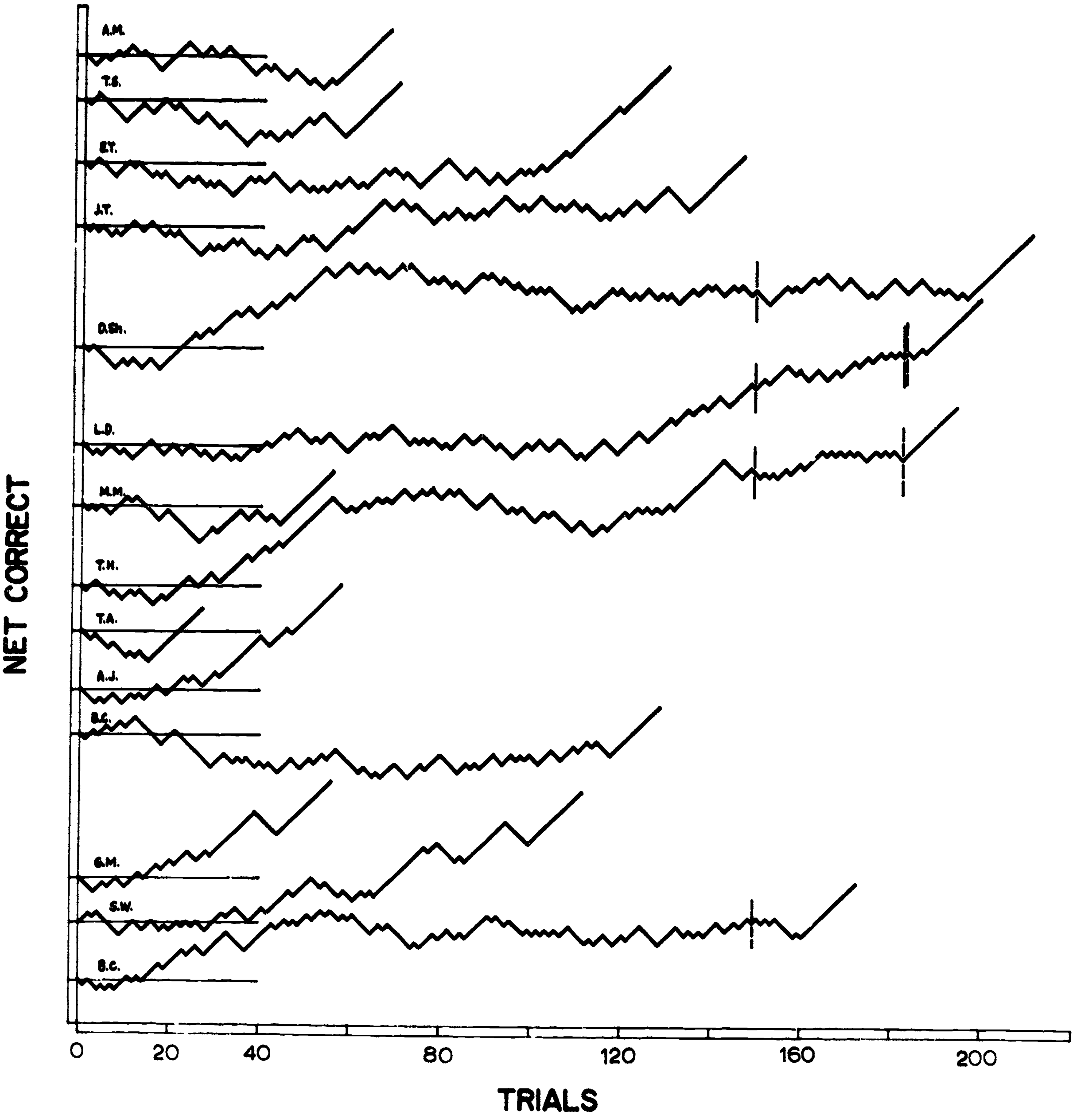

A.M.
T.S.
E.T.
J.T.
D.Sh.
L.D.
M.M.
T.H.
T.A.
A.J.
B.C.
G.M.
S.W.
B.C.
NET CORRECT
0
20
40
80
120
160
200
TRIALS

Figure 2. Performance functions for students in group IW-DB learning oddity with respect to forms while color varied between trials. Each correct trial is indicated by an upward diagonal deflection and each error by a downward diagonal deflection. The CP and SRR procedures are indicated by a solid and dashed line, respectively, intersecting the functions.

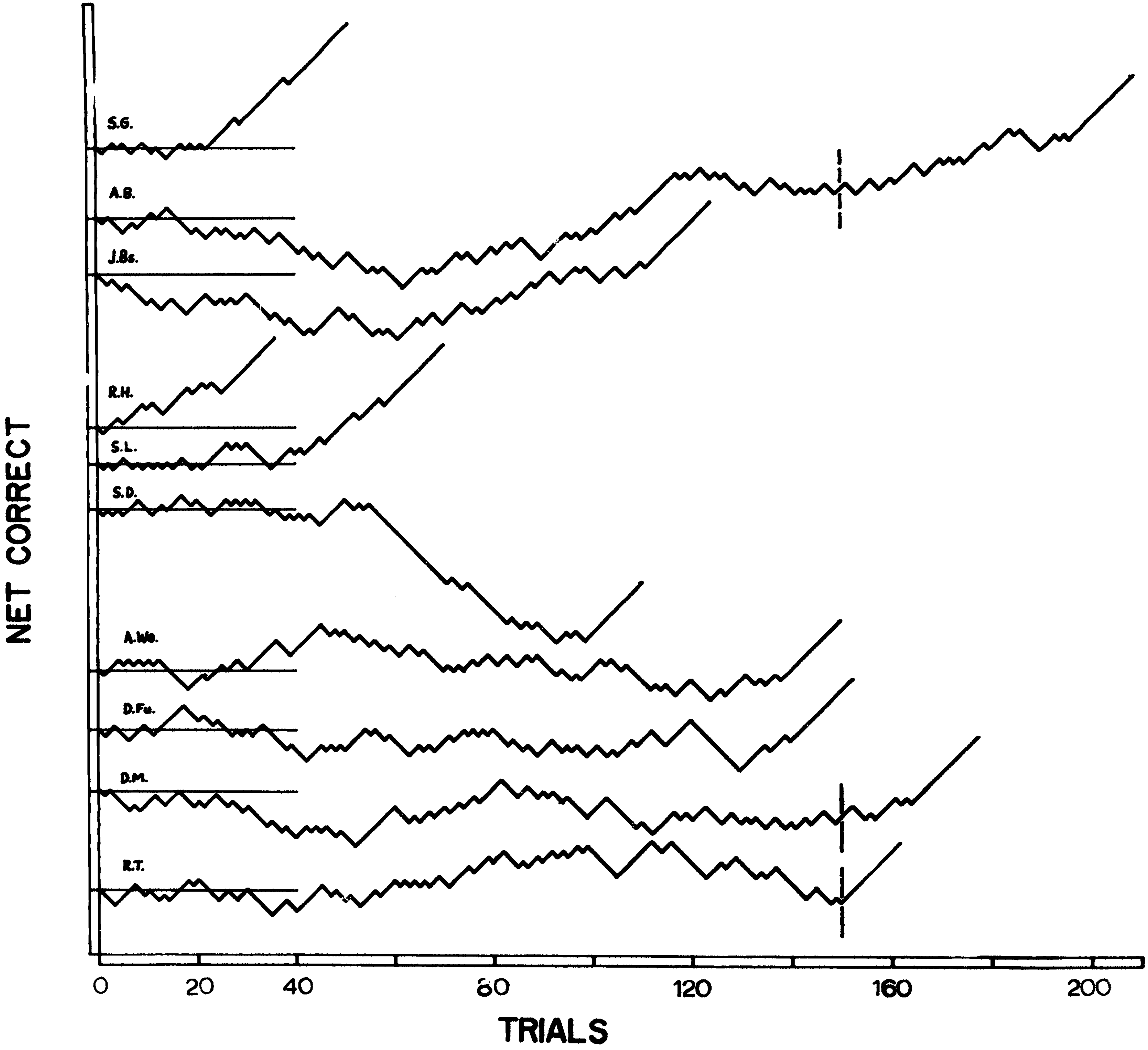
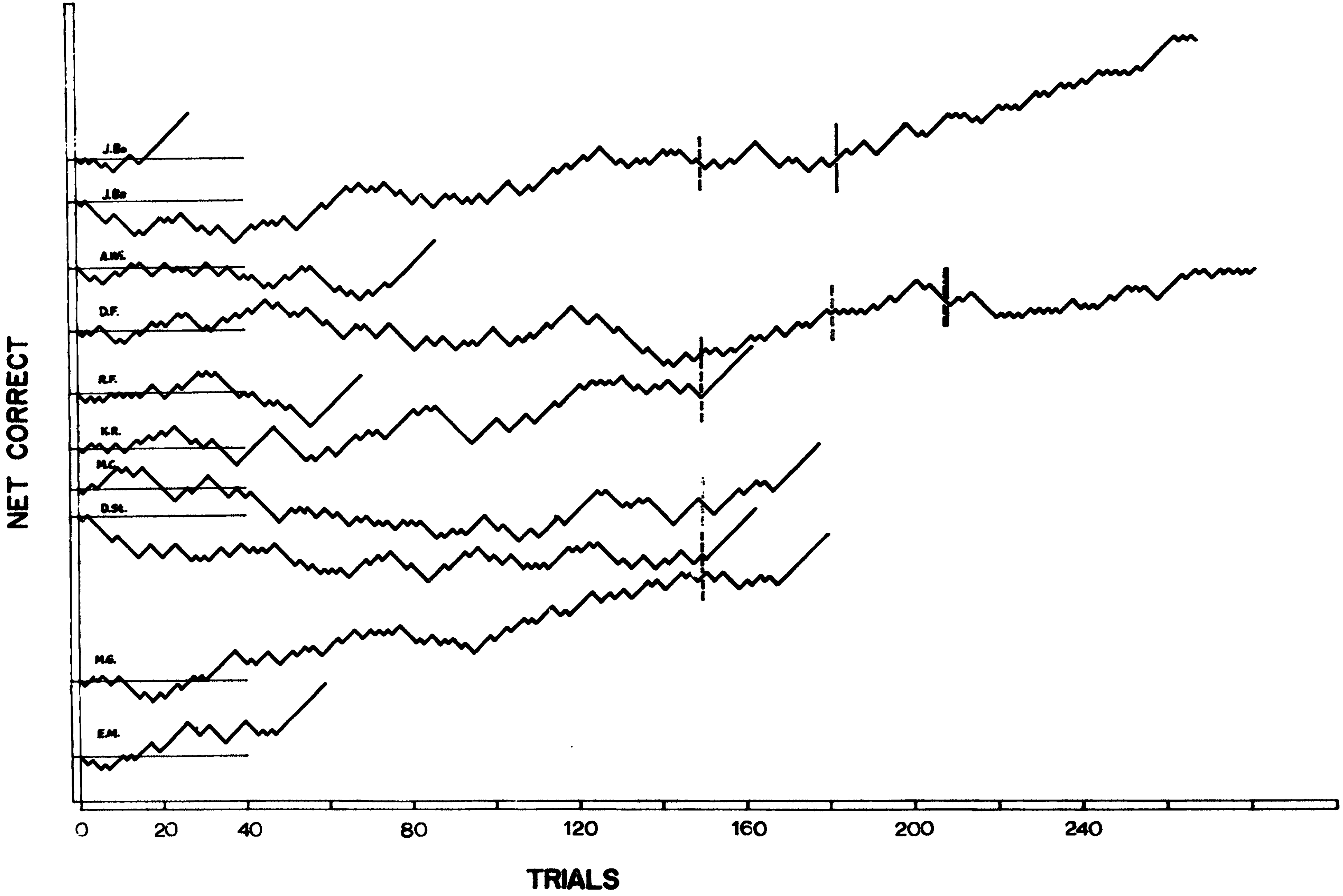

S.G.
A.B.
J.Bs.
R.H.
S.L.
S.D.
A.We.
D.Fu.
D.M.
R.T.
NET CORRECT
0
20
40
80
120
160
200
TRIALS

Figure 3. Performance functions for students in group DW-DB learning oddity with respect to forms as color varied both within and between trials. Each correct trial is indicated by an upward diagonal deflection and each error by a downward diagonal deflection. The CP and SRR procedures are indicated by a solid and dashed line, respectively, intersecting the functions.


J.Be
J.Ba
A.W.
D.F.
R.F.
K.R.
M.C.
D.St.
M.G.
E.M.
NET CORRECT
0
20
40
80
120
160
200
240
TRIALS

Several students appeared to adopt a matching strategy in that errors were made for 6 or more consecutive trials at some point in the course of training. For example, students M. M. and B. C. in fig. 1 apparently matched over several successive trials. Such a strategy might at least indicate that students were performing on the basis of conditional discrimination rule, which is to say that the ST stimulus was controlling CO choices to some extent. It may also indicate some transfer of previous experience with a matching paradigm. If matching was a precurrent strategy, more rapid acquisition might have been expected with matching than with either oddity or another conditional discrimination rule.

Taking the assumption that matching on 6 or more consecutive trials represents a clear strategy, the number of subjects adopting a matching strategy may be compared with the number who adopt an equivalent oddity strategy prior to criterion performance. In addition, the trial number on which a series of trials indicating a consistent strategy began may be compared across subjects. If matching was a common, precurrent strategy more students should have adopted a matching strategy than oddity, and matching trials should have appeared earlier in training than oddity. Of 16 students who displayed only one of the two strategies, 6 students showed a matching strategy and 10 showed oddity, at some point. Only student S. D., in group IW-DB in fig. 2, matched on a number of trials equal to the oddity criterion. Of 13 students who displayed both strategies at some time, 7 students displayed matching prior to oddity. Differences in either measure are insignificant. These data may also indicate that fewer than 12 consecutive trials with any strategy whether consistently reinforced (as for oddity) or inconsistently reinforced or non-reinforced (as for matching or any other conditional rule), is an insufficient number to reliably identify any strategy in children of these ages. This observation would suggest a relative persistance with any response rule for these children. Trabasso and Bower (1968) however, found it reasonable to assume shifting among problem hypotheses after a single error trial in simple discriminations with adults. Unfortunately, without a detailed analysis of several stragegies, it is impossible to compare other strategies in the same manner.

Several students exceeded 150 trials before criterion and were subject to either or both the correction procedure, (CP), and the stimulus report request, (SRR). One student in DW-DB, two students in IW-IB, and three students in IW-IB were placed on CP at trial 151. CP is indicated in figs. 1, 2, and 3 by a solid line intersecting the performance functions at trial 151. Six students in DW-DB and one student in each of IW-IB and IW-DB were placed on SRR. SRR is indicated by a dashed line intersecting performance functions at trial 151. Five of the eight students on SRR began their criterion run within 20 trials of SRR introduction, while two of six students on CP began criterion run within 20 trials. Three of these latter CP students were subsequently exposed to SRR, either in addition to CP or as its replacement. Two of these three began the criterion run within 6 trials. One student who began trial 151 with SRR was subsequently exposed to CP but failed to acquire.

The SRR procedure apparently produced a moderate acceleration of acquisition. It is interesting that student reports, by this time, contained form words but no color words. These findings possibly suggest an important role for interverbal correspondences in mediating choices.

Experimental groups were ordered with respect to acquisition rate on several measures. The mean numbers of trials to criterion were: IW-IB -- 116.0; IW-DB -- 124.2; and DW-DB -- 140.9. The order was changed slightly by using a maximum of 150 trials for those functions in excess, and counting trials to the criterion run. The mean values were: IW-IB -- 104.7; IW-DB -- 94.9; and DW-DB -- 107.2. The first two groups exchanged ordinal position and the difference between these and DW-D3 was attenuated with this adjustment, which would produce some regression around the grand mean. The number of students exceeding 150 trials in each group was: IW-IB -- 4; IW-DB -- 5; DW-DB -- 6, a measure which restores the ordering.

Thus, it would appear on the basis of both sensitive and gross measures from a relatively small sample over a 3-yr age range, that both types of color variation produced differences in learning form oddity.

Further replications to establish the reliability of the effects are certainly indicated. The apparent difference due to between-trial color variation is particularly interesting and suggests sequential dependencies on color from trial to trial. Another study using a simple discrimination could more precisely measure the magnitude of this effect.

There are also possible variations within an irrelevant dimension according to the ST and CO stimulus functions. That is, it would be useful to determine whether distraction differs when an irrelevant stimulus varies only for ST or for CO stimuli.

More to the point of the present program, it is clear that some stimulus variations, unspecified by reinforcement contingencies, do exercise control over behavior. It would be important to obtain discriminative control by one dimension in such a way that irrelevant stimuli appear, as if to preserve the richness of natural discrimination problems, but have never in the student's experimental history, distracted the student from solving the relevent problem. In another direction, learning programs might take advantage of the control exercised by one dimension to encourage learning with respect to a second dimension before the first dimension takes on the irrelevant relationship it has in natural conditions.

Note

[1] The authors want to acknowledge and to express their gratitude to Mrs. Charlotte Beamer, Principal at Margaret Beeks, and to Mr. R. S. Wheeler, Principal at Gilbert Linkous Elementary School. Both principals provided the important physical space and cooperative spirit necessary to the study.

SUCCESSIVE CONDITIONAL DISCRIMINATION REVERSALS

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ABSTRACT

Two White King cock pigeons were exposed to cued, successive conditional discrimination reversals of matching and its reverse, oddity. Both subjects showed some type of improvement over reversals and one subject, 33, was disrupted less by, and required fewer sessions to attain criterion accuracy for, each successive reversal By the third exposure to oddity, it was clear that a stimulus which cued matching exercised powerful control over rule-guided behavior.

When subjects are exposed to several successive discrimination reversals, in that following training to select one of two stimulus alternatives to criterion accuracy, the subject is trained to select the other alternative, they typically improve the rates of attaining criterion (Mackintosh, Mc Gonigle, Holgate, & Vanderver, 1968). Sutherland (1964) has proposed a selective attention theory to explain and describe such discrimination reversal improvements.

However, Bitterman (cf. 1969) has presented data from fish in which no reversal improvement occurs, and he has suggested that parametric variation of an attention theory does not appreciate the difference. Behavioral differences between two classes of animals obscure the explanation for effects in either class. Besides the possibilities of changing a theory's parameter values and presuming structural differences (which Bitterman prefers), differences may be attributed to differences in experimental conditions for the two classes or to inadequate sampling of species populations; both are alternatives which have clouded comparative behavior research for years and which have unlimited possibilities. Resolution requires a closer analysis of the discrimination reversal behavior so that a behavior theory can consider all important events or that structural responsibility may be specified.

Apparently all experiments studying several successive discrimination reversals have employed simple discrimination contingencies. This is unfortunate since the cues mediating reversal and the conditions maintaining behavior are confounded in the reinforcement contingencies. More suitable would be a situation in which these factors were separate and in which it would be possible to control the variables which themselves control reversal. If these variables are stimuli, or have an isomorphic relation with stimuli, successive discrimination reversals become a special case of conditional discriminations in which the significance of a comparison (CO) stimulus is not invariant, sometimes reinforced and sometimes unreinforced, but depends upon the standard (ST) stimulus. In matching-to-sample, for example, given a red ST, a response to a green CO goes unreinforced while given a green ST, a green CO does predict reinforcement. Matching is, therefore, an explicitly cued, trial-by-trial discrimination reversal.

If the ST stimulus can be said to control reversals with respect to CO stimuli, it is interesting to attempt the control of ST functions with a still superordinate stimulus. In practice, this reasoning comes to cueing the reversal (or some other shift in rules) of a conditional discrimination. The study of functional relations about the ST and superordinate stimuli should return understanding of discrimination reversal behavior. The present experiment begins such a program to see whether conditional discrimination reversals may be abstracted with an explicit stimulus. The conditional discrimination employed here is 3-ST matching of line stimuli; its reverse is oddity. Except for the initial acquisition, matching is indicated by a green background and oddity is indicated by a red background upon which the line ST stimuli are superimposed.

METHOD

Subjects: Two White King cock pigeons, 5-6 yr old, were run daily provided weights were within 15 g of 80% free-feeding weights. Food rations were given daily as needed to maintain 80% weights.

Apparatus: A standard operant chamber for pigeons (LVE 1519C) was outfitted with three pecking keys, each 2.54 cm in diameter, aligned horizontally 8.3 cm apart and 15.2 cm from the floor. A 5.1 cm square hole provided access to an automatic grain magazine at which grain reinforcement (50% kaffir, 40% vetch, 10% hempseed) was occasionally available for 3-sec periods. This hole was below the center key 9.5 cm from the floor. A speaker mounted on the left side of this panel provided white masking noise (86 db re: SPL) and a fan provided ventilation continuously. A 3-W lamp located above the center key near the chamber ceiling provided general, houselight illumination.

Light stimuli which transilluminated pecking keys were provided by IEE display units with 313 X lamps. Stimuli consisted of three white line forms approximately .47 cm wide and 2.5 cm long on dark achromatic backgrounds. They were: a vertical line (V), a horizontal line (H), and a cross with perpendicular arms oriented 45° from horizontal (X). In addition, center key lines appeared on either a red (R) or green (B) background light which filled the key area.

Automatic programming and recording apparatus was housed in a separate room from that housing experimental chambers.

Procedure: Both pigeons were fed their daily rations at the grain magazine location on three successive days. Then, they were trained to peck at V, H, and X and given an equal number of reinforcements for pecks to each, by a modified "autoshaping" procedure (Brown & Jenkins, 1968). Then both birds received simple successive discrimination training between all pairs of V, H, and X such that all stimuli served equally as the positive and negative stimulus of the pair.

With the completion of the simple discrimination training, both subjects were placed on matching with respect to the three lines. A matching trial started by illuminating the center key with a line (ST). A center-key peck immediately illuminated CO lines on the two side keys; further center-key responses had no effect. A response to the matching CO produced 3-sec reinforcement and a peck to the non-matching CO produced 3-sec blackout, in which all chamber illumination was extinguished. A response to either CO immediately darkened all keys. After either reinforcement or blackout, a 22.5-sec intertrial interval was timed during which the houselight was on, all keys were dark, and responses re-started timing of the interval, after which the next trial started.

In the conditional discrimination with three STs and two COs an any trial, there are 12 possible trial combinations assuring that each line appears equally often as ST and CO and on left and right side keys. Each session consisted of 120 trials, 10 blocks of random permutations of the 12 trial types.

Oddity sessions were run identically to matching except that discrimination rules were reversed so that responding to the non-matching CO produced reinforcement, and responding to the matching CO produced blackout. That is, if matching rules are stated: if ST_V, go CO_V, if ST_H, go CO_H, and if ST_X, go CO_X, then oddity rules are: if ST_V, don't go CO_V, or if ST_V, go CO_H, or go CO_X, etc.

Both birds began matching lines on the standard procedure but after 6 sessions for Bird 33 and 13 sessions for Bird 32 they were placed on a correction procedure to obtain accuracies suitable for a technical demonstration. In the correction procedure any trial on which an error is made is repeated until the subject responds correctly and then the next programmed trial was presented. The correction procedure was in effect for 17 sessions for 33 and 20 sessions for 32 after which the standard, non-correction procedure was used throughout.

When matching performance had stabilized, subjects were reversed to oddity and when this performance was stable and accurate, the contingencies were again reversed. At the time of writing, 33 had completed five reversals and 32 had completed three reversals. In general, subjects were kept on either matching or oddity until five successive sessions at stable, high accuracies were observed. Judgments of stability were by visual inspection of acquisition functions and considered trends and performance variability. This is a loosely defined criterion, but reversals were made only in the confidence that performance asymptotes were reached.

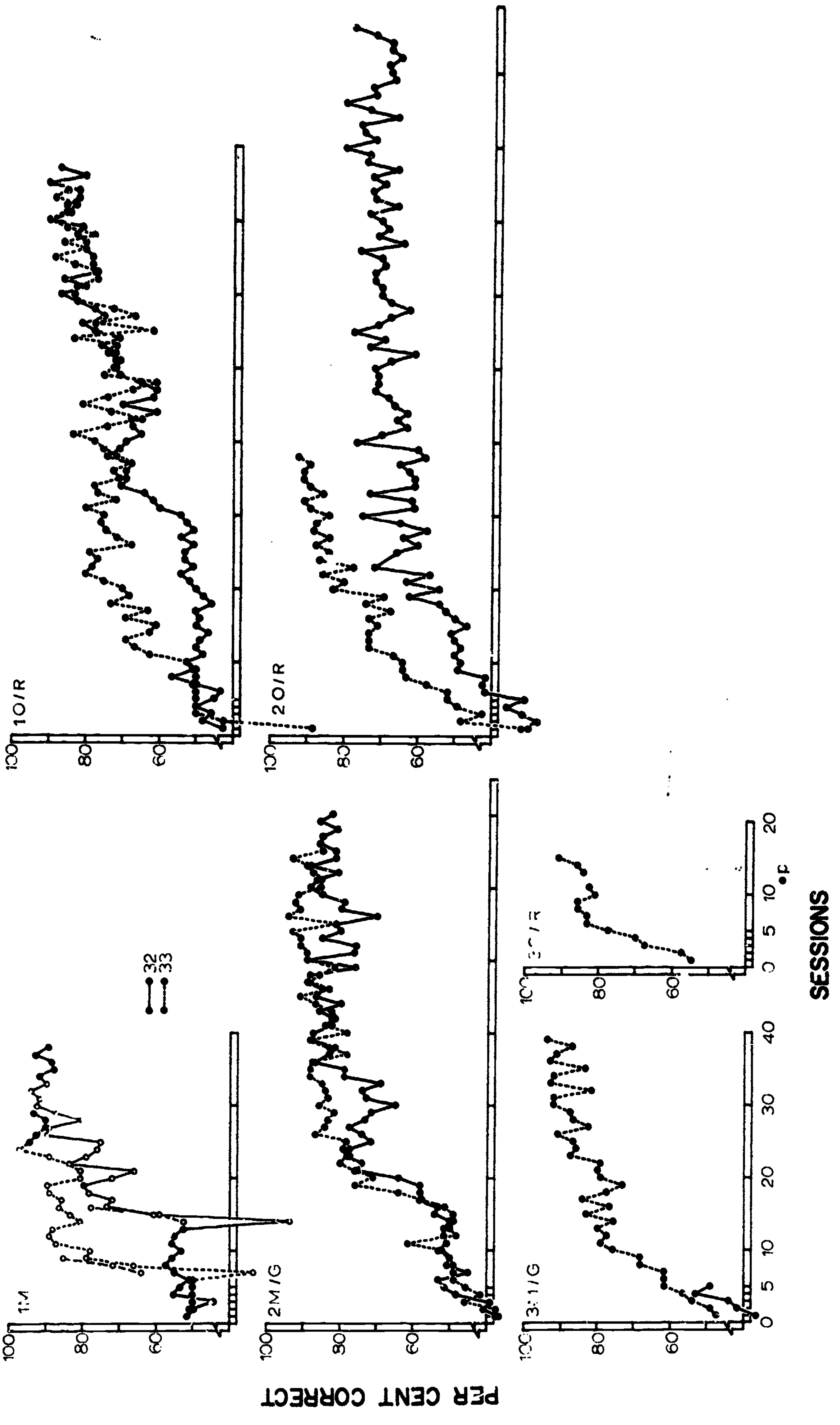
On all reversals after initial matching acquisition, matching sessions were indicated by a green background for ST stimuli and oddity sessions were indicated by a red background for STs. Thus, the rules were consistent: if ST_{V+G}, go CO_V, if ST_{V+R}, don't go CO_V, etc.

Other procedural variations are described in discussing the results.

RESULTS AND DISCUSSION

Figure 1 presents the performance of both subjects over the series of conditional discrimination reversals. Data plotted are the per cent of session trials correct across sessions, which are separated according to

Figure 1. Performance on a series of matching to oddity reversals. Numerals indicate the ordinal position of procedures, M or O indicate matching or oddity, and G or R indicates superordinate stimulus coincident with STs. Open points in 1M signify a correction procedure and a point in 30/R indicates a probe session discussed in text.


PER CENT CORRECT
1M
2M/G
3M/G
1O/R
2O/R
3O/R
32
33
100
80
60
0
5
10
20
30
40
SESSIONS

discrimination rules. These conditions are indicated by M and O, for matching and oddity, and a numeral, which indicates the ordinal position of each procedure. In addition, G and R indicate the presences of a green and red background coincident with the ST stimulus.

Initial acquisition, 1M, was interrupted for the correction procedure while both subjects were performing about 50% chance level. Open points indicate those sessions for which the correction procedure was in effect. When the correction procedure was introduced the per cent of total trials correct (including correction trials) dropped. Data from the first three correction sessions, were also calculated in terms of per cent of the 120 program trials (excluding correction trials) correct, and connected by large dashes, they show that accuracy on these days was underestimated, meaning that a small number of trials were corrected many times. After the first correction session there were only small differences between the two scores.

In this case, the correction procedure produced a rapid change to more accurate performance as compared to the usual acquisition rate of line matching seen in "Multidimensional conditional stimulus control: Some data on two-dimensional matching-to-sample." Further, if the two 1M functions had been adjusted so that the first sessions of correction were equal, they would overlap nearly exactly.

Performanced dropped below chance for both birds on the first session of 1O/R. Thereafter, oddity acquisition showed the overall relative slow improvement rate typical of oddity acquisition (Berryman, Cumming, Cohen, & Johnson, 1965). The two subjects differed, however, in the rate of leaving chance level performance, although both display comparable asymptotes about 83% within the same number of sessions.

Over successive reversals a number of trends appeared. For 33, the effect of reversals on first reversal-session accuracy became less severe until accuracy on session 1 of 3O/R was above chance level. This subject also began to reach criterion within fewer sessions over successive reversals. Bird 32 did not show equivalent improvement although this bird had not completed as many reversals. During 2O/R, this subject left chance level performance sooner than during 1O/R, but once an approximate 70% correct level was attained, there was no further improvement in 80 more sessions. Curiously, both birds acquired at like rates with matching but were different with oddity. At the time of writing Bird 32 was similar to 33 beyond the few points plotted in 3M/G.

Thus, there is no simple description of improvement over successive reversals. The differences between the subjects so far observed raise a number of possibilities for interpretation. Two interesting accounts of the relatively poor performances by 32 which demand more detailed data, would be (1) generalization or confusion between ST and CO functions for any particular line, as, perhaps, explicity produced by the reversals, and (2) different performance strategies.

During 30/R for Bird 33, control exercised by the superordinate color stimulus was probed. On session 12 of 30, the oddity contingencies were maintained but the green (matching) stimulus, instead of R (oddity), was presented with line ST stimuli. If superordinate color exercised any control at all, some disruption of high accurate performance would be expected. Bird 33 was at 85% correct on preceding days, but on the session 12 probe day, accuracy dropped to 30% correct oddity, meaning 70% matching performance, in the face of maintained oddity rules! This significant level of matching performance indicated powerful control by the green superordinate stimulus for this subject. One can well anticipate sessions in which superordinate control would be accurate on a trial-by-trial basis.

Thus, since realization of superordinate control of factors controlling reversal behavior is immanent, better understanding of reversal behavior will be possible.

GENERALIZATION GRADIENTS AROUND S$^{\Delta}$ FOLLOWING ERRORLESS DISCRIMINATION LEARNING[1]

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ABSTRACT

Four pigeons were shaped by an errorless procedure to discriminate a blank key as S^{D} and key lit by 576 nm as S$^{\Delta}$, and then discrimination training continued on a MULT RI 1 nim, EXT schedule before generalization tests were conducted on wavelength and intensity dimensions. Generalization gradients along wavelength were flat at zero response rate while intensity generalization gradients were sloped to high response rates at low intensities. Implications for defining generalization of inhibition were drawn.

Brown & Jenkins (1967) demonstrated conditions of operant discrimination learning with pigeons in which S^{Δ} controlled behavior (R_2) which was antagonistic to the S^{D}-controlled key-peck (R_1). It is in this sense that Jenkins (1965) identified inhibitory stimulus control, and based upon this idea, Jenkins suggested a way to observe generalization of inhibitory stimulus control. The rationale requires choosing S^{Δ} and S^{D} from different stimulus dimensions and observing changes in R_2 for variations in the S^{Δ} dimension as in a standard generalization test. Decreases in R_2 strength occur with a decrease in strength of the behaviors $\bar{R}_1 \cup \bar{R}_2$ and is thus observed as an increase in R_1.

Terrace (1966) suggested that S^{Δ} exercised inhibitory stimulus control only when R_1 occurs and goes unreinforced in the presence of S^{Δ} (errors). He found generalization gradients around S^{Δ} were flat at zero response rate when discriminations were acquired without errors, while gradients about S^{Δ} following discrimination learning with errors took the more familiar, shallow U-shape, showing increases in R_1 (Jenkins & Harrison, 1962; Honig, Boneau, Burstein & Pennypacker, 1963).

The present experiment replicated the essential conditions of the Terrace experiment in that pigeons were trained to discriminate without errors a dark, achromatic key as S^{D} and a key lit by 576 nm as S^{Δ}. Successive generalization tests were subsequently conducted along two dimensions, wavelength and intensity, of S^{Δ}.

METHOD

Subjects: Four naive, White King cock pigeons were maintained at 80% of their free-feeding weights and were run daily provided that running weights were within 15 gm of 80% weights.

Apparatus: A standard operant conditioning chamber (LVE 1519C) contained a single pecking key, 2.54 cm in diameter centered on a front panel 25.4 cm from the floor. A 5.1 cm square hole, centered below the key 12.5 cm from the floor, provided access to an automatic grain magazine where reinforcement grain (50% kaffir, 40% vetch, 10% hempseed) was occasionally made available for 3-sec periods as reinforcement.

A 3 w lamp houselight above the key provided general illumination, a speaker presented masking white noise at 86 db re:SPL and a fan provided chamber ventilation.

Light was collimated and passed through Wratten narrow-band monochromatic filters and neutral density filters to transilluminate the pecking key. Five narrow-band filters had fundamental wavelengths of 490, 538, 576, 605, and 678 nm; halfwidths were about 50 nm.

Procedure: All birds were fed their daily ration at the chamber magazine location for three successive days; this was followed on three successive days with magazine training during which the magazine was presented occasionally for 60 3-sec periods. Each subject was then shaped by approximation methods to peck the key.

Shaping was carried out to a dark, unlit key with the houselight on. When the tenth reinforcement was delivered, the subjects were placed directly on a random-interval 1 min schedule of reinforcement (Farmer, 1963; T = 3.75 sec, p = 1/16) for 90 sec. At the end of this 90 sec a 5-sec blackout, during which all chamber illumination was extinguished and responses were never reinforced, occurred and was followed by a 2-sec presentation of 576 nm light at 0.76 log ml, with houselight on. During the lighted key periods responses were never reinforced. Thus, the unlit key was S^D and the 576 nm lit key was S^Δ.

From this point S^D and S^Δ periods were alternated with intervening 5-sec blackouts. S^D periods varied between 30-90 sec and S^Δ periods gradually increased in duration according to the series 2, 2, 5, 10, 15, 20, 25, 30 until S^D was presented at 30 sec duration for three S^Δ periods. During the second training session S^D again varied between 30-90 sec and S began at 5 sec and increased to 10 sec and then in 10-sec increments to 60 sec over successive S^Δ periods until 5 S^Δ periods of 60 sec were presented. In the third session S^D duration was stable at 60 sec and S^Δ was presented initially at 30 sec and then at 60 sec when S^D and S^Δ periods alternated in a quasi-random sequence assuring equal exposure time to each.

There followed 7 standard discrimination training sessions in which 60-sec S^D and S^Δ components alternated in a quasi-random sequence with an intervening 5-sec blackout until each had appeared for 20 presentations. During S^D responses were reinforced on a RI 60 sec schedule. On the eleventh day a generalization test was conducted in extinction by presenting the five wavelengths and the unlit key for 50-sec periods with intervening 10-sec blackouts, in mixed orders, until each stimulus was presented 10 times.

All subjects were then returned to discrimination training for 3 sessions. After this, a generalization test was conducted in extinction by presenting five intensities of the 576 nm light in addition to the unlit key. This test was identical in all other respects to wavelength generalization tests. Here, subjects 47 and 50 were exposed to five values over a wide range of intensities including -1.64, -1.24, -.64, 0.16, and 0.76 log ml, while subjects 48 and 49 were exposed to a narrow range of intensities including -1.54, -1.24, -.94, -.64, and -.44 log ml.

RESULTS

Birds 47, 48, and 49 were considered to have learned the discrimination without errors and responses to S^{Δ} made by these subjects in the first and all discrimination sessions, respectively, was 47 - 6,6 48 - 1,14 and 49 - 0,1. In fact, most errors after the initial session by these birds appeared to be "spill-over" from responding during blackout. Bird 50, on the other hand, responded regularly to S^{Δ} at the low rate about 8 responses per hr after making 9 errors in the initial training session.

The first generalization test varied wavelength of the lighted key and the obtained gradients are presented in Fig. 1. Gradients for the three

Figure 1 about here

birds which acquired the discrimination without errors are flat at essentially a zero response rate; virtually all responding occurred to the blank key. Bird 50 responded to other stimuli than the blank key, but, paradoxically nearly all that responding occurred to the S^{Δ} value, 576 nm. Bird 50's test responding would be understandable had errors been maintained in a superstitious fashion during training, but no such behavior was apparent in the records.

In the second generalization test, intensity of the 576 nm light was varied within two ranges for two groups of birds and the obtained gradients are presented in Fig. 2. All gradients were about equally, steeply sloped

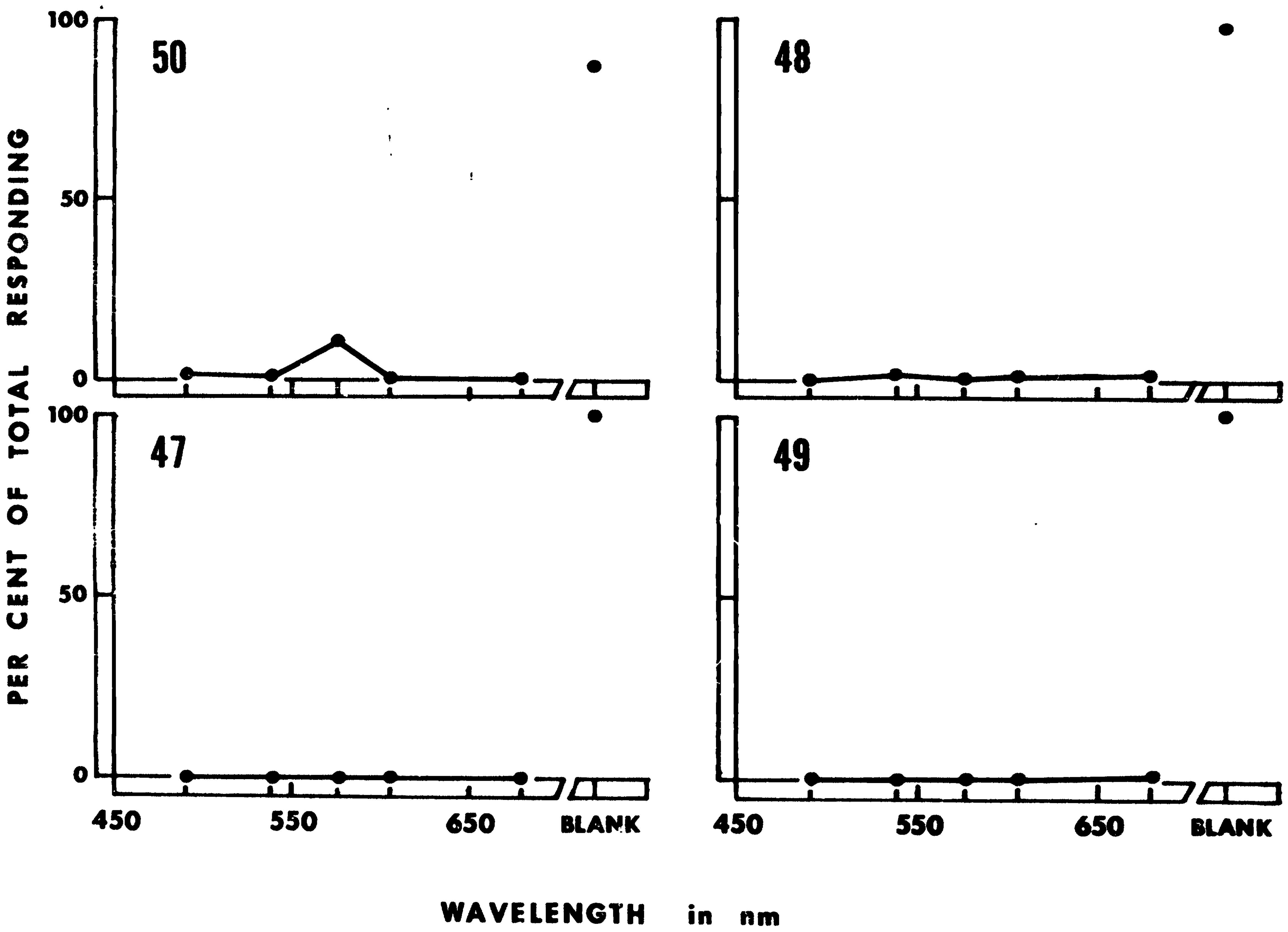
Figure 2 about here

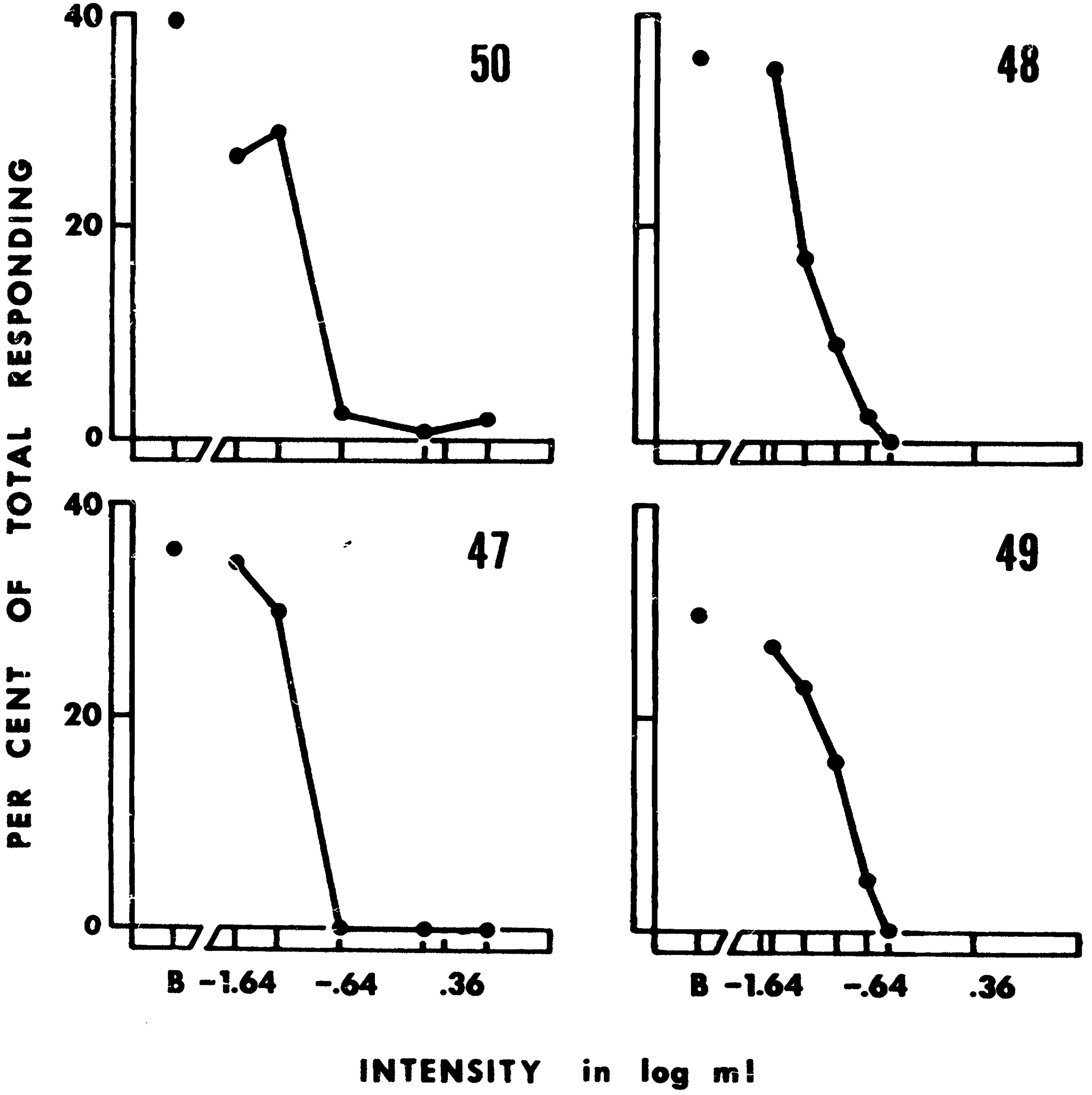
from high rates at low intensities, similar to the blank-key rates, to essentially zero rate at higher intensities. In fact, slopes compare well with intensity gradients obtained about S^{D} by Blough (1959). Gradients appear no different depending upon the wide or narrow range of intensity values. Further, there is no apparent relation to number of errors committed during discrimination training.

FIGURE CAPTIONS

Fig. 1. Generalization gradients across wavelength for four individual pigeons. Blank indicates the blank key, positive training stimulus condition.

Fig. 2. Generalization gradients across intensity for four individual pigeons. B indicates the blank key, positive training stimulus.


PER CENT OF TOTAL RESPONDING
100
50
0
50
48
47
49
450
550
650
BLANK
WAVELENGTH in nm


50
48
47
49
40
20
0
PER CENT OF TOTAL RESPONDING
B -1.64 -.64 .36
INTENSITY in log ml

DISCUSSION

If Jenkins' (1965) definition of generalization of inhibition were followed strictly, one would conclude, as Terrace (1966) did, that no inhibitory stimulus control was exercised by wavelength for those subjects which acquired without errors, since those generalization gradients were flat at zero response rate. Bird 30 is anomalous; while responding occurred (that is, the tendency for R_2 decreased) these data do not seem to form an inhibitory gradient since that responding occurred primarily to the S^{Δ} value.

There are several possible descriptions for the intensity generalization gradients. First it may be said that the intensity dimension did exercise inhibitory stimulus control since R_2 strength clearly decreased away from S^{Δ}, seen as an increase in R_1.

A second thought would simply disallow these gradients as unambiguous evidence since the test violates the requirement that test stimuli be equidistant from S^D. However, one may argue that the absence of energy is on no physical dimension with the presence of any energy, parallel to Jenkins' argument that "absence of a tone or white noise are stimuli without a sensible dimension of tonal frequency [p. 57]." Any argument otherwise derives from the behavioral observation in pigeon and man that no light energy is generalized to certain low values of light energy present, with the response, "I do not see the light." But this evidence has the same form as the present data, and for that matter, as all experiments purporting to display gradients of inhibitory stimulus control, namely that a response occurs with some strength in different stimulus situations.

Thus, the third possibility is anticipated, that excitatory stimulus control, or generalization around S^D was observed here. The fact that the experimenter could match the blank key with a luminance about -1.45 log ml and that intensity gradients changed most drastically near that value makes this description seem more reasonable. This is a sensible conclusion only with data, as in the present case for intensity generalization gradients, where generalization of a response to values on different physical dimensions is well established, as by psychophysical data.

Describing any increase of R_1 strength in "inhibitory" generalization gradients instead as generalization around S^D is clearly more parsimonious. R_2 is never directly observed unless all stimuli except S^{Δ} set the occasion for R_1, e.g., Brown & Jenkins (1967), Johnson, Kinder, & Scarboro (1969), otherwise absence of R_1 may mean the presence of either R_2 or $\overline{R_1 \cup R_2}$. Maintenance of the excitatory-inhibitory gradient distinction in Jenkins' sense derives from identifying different physical specifications for a white vertical line and a field of 490 nm light (as in Terrace, 1966) or unlit, black vertical line on a white lit background and a fully white lit key (as in Honig, et al., 1963). But behavioral equivalence is an empirical matter and Lashley (1938) ovserved generalization of R_1 between many stimulus pairs of different physical specifications. If orthogonal physical dimensions guaranteed stimulus control independence, it would be impossible to understand how Jenkins & Harrison (1960), who first found flat generalization gradients for pigeons across tonal frequency, later found peaked gradients across frequency following discrimination training between tone and no tone! Generalization of inhibition must be observed in the same circumstances in which inhibition is unequivocally identified.

The foregoing suggests that errorless discrimination training makes S^D control quite independent of S^Δ dimensions except those on which generalization may have been previously trained, such as brightness, by natural or experimental conditions.

REFERENCES

Berryman, R., Cumming, W. W., Cohen, L. R., & Johnson, D. F. Acquisition and transfer of simultaneous oddity. Psychological Reports, 1965, 17, 767-775.

Bitterman, M. E. Habit-reversal and probability learning: Rats, birds and fish. Part 1. In R. M. Gilbert & N. S. Sutherland (Eds.) Animal discrimination learning. London: Academic Press, 1969.

Blough, D. S. Generalization and preference on a stimulus intensity continuum. Journal of Experimental Analysis of Behavior, 1959, 2, 307-317.

Brown, P. L. & Jenkins, H. M. Conditioned inhibition and excitation in operant discrimination learning. Journal of Experimental Psychology, 1967, 75, 255-266.

Brown, P. L. & Jenkins, H. M. Auto-shaping of the pigeon's key-peck. Journal of Experimental Analysis of Behavior, 1968, 11, 1-8.

Butter, C. M. Stimulus generalization along one and two dimensions in pigeons. Journal of Experimental Psychology, 1963, 65, 339-346.

Carter, D. E., Cumming, W. W. & Eckerman, D. A. Some properties of the complex discriminated operant: Is the matching relation a unique case of the conditional discrimination? Eastern Psychological Association, Philadelphia, 1968.

Catania, A. C. Behavioral contrast in a multiple and concurrent schedule of reinforcement. Journal of Experimental Analysis of Behavior, 1961, 4, 335-342.

Catania, A. C. Independence of concurrent responding maintained by interval schedules of reinforcement. Journal of Experimental Analysis of Behavior, 1962, 5, 175-184.

Catania, A. C. Concurrent operants. In W. K. Honig (Ed.) Operant behavior: Areas of research and application. New York: Appleton-Century-Crofts, 1966.

Coate, W. B. & Gardner, R. A. Sources of transfer from original training to discrimination reversal. Journal of Experimental Psychology, 1965, 70, 94-97.

Cumming, W. W. & Berryman, R. The complex discriminated operant: Studies of matching-to-sample and related problems. In D. Mostofsky (Ed.) Stimulus generalization. Stanford: Stanford University Press, 1965.

Farmer, J. Properties of behavior under random interval reinforcement schedules. Journal of Experimental Analysis of Behavior, 1963, 6, 607-616.

Findley, J. D. Preference and switching under concurrent scheduling. *Journal of Experimental Analysis of Behavior*, 1958, *1*, 123-144.

Goodwin, W. R. & Lawrence, D. H. The functional independence of two discrimination habits associated with a constant stimulus situation. *Journal of Comparative and Physiological Psychology*, 1955, *48*, 437-443.

Honig, W. K., Boneau, C. A., Burnstein, K. R. & Pennypacker, H. S. Positive and negative generalization gradients obtained after equivalent training conditions. *Journal of Comparative and Physiological Psychology*, 1963, *56*, 111-116.

Jenkins, H. M. Generalization gradients and the concept of inhibition, In D. Mostoksky (Ed.), *Stimulus generalization*. Stanford: Stanford University Press, 1965.

Jenkins, H. M. & Harrison, R. H. Effect of discrimination training on auditory generalization. *Journal of Experimental Psychology*, 1960, 59, 246-253.

Jenkins, H. M. & Harrison, R. H. Generalization gradients of inhibition following auditory discrimination learning. *Journal of Experimental Analysis of Behavior*, 1962, *5*, 435-441.

Johnson, D. F. Determiners of selective stimulus control in the pigeon. *Journal of Comparative and Physiological Psychology*, 1970, *70*, 298-307.

Johnson, D. F. & Cumming, W. W. Some determiners of attention. *Journal of Experimental Analysis of Behavior*, 1968, *11*, 157-166.

Johnson, D. F., Kinder, B. N. & Scarboro, G. N. Determination of selective stimulus control by part of a compound S^{Δ}. *Psychonomic Science*, 1969, *17*, 7-8.

Krechevsky, I. "Hypotheses" in rats. *Psychological Review*, 1932, *39*, 516-532.

Lashley, K. S. The mechanism of vision: XV. Preliminary studies of the rat's capacity for detail vision. *Journal of General Psychology*, 1938, *18*, 123-193.

Lashley, K. S. An examination of the "continuity theory" as applied to discrimination learning. *Journal of General Psychology*, 1942, *26*, 241-265.

Lawrence, D. H. Acquired distinctiveness of cues: I Transfer between discriminations on the basis of familiarity with the stimulus. *Journal of Experimental Psychology*, 1949, *39*, 770-784.

Lawrence D. H. The nature of a stimulus: Some relationships between learning and perception. In S. Koch (Ed.) Psychology: A study of a science. Vol. 5. New York: McGraw-Hill, 1963

Lin, S. W. & Zeiler, M. D. Independence of concurrent discriminations. Journal of Comparative and Physiological Psychology, 1968, 65, 61-65.

Lovejoy, E. Attention in discrimination learning. San Francisco: Holden-Day, 1968.

Mackintosh, N. J. The effect of attention on the slope of generalization gradients. British Journal of Psychology, 1965, 56, 87-93. (a).

Mackintosh, N. J. Selective attention in animal discrimination learning. Psychological Bulletin, 1965, 64, 124-150. (b).

Mackintosh, N. J., McGonigle, B., Holgate, V. & Vanderver, V. Factors underlying improvement in serial reversal learning. Canadian Journal of Psychology, 1968, 22, 85-95.

Miles, C. M. & Jenkins, H. M. Overshadowing and blocking in discriminative operant conditioning. Psychonomic Society, 1965.

Reynolds, G. S. Behavioral contrast. Journal of Experimental Analysis of Behavior, 1961, 4, 57-71.

Schoenfeld, W. N. & Cumming, W. W. Behavior and perception. In S. Koch (Ed.), Psychology: A study of a science. Vol. 5. New York: McGraw-Hill, 1963.

Spence, K. W. The differential response in animals to stimuli varying within a single dimension. Psychological Review, 1937, 44, 430-444.

Sutherland, N. S. Stimulus analysing mechanisms. In Proceedings of a symposium on the mechanization of thought processes, Vol. II, London, H.M.S.O., 1959.

Sutherland, N. S. Visual discrimination in animals. British Medical Bulletin, 1964, 20, 54-59.

Terrace, H. S. Discrimination learning with and without "errors." Journal of Experimental Analysis of Behavior, 1963, 6, 1-27.

Terrace, H. S. Discrimination learning and inhibition. Science, 1966, 154, 1677-1680.

Terrace, H. S. Stimulus control. In W. K. Honig (Ed.) Operant behavior: Areas of research and application. New York: Appleton-Century-Crofts, 1966.

Trabasso, T. & Bower, G. H. Attention in learning: Theory and research. New York: Wiley, 1968.

Touchette, P. E. Transfer of stimulus control: Measuring the moment of transfer. Presented at Eastern Psychological Association convention, Atlantic City, N. J., 1970.

Wyckoff, L. B., Jr. The role of observing responses in discrimination learning. Psychological Review, 1952, 59, 431-442.