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Instructional and trial durations in conditional discrimination

Cooper, Lee David, Ph.D.

The University of North Carolina at Greensboro, 1988

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INSTRUCTIONAL AND TRIAL DURATIONS IN CONDITIONAL DISCRIMINATION

by

Lee D. Cooper

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the Faculty of the Graduate School at
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Approved by

Dissertation Adviser

APPROVAL PAGE

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Cooper, Lee D., Ph.D. Instructional and Trial Durations in Conditional Discrimination. (1987) Directed by Dr. Richard L. Shull, Pp. 75.

Pigeons acquired a conditional discrimination in an autoshaping procedure in which a color (instructional) stimulus signalled which positional (trial) stimulus would be followed by food. The design employed temporal parameters which allowed different ratios of the instructional stimulus (I) duration to the trial stimulus (T) duration keeping the absolute duration of the instructional stimulus constant, and different absolute durations of the instructional stimulus keeping the ratio of the instructional to trial stimulus durations constant. These manipulations were studied at two cycle durations, permitting the examination of the cycle to trial ratios as well. Six groups of birds were studied at instructional stimulus durations of either 60-, 30-, or 6-sec and trial durations of either 12-, 6-, or 3-sec. Groups were exposed to either a 60- or 30-sec cycle duration. The results showed that the larger the duration of the instructional stimulus relative to the trial stimulus, the greater the rate and final level of acquisition, implicating the ratio of I/T as a controlling variable. There was one exception to this general finding, a group exposed to the simultaneous presentation of the instructional and trial stimuli. A simple model of instructional control based on temporal factors was presented.

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CHAPTER I

INTRODUCTION

A common feature of respondent- and operant-conditioning procedures is that a conditioned response is brought under stimulus control, where stimulus control refers to the extent to which an antecedent stimulus determines the occurrence of a response. Skinner (1969) proposed the antecedent stimulus-response-consequence relation as the fundamental unit of analysis of operant behavior. Table 1A diagrams a stimulus-response-consequence relation, usually referred to as a three-term contingency. The schematic shows that in the presence of a particular environmental event, (S1), a particular form of behavior, (R1), is followed by a particular consequence (C1). For example, a laboratory pigeon's peck can produce food, but only if the key has a vertical line on it. In contrast, when a horizontal line is on the key, the two-term contingency does not exist; pecking the key will not produce grain. Thus, a two-term, response-consequence relation holds true only in the presence of the vertical line. Stimulus control is demonstrated when the organism responds more rapidly in the presence than in the absence of a stimulus property (i. e., vertical line) associated with reinforcement. In behavior-analytic terms, the two-term relation is placed under *discriminative control* and the antecedent stimulus correlated with differential responding is referred to as a *discriminative stimulus.*

Additionally, stimulus-control functions involving three-term contingencies can themselves be placed under stimulus control. The upper half of Table 1B shows that the three-term relation is now correlated with a fourth element, S3. Suppose a pigeon has two keys available, a vertical line on one and a horizontal line on the other, but now we introduce a third key, which is sometimes red (S3) and

Table 1

Contingency Diagrams

S = Stimulus; R = Response; C = Consequence

A) The Three-Term Contingency (Discrimination)

S1 (vertical line) - - - -(R1 (keypeck) - - > C1 (food))

S2 (horizontal line) - - (R1 (keypeck) - - > C2 (no food))

B) The Four-Term Contingency (Conditional Discrimination)

S1 (vertical line) - -(R1 (keypeck) - - > C1 (food))
S3 (red) { }
S2 (horizontal line) - - (R1 (keypeck) - -> C2 (no food))
- -
S1 (vertical line) - -(R1 (keypeck) - - > C2 (no food))
S4 (green) { }
S2 (horizontal line) - - (R1 (keypeck) - - > C1 (food))

sometimes green (S4). The pigeon's peck to the vertical line, but not to the horizontal line, can produce food, but only if the new key is red. Conversely, pecks to the horizontal line, rather than sometimes green (S4). The pigeon's peck to the vertical line, but not to the horizontal line, can produce food, but only if the new key is red. Conversely, pecks to the horizontal line, rather than pecks to the vertical line, are reinforced when a green keylight is illuminated. Because the color of the third key changes, this four-term relation is a contingency; the three-term relation depends on the color of the center key. In such situations the three-term contingency relation has been placed under *conditional* control, and the four-term contingency is referred to as a *conditional discrimination.*

The function of a discriminative stimulus corresponds to stimuli colloquially called signals or cues. They do not elicit responses in the manner of unconditioned and conditioned stimuli in Pavlovian conditioning. Rather they set the occasion on which responses have consequences. There are, however, two alternative views of the functional role of the conditional stimulus (red or green in the above example) within a conditional discrimination. The first may be described as a configurational view: the conditional stimulus and discriminative stimulus form a stimulus compound that functions as an unitary discriminative stimulus for accurate conditional discrimination performance. This approach holds that all aspects of the stimulus situation, or configuration, can come to exert some control over the discriminative response. According to the configurational view, the four-term contingency shown in Table 1B could be reduced to a three-term contingency by specifying the discriminative stimuli as "red-plus-vertical line" and "green-plus-horizontal line". If this were so, there would be no need for behavioral analysis to expand beyond the three-term unit of analysis in order to account for conditional discriminations. A second view is an instructional account in which the discriminative stimuli may be referred to as figure, and all other aspects of the configuration as ground. This view holds that a particular stimulus (the sign) may exhibit an "instructional" function which momentarily strengthens, or activates, a particular three-term contingency. At a descriptive level, subjects learn instructions of the form "if S1 then S2 predicts reinforcement". For example, the subject may learn the instruction "if red-then-peck-vertical line" as represented on the top line of Table1B. It should be noted that the term "instruction" refers here only to the empirically demonstrable relationship between the presentation of a critical feature of the ground (the sign) and differential responding to a particular discriminative stimulus. More broadly, this account suggests that stimuli are capable of acquiring a stimulus control function different from discriminative control, thus requiring behavioral analysis to extend its units of analysis to, at least, a four-term contingency in describing the environment's ability to activate particular three-term units of stimulus control. The answer to the question of which view is correct lies in examining some of the detailed properties of behavior in the conditional discrimination situation.

The structure of the four-term unit suggests that conditional and discriminative control may be different stimulus functions (cf. Michael, 1982). A discriminative stimulus (S1) is identified in reference to a differential response (R1). That is, the vertical line is said to exert discriminative control if its presence and absence are correlated with changes in behavior due to past differential reinforcement of that behavior- the subject learns to peck the key in the presence of the vertical line, but not in its absence. A conditional stimulus is said to exert conditional control if its presence and absence are correlated with a change in the control exerted by other stimuli. For example, only in the presence of red, but not green, does an increase in responding occur to the vertical line. Consequently, the conditional stimulus (S3) may need no additional differential behavior for its identification. Several researchers have suggested, however, that the conditional stimulus serves a discriminative function for a "mediating" or "coding" response (e. g., Schoenfeld and

Cumming, 1963). According to this view, the response to the discriminative stimuli is conditional on the occurrence of a covert response (see Eckerman, 1970) controlled by the conditional stimulus. In any case (mediating response or not), the current view is that conditional stimuli may not control response-reinforcer relations directly, but may actually determine the control which other stimuli exert over response-reinforcer relations.

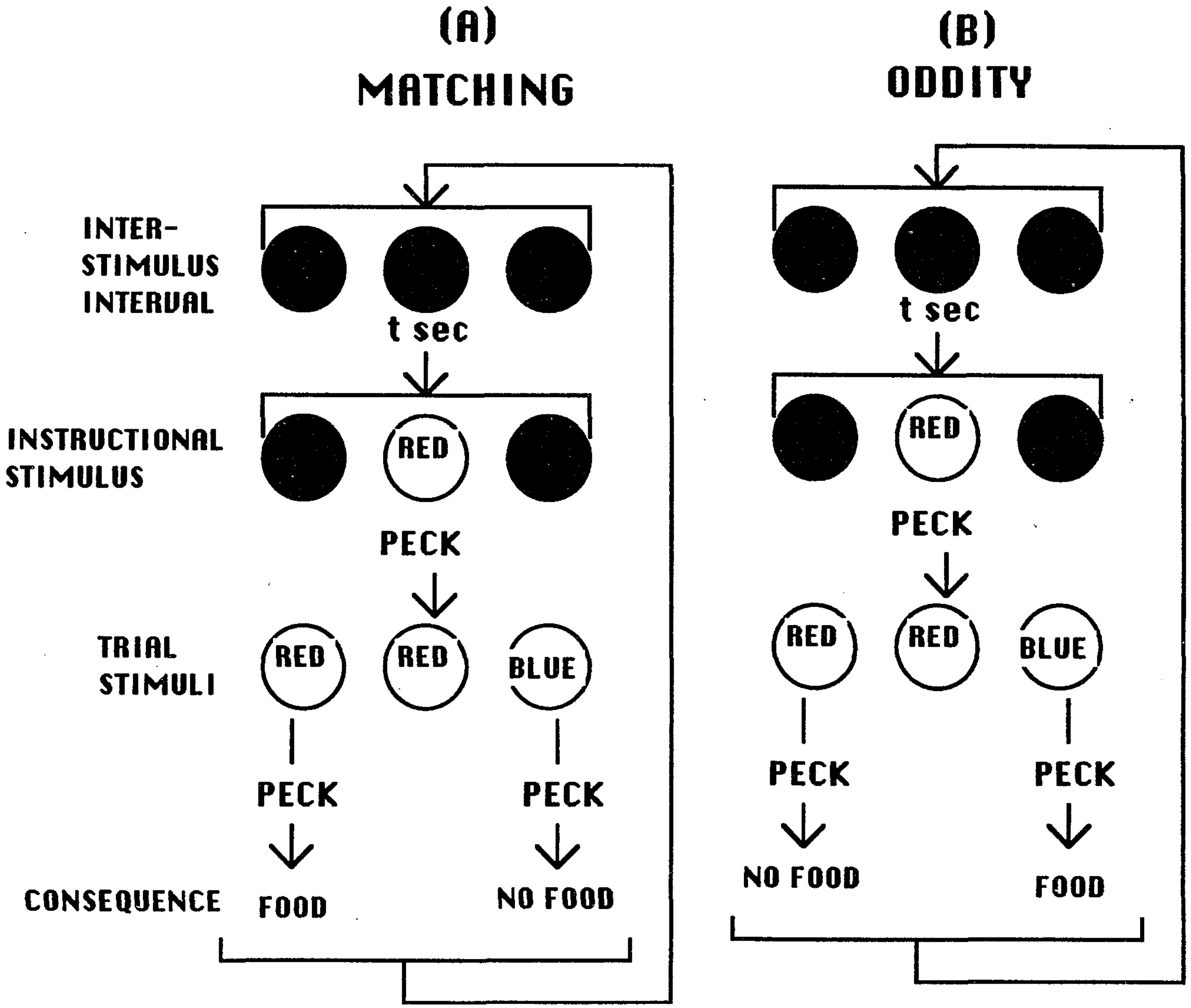
Cumming and Berryman (1965) summarized a number of experiments in an attempt to demonstrate separate roles of discriminative and conditional stimuli within an operant paradigm. In their basic conditional discrimination procedure, a pigeon was presented with a "sample" stimulus, and a response to this stimulus produced several "comparison" stimuli. Responses to the comparison stimuli were reinforced or nonreinforced according to some predetermined rule. One rule they employed was to reinforce responses to the comparison stimuli that matched the physical properties of the sample stimulus, referred to as "matching-to-sample". In their first experiment (Cumming and Berryman, 1961), three pigeons were trained on a matching problem using three hues: red, green, and blue. Figure 1A diagrams one cycle (and stimulus combination) of the conditional discrimination procedure. A pigeon's keypeck to a red center key of a three-key chamber produced a blue light on one side key and a red light on the other side key. A peck to the red side key was followed by reinforcement whereas a peck to the blue side key led to nonreinforcement. Cumming and Berryman (1961), employing red, green, and blue stimuli, found that matching performance reached a level of at least 90% accuracy within six to nine sessions.

A variation of the "matching" procedure was also employed which bears on a configurational or instructional account of a conditional discrimination. An "oddity" problem was established by reinforcing responses to the nonmatching key. In the oddity procedure, reinforcement was contingent upon a pigeon's keypeck to the comparison stimulus which was physically different from the sample stimulus. Figure 1B shows that a pigeon's keypeck to the blue side key, if the center was red, was followed by reinforcement whereas a peck to the red side key led to nonreinforcement. Berryman, Cumming, Cohen, and Johnson (1965) trained six pigeons on an oddity problem, again using red, green and blue stimuli. The acquisition curves showed that the subjects improved their performance very slowly in comparison to performance on the "matching" procedure.

If the sample cue was functioning as a conditional cue there are two varieties of instructions which can account for the slower acquisition of oddity behavior. Consider a trial on which the sample stimulus was red and the comparison stimuli were red and blue. It could be assumed that the bird learned to avoid red on the side key. In other words, the subject might learn the instruction, "after pecking red on the center key, avoid pecking red on the side keys". The sample stimulus is assumed to serve as a cue designating which of the comparison stimuli is to be avoided. Instructions of this type will be referred to as S- rules. But as an alternative, the pigeons could have learned the instruction "after pecking red on the center key, approach and peck blue on the side keys". This is an S+ rule. In the oddity procedure used by Berryman et al. (1965), it was not possible to determine whether the birds were learning a S+ rule ("if red then peck blue") or a S- rule ("if red then avoid red"). To find out, they altered their procedure after the twentieth session by replacing all of the blue keylights with yellow ones. This meant that on any trial in which a blue light was scheduled to be presented on either the center or side keys, a yellow light appeared.

The S+ and S- rules lead to different predictions about the way pigeons should transfer oddity behavior to novel stimuli. The transfer predictions of interest concern the trials on which the novel yellow stimulus appeared only on the side key. These trials were ones in which green or red appeared on the center key as a sample stimulus and yellow appeared on one of the side keys as a comparison stimulus. On a transfer trial with a green sample, a bird

Figure 1. Diagram of one trial in a conditional discrimination procedure in a three-key pigeon chamber. A) The "matching" procedure: After a period of no stimulus presentations for t sec, an instructional stimulus (red) appears on the center key. A peck on the center key turns on the two side keys. If the pigeon pecks the blue trial stimulus, food is delivered and the intertrial interval of a new trial begins; if the pigeon pecks the red stimulus, the next intertrial interval follows without food. The instructional stimulus and the location of the trial stimuli vary from trial to trial. B) The "oddity" procedure: After an intertrial interval of t sec, an instructional stimulus (red) is presented on the center key and a peck on that key turns on two side keys. A peck to blue leads to reinforcement and a peck to red leads to no reinforcement.


(A)
MATCHING
(B)
ODDITY
INTER-STIMULUS INTERVAL
t sec
t sec
INSTRUCTIONAL STIMULUS
RED
RED
PECK
PECK
TRIAL STIMULI
RED
RED
BLUE
RED
RED
BLUE
PECK
PECK
PECK
PECK
CONSEQUENCE
FOOD
NO FOOD
NO FOOD
FOOD

that has learned a set of S+ rules would do no better than chance performance, because green on the center key is a cue for selecting either red or blue and neither was available. In contrast to this prediction, birds that have learned a set of S- rules should have showed no change in performance because the birds would already have learned to avoid a green comparison stimulus after pecking a green sample stimulus. Similar predictions may be made for trials on which the sample was red. The data from the transfer test showed that both for the trials on which the sample was green and trials on which it was red, oddity performance dropped to near chance level after yellow stimuli had been substituted for blue ones. These data suggest that oddity behavior with three stimuli is best described by a set of six S+ rules ("if red, peck blue"; "if red, peck green"; "if green, peck red"; "if green, peck blue"; "if blue, peck red"; and "if blue, peck green"). Furthermore, these data suggest that matching with three stimuli may result from a set of three S+ rules ("if red, peck red", "if blue, peck blue", and "if green, peck green"), half the number of S+ rules required to solve the oddity problem.

Although this analysis rules out the possibility of S- rules, it does not rule out a configurational account of these results. The <u>number of rules</u> has been used as a criterion for which view, configurational or instructional, best accounts for a conditional discrimination. The logic of this reasoning is as follows: the instructional model predicts that in oddity experiments with three stimulus alternatives, the bird must learn a total of six S+ rules, whereas matching birds require only three rules. Presumably, the greater the number of rules the birds must learn the greater the number of sessions required for acquisition. Because the matching birds need learn only half the number of S+ rules needed to master the oddity problem, they might be expected to learn twice as rapidly as the oddity group. Alternatively, a configuration position posits that animals respond to the entire configuration of stimuli on any given trial of a conditional discrimination experiment. The configuration model holds that each three-key combination of hues is learned separately, i. e., the animal learns the appropriate response for each stimulus combination. Thus, if the control were by configuration, data from matching and oddity experiments should show equal rates of acquisition for any fixed number of stimulus alternatives. Carter and Werner (1978: Figure 4 in their article) compared directly the original matching data with the acquisition function for oddity and found that the rate of acquisition depends on the number of S+ rules to be learned, thus supporting an instructional account of conditional discrimination.

Cumming and Berryman (1965) provided additional experimental evidence which suggests that the sample stimulus and comparison stimulus functions may be relatively independent. Their strategy was to perform the same experimental operations (e. g., extinction) on both the instructional and discriminative stimuli. If these stimuli have similar functions, the effects of the experimental operations should be similar for both stimuli. However, they found that a particular experimental manipulation had an effect on either the instructional stimulus or the discriminative stimulus, but not both. For example, increasing the temporal interval between the sample stimulus and reinforcement did not weaken the ability of the sample stimulus to control discriminations, but did weaken its own discriminative control over responding (Berryman, Cumming, and Nevin, 1963). Therefore, the evidence on conditional discrimination learning by pigeons in an operant paradigm suggests that the sample stimulus can function as a conditional cue that indicates which of two discriminative stimuli will be followed by reinforcement. These findings suggest that the sample stimulus exercises what might be best described as an *instructional* function.

Another method which has helped demonstrate separate stimulus functions within a discrimination paradigm is *topography tagging*. The rationale of topography tagging is that if a compound is formed by combining two stimuli that evoke very different behaviors, then the controlling stimulus can be determined by observing the nature of responding controlled by that compound.

One phenomenon in which topography tagging has been quite informative is the feature-positive discrimination (Jenkins and Sainsbury, 1969). A feature-positive discrimination involves a compound stimulus (AX) that is reinforced while one of its separate elements (the common element, A) is nonreinforced. This procedure may be described as a simple conditional discrimination since the significance of one stimulus (A) depends on the presence of another stimulus (X).

Peter Holland and his co-workers have studied an organism's responding in a feature-positive discrimination by using respondent (Pavlovian) conditioning procedures. Hungry rats were given pairings of various visual and auditory conditioned stimuli (CSs) with the delivery of food pellets. Conditioning was assessed by direct observation of the rats' behavior during the CSs using video recording equipment. An unusual feature of this conditioning preparation is that the form of conditioned behavior observed depends on the nature of the CS. Since different conditioned stimuli elicit topographically distinct conditioned behaviors, stimulus-response relations are "tagged" and readily observed without the need for separate tests of individual elements. Two stimuli were used in Holland's experiments, a flashing houselight and a tone. In previous experiments (e. g., Holland, 1977) the light elicited *rearing* (standing quietly with both feet off the floor) when it was separately paired with food, whereas the tone elicited a very different behavior, *headjerk* (a rapid movement of the head).

In one experiment, Ross and Holland (1981) employed a respondent (Pavlovian) feature-positive discrimination with three groups of rats in which a compound light+tone stimulus was reinforced while either the tone alone (Group LT+/T-), the light alone (Group LT+/L-), or neither element (Group LT+) was separately nonreinforced. Thus, in Group LT+/L- the predictive feature was the tone, in Group LT+/T- it was the light, and in Group LT+ both elements were equally predictive. If the predictive feature alone controlled responding to the compound in these feature-positive discriminations (because it is a more valid predictor of reinforcement) then the form of responding to the LT compound should be characteristic of that to the visual feature (rearing) in Group LT+/T-, tone characteristic (head jerk) in Group LT+/L-, and a combination of both in Group LT+. An additional prediction is that the configurational cue (compound) might be expected to elicit a topographically unique response rather than either head jerking or rearing. If this were the case, then responding to the compound might differ from that elicited by either element alone, and might be fairly similar regardless of whether the tone or the light was separately reinforced.

The results of Ross and Holland's (1981) experiment showed that when the light+tone compound was reinforced, both elements acquired direct eliciting control over responding. The light+tone compound in Group LT+ elicited moderate levels of both head jerk and rearing behaviors. The light alone elicited only rearing and the tone alone elicited only head jerks. However, under the usual feature-positive procedure in which there are no separate non-reinforced presentations of the positive feature, the amount of responding elicited by the positive feature alone (light in Group LT+/T- and tone in Group LT+/L-) was generally equal to that elicited by the compound (light+tone). Hence a configurational cue cannot be the controlling stimulus in a typical feature-positive discrimination. The responding to the compound stimulus appears entirely attributable to conditioning of the more predictive feature stimulus.

It appears that responding in feature-positive discriminations is not controlled by configurational cues unless certain contingencies are arranged. Holland and Block (1983) trained rats on a Pavlovian positive-patterning (AX+, A-, X-) discrimination in which a tone+light compound was reinforced but presentations of either the light or tone alone were not reinforced. Presumably, the unique compound cue would control responding in this discrimination, since it is the most valid predictor of reinforcement. The results showed that the discrimination was accompanied by the emergence of a unique response topography (rear head jerk) in the presence of the compound. Thus configurational control seems to emerge only when two stimuli presented simultaneously are reinforced and both stimulus elements are separately nonreinforced.

Ross and Holland (1981) investigated the difference between serial and simultaneous feature discriminations by inserting an interval between the onset of the light and the onset of the tone (L->T+, T-). They found that in this serial procedure direct control over rearing accrued to the light, but the light's instructional function was also evident. Subjects responded little to the tone on non-compound trials whereas when the tone was preceded by the light the tone elicited substantial head jerking. Note that in this serial feature-positive discrimination, responses occurred to the less predictive common element (tone) rather than to the feature that predicted reinforcement. That is, the feature stimulus (light) predicted the occurrence of food on 100% of the trials in which the light was presented, whereas the tone predicted food on 50% of the trials. The light was not predictive with respect to time, but rather in a probabilistic sense. The feature's control over the behavior during the tone which is characteristic of a tone-reinforcer association suggests that the function of the feature was to activate the direct control over behavior by the tone.

Thus, the function of the stimulus events in Pavlovian feature-positive discriminations can be significantly altered by relatively simple procedural variations, and these different functions can be revealed by the method of topography tagging. First, when two stimuli presented coextensively are followed by reinforcement and each stimulus alone is nonreinforced, then the stimulus configuration can come to directly control a topographically unique response (Holland and Block, 1983; Ross and Holland, 1982). Second, in the usual feature-positive discrimination in which only the common element is separately nonreinforced, the more predictive feature stimulus exerts direct control over responding. Third, when the feature precedes the common element on reinforced compound trials, the feature can simultaneously exert direct control over responding and function as a higher-order instructional cue (Ross and Holland, 1981). Importantly, these findings suggest that one critical variable in feature-positive discriminations that may determine separate functions of the feature stimulus is the time interval between the onsets of the feature and the common element on reinforced compound trials. These findings also raise the possibility that a similar process operates in the case of conditional discriminations: simultaneous presentations of the sample and comparison stimuli form a configurational cue whereas serial presentations of these stimuli may be more likely to result in the sample stimulus acquiring an instructional function.

Holland (1983; 1985) refers to a feature stimulus which signals the relation between a second stimulus and the reinforcer as an "occasion-setter". It is worth noting the resemblance of occasion-setters within a respondent paradigm to discriminative stimuli within operant paradigms (see Ross and Lolordo, 1987). Skinner's (1938) description of a discriminative stimulus as a stimulus that sets the occasion for a particular response to be followed by reinforcement appears analogous to Holland's (1983) description of the feature stimulus as setting the occasion for the pairing of the common element with an unconditioned stimulus in serial feature-positive discriminations. The two descriptions differ in that the discriminative stimulus is said to set the occasion for a response-reinforcer relation, but the feature stimulus sets the occasion for a stimulus-reinforcer relation. From this viewpoint, the discriminative stimulus and the occasion-setter both exhibit signalling properties which momentarily increases the occurrence of a certain response in the presence of a particular stimulus.

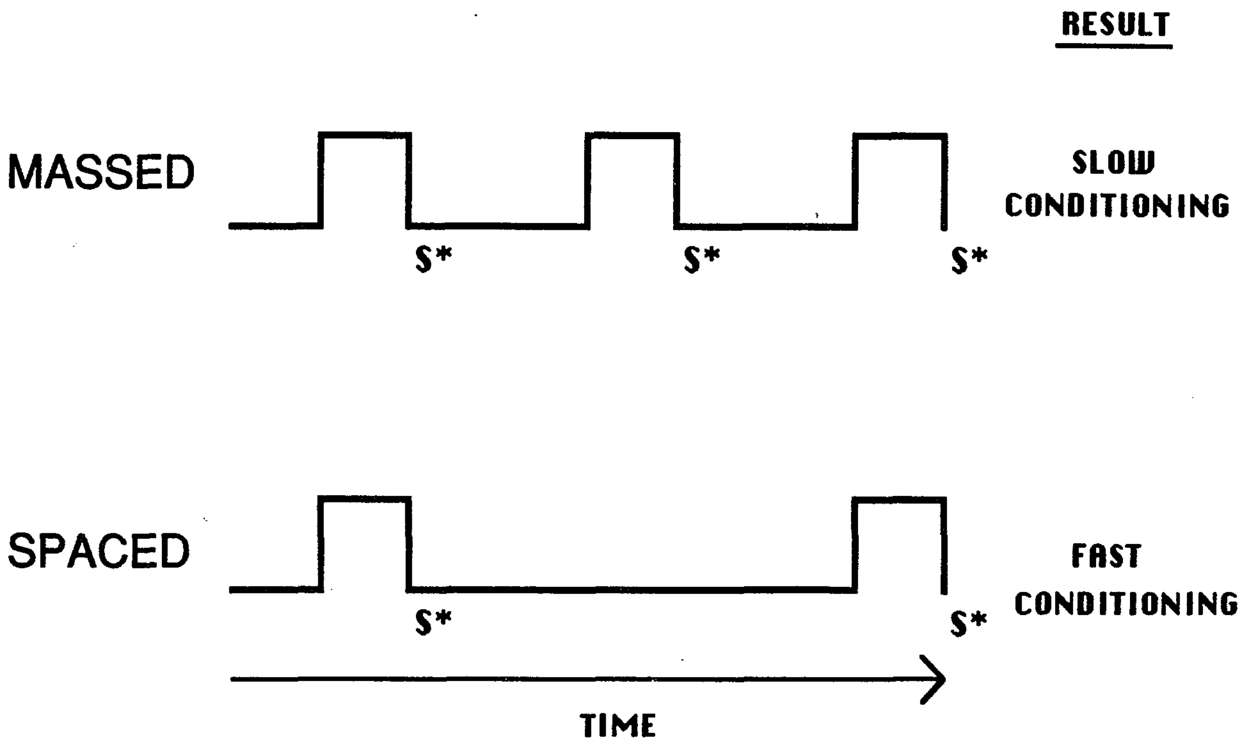
In sum, there are two major issues raised by these results concerning the conditional discrimination procedure. The first is whether conditional stimuli function as "higher-order" stimuli which control three-term stimulus-response-reinforcer contingencies or do they function as discriminative stimuli controlling response-reinforcer relationships. This issue has been formulated in terms of instructional vs. configurational accounts of stimulus control. The findings suggest that instructional control might, indeed, differ from other kinds of stimulus control (i. e., discriminative stimuli) in their manner of influencing learned behavior (Cumming and Berryman, 1965; Carter and Werner, 1978). Directly related to this issue is that some methods (e. g., topography tagging) may be useful in distinguishing these kinds of stimulus control (Holland, 1983; Carter and Werner, 1978). More broadly, the clarification of instructional control as functionally distinct from discriminative control makes it necessary to reexamine the basic units of behavior analysis. The second major issue raised by these results is what are the influential temporal properties in instructional control. Recent evidence suggests certain temporal variations of the conditioning procedure may influence the nature of control exhibited by stimuli; for example, the simultaneous presentation of stimuli may result in configurational control whereas a serial presentation might result in "higher-order" instructional control (Holland, 1983). Although many properties of stimuli (such as temporal duration, temporal placement or frequency) probably influence the degree and strength of instructional control, temporal properties seem to be important and their role might be quite general since temporal variables are arranged regardless of the particular stimulus modality.

TEMPORAL FACTORS IN CONDITIONING

A precise account of conditional discriminations must include an explication of which aspects of the environment influence instructional control. All environmental stimuli are multidimensional in that they lie on more than one sensory continuum. A visual stimulus, for example, will have wavelength, intensity, spatial, and temporal properties. The manipulation of the independent variable in all learning experiments necessarily involves the temporal placement and duration of effective environmental events. The temporal structure of environments can be specified independently of sensory modality (sound, light etc.). It may be that the temporal structure has a common influence independent of modality and more potent than modality differences. Thus, temporal factors may constitute a trans-modal feature of the environment that is primary in discriminative and conditional learning procedures. A model of learning that includes temporal variables as its central feature may adequately describe a wide range of diverse results independent of other parameters. Historically, effective characterizations of the temporal dimensions of environmental events have contributed significantly to the understanding of learning processes in both operant- and respondent-conditioning procedures (e. g., Ferster and Skinner, 1957; Pavlov, 1927).

One classic example of the importance of analyzing temporal variables in learning is the effect of "massed" versus "spaced" training. In a respondent conditioning procedure, a previously ineffective stimulus is immediately followed by a reinforcer (S* or US). The result is that the previously ineffective stimulus comes to elicit anticipatory behavior relative to the reinforcer. Consider two procedures involving a series of pairings of the stimulus with the reinforcer, which differ only in the temporal spacing of the stimuli. Figure 2 illustrates the temporal sequence of events in the two training procedures; in the top portion stimuli are presented closely together or "massed", whereas in the bottom portion the stimuli are "spaced" apart. In other words, the time between the stimuli, or the interstimulus interval, is greater in the spaced procedure than in the massed procedure. A view of associative learning based only upon associated contiguous events would not differentiate the two procedures. The stimulus is paired equally often with food when the stimuli are massed and when they are spaced. Yet, massed training produces slow conditioning and spaced training produces rapid conditioning. Thus, a critical feature of the environment that influences learning is the quantitative characteristics of the temporal parameters of training.

Figure 2. Diagram of massed versus spaced trials conditioning procedure. Trial durations are indicated by raised portions. Grain presentations are indicated by S*. Note that the spaced trial procedure produces more rapid conditioning than the massed trial procedure.


RESULT
MASSED
S*
S*
S*
SLOW
CONDITIONING
SPACED
S*
S*
FAST
CONDITIONING
TIME

It is clear that variations in temporal dimensions are transmodal influential features of the environment and that any adequate theory of conditioning must account for such variations (e. g., Gibbon, 1977). Theorists have struggled to discover how best to describe the critical dimension of the temporal structure (e.g., Gibbon and Balsam, 1981; Jenkins, Barnes, and Barrera, 1981). The following discussion is restricted to a descriptive formulation of Gibbon and Balsam's (1981) model because it represents a particularly precise and effective statement about how temporal variations influence conditioned responding.

In a typical conditioning experiment, reinforcement is contingent upon a particular class of responses a pigeon may emit in the presence of particular stimuli. The pigeon may, however, walk around the chamber several times before it responds or it may respond very quickly to the onset of the stimuli. Since the stimuli are terminated as soon as the pigeon responds, the pattern of responding determines the temporal duration of the stimulus events. Accordingly, it is difficult to specify in advance and manipulate the duration of effective stimuli.

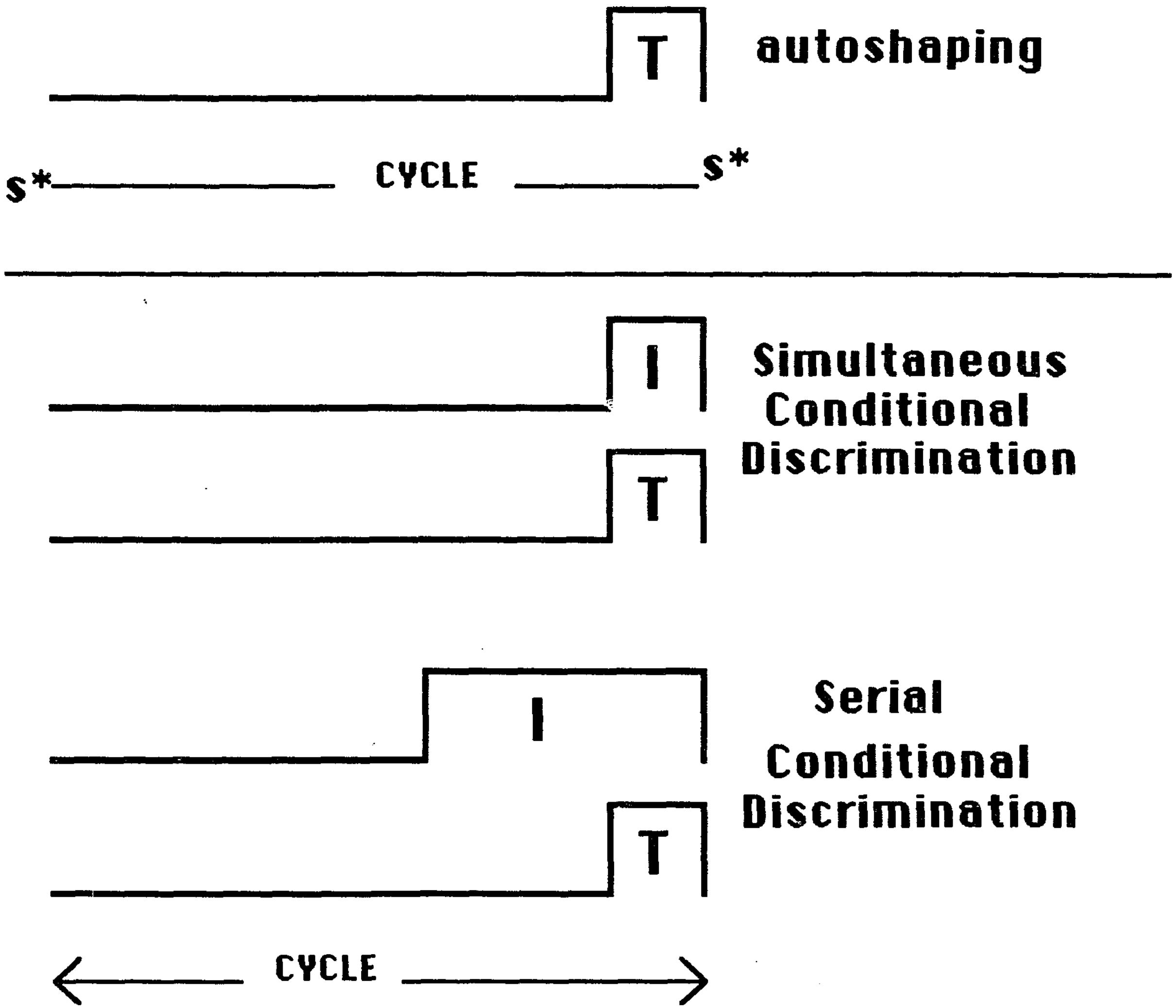
A procedure has been developed that permits the manipulation and control of explicit stimulus-reinforcer relations, independent of response requirements (Brown and Jenkins, 1968). This procedure, referred to as *autoshaping*, usually involves presenting a stimulus for a brief period of time immediately followed by reinforcement. Since reinforcement is not contingent upon the subject's behavior, this paradigm resembles a typical respondent procedure. For example, by pairing the keylight and the food, the keylight comes to elicit a response similar to that elicited by the food (i. e., pecking). The autoshaping paradigm differs from the typical respondent preparation, however, in that the conditioned stimuli evoke directed responses, the type of behavior usually considered as operant behavior (i. e., *key*-pecking). For these reasons, the autoshaping preparation has advantages for the systematic study of the effects of stimulus element durations on the acquisition of stimulus control.

The autoshaping procedure illustrated in the top part of Figure 3 shows two commonly studied intervals between stimuli that can influence learning. They are the trial duration and the cycle. The trial (T) duration refers to the interval between the stimulus onset and the stimulus offset. The cycle (C) duration refers to the time between reinforcement presentations. The effects of variation in each of these intervals are well known and described elaborately for conditioning (Gibbon and Balsam, 1981). First, there is an inverse relation between the time from T onset to reinforcer onset and the speed of acquisition in autoshaping (Gibbon, Baldock, Locurto, Gold, and Terrace, 1977; see also Cooper and Brownstein, 1985). The shorter the duration of T, given that C is constant, the faster the acquisition of autoshaped responding. Conversely, the effect of increasing T is to slow the speed of acquisition. Second, the effects of varying C are directly related to the previous discussion of massed versus spaced trials (Terrace, Gibbon, Farrell, and Baldock, 1975). With T constant, acquisition is faster with a long C (or spaced trials) than with a short C (or massed trials). In sum, performance in an autoshaping procedure is directly related to the time between reinforcements, C, and inversely related to the time from stimulus-onset to stimulus-offset, T.

Further research has revealed how these different intervals interact with one another to determine performance in an autoshaping procedure. The results of studies that have varied temporal parameters are best summarized in terms of the ratio of C to T (Gibbon and Balsam, 1981; Jenkins, Barnes, and Barrera, 1981). In other words, acquisition speed does not depend on the absolute values of C and T; rather, the relative time to reinforcement is the controlling variable. Gibbon, Baldock, Locurto, Gold and Terrace (1977) examined the speed of acquisition as a function of trial duration and cycle combinations. In their experiment, each of

Figure 3. Top Part: Schematic representation of the temporal intervals in an autoshaping procedure. C is the duration of the cycle or the interval between reinforcements. T is the trial stimulus or the duration between stimulus onset and stimulus offset.

Bottom Part: Schematic representation of the temporal intervals in a conditional discrimination procedure (simultaneous and serial). C is the duration of the cycle or the interval between the onset of the intertrial interval and the offset of the trial stimulus. T is the trial stimulus. I is the instructional stimulus.


T
autoshaping
S*
CYCLE
S*
I
Simultaneous Conditional Discrimination
T
I
Serial Conditional Discrimination
T
CYCLE

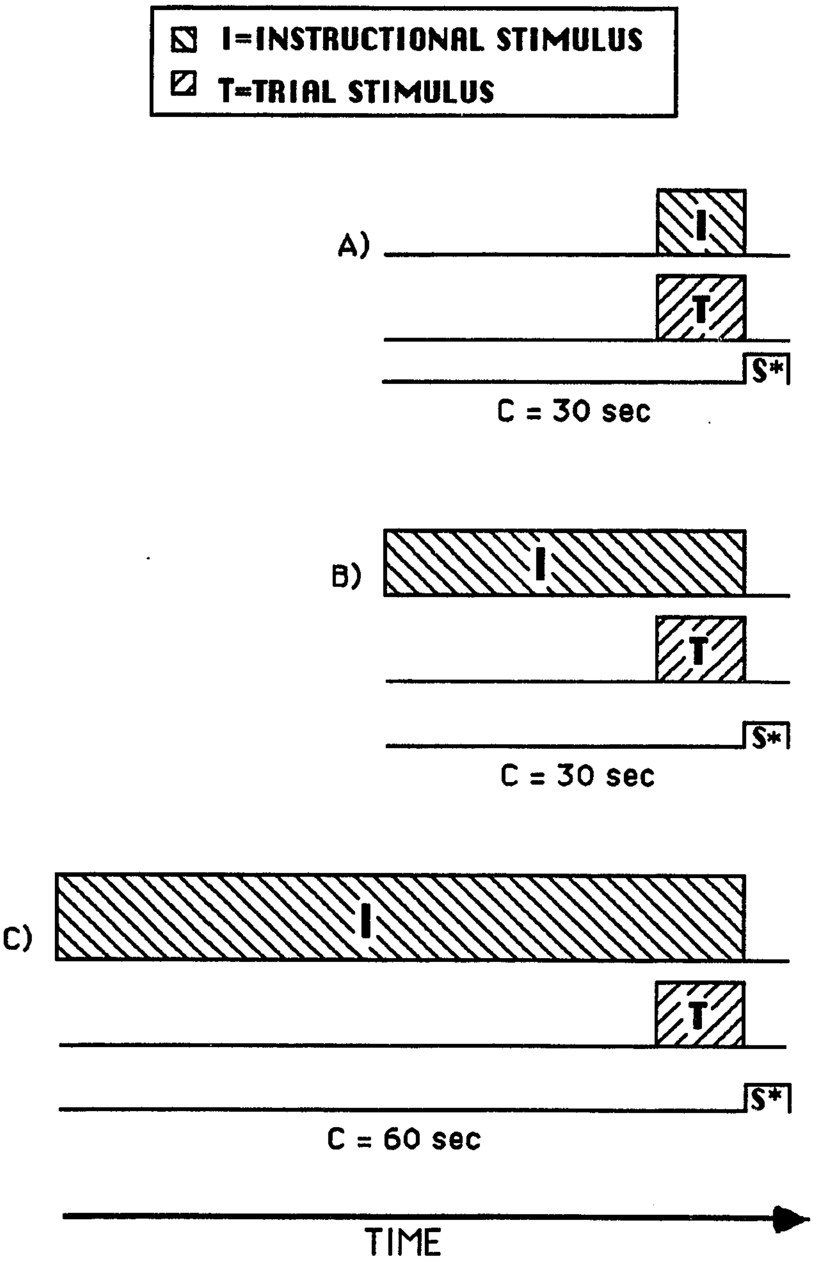
twenty-four groups of pigeons were exposed to a combination of a wide range of trial durations (1 to 644 sec) and cycle durations (7 to 1412 sec). The results of their study suggested that the ratio of cycle to trial durations (C/T), rather than the absolute durations, accurately described the variable which appeared to be modulating the speed of acquisition. If both the trial signal and cycle were increased by the same proportion (for instance, if a 28 sec C with a 4 sec trial was increased by a factor of two (2) to a 56 sec C with a 8 sec trial) then the speed of acquisition was roughly equal. Additionally, they found that the higher the C/T ratio, the faster the rate of acquisition. For example, a group with a C = 100 sec and T = 10 sec, or a C/T ratio of 10, exhibited conditioned responding with fewer trials than a group with a C= 50 and T = 10 sec, or a C/T ratio of 5.

In sum, Gibbon and Balsam (1981) have suggested that the strength of the performance controlled by a particular stimulus depends on the temporal duration of a signal for reinforcement relative to the time between reinforcements. According to their formulation, the critical temporal property of the environment is the ratio of the duration of the time between reinforcements (C) to the stimulus duration (T), or the C/T ratio. More specifically, the larger the C/T ratio the faster the speed of acquisition. Gibbon and Balsam's account of conditioned responding, along with Holland's (1983) finding that the temporal placement of stimulus elements influenced the nature of control exerted by the stimuli, suggest that the temporal arrangement of the instructional stimulus, the discriminative stimulus, and the interreinforcement interval may play a role in the acquisition of instructional control. The conditional discrimination procedure illustrated in the bottom part of Figure 3 shows these three temporal parameters both in a simultaneous and serial conditional discrimination. They are the instructional stimulus interval (I), the trial interval (T), and the cycle (C). Note that in the conditional discrimination paradigm, the trial stimulus (T) is a procedural term that refers functionally to the discriminative stimulus, and the cycle (C) refers to the interval between the onset of the intertrial interval and the offset of the reinforcer. Also note that the specification of some intervals necessarily fixes the durations of other intervals.

TEMPORAL FACTORS IN CONDITIONAL DISCRIMINATION

This section will describe previous research on how the temporal duration of the cycle, trial stimulus, and instructional stimulus effects the acquisition of a conditional discrimination and discuss its implications. Williams (1982) studied the acquisition of a conditional discrimination in pigeons with an autoshaping procedure in which certain stimulus-stimulus combinations were followed by food and others were not followed by food. Figure 4A illustrates his study in which an instructional stimulus (I) + trial stimulus (T) combination consisted of two keylights illuminated simultaneously for the last 5 sec of a 30 sec cycle (C). Green+line or red+circle were followed by 3 sec access to grain; green+circle or red+line were followed by a darkened chamber for the same 3 sec period. All pigeons exposed to this condition quickly acquired the conditional discrimination. The majority of the birds' responding occurred in the positive trials, rather than equally in both positive and negative trials. This result replicated and extended the finding that pigeons acquire a conditional discrimination under conditions where both the (simultaneous) stimuli and the reinforcers are response-independent. Conditional discrimination had been demonstrated previously with an autoshaping procedure (Looney, Cohen, Brady, and Cohen, 1977) but with the stimulus elements presented successively rather than simultaneously. Thus, Williams' result showed that pigeons could acquire a conditional discrimination when the instructional stimulus and the trial stimulus were presented simultaneously for a brief period of 5 sec at the end of a 30-sec cycle.

Figure 4. Diagrams of the temporal parameters for Williams, Experiments 1 and 3 (1982) (A); Williams, Experiment 1 (1982) (B); and unpublished work in our laboratory (C): Stimulus durations indicated by raised portions. I is the instructional stimulus. T is the trial stimulus. C is the cycle. S* is grain presentation.


I=INSTRUCTIONAL STIMULUS
T=TRIAL STIMULUS
A)
I
T
S*
C = 30 sec
B)
I
T
S*
C = 30 sec
C)
I
T
S*
C = 60 sec
TIME

It might be expected that presenting the instructional stimulus prior to the onset of the trial stimulus would facilitate the acquisition of the conditional discrimination; increased visual information provided by the instructional stimulus would increase the organism's attention to the upcoming trial combination. In this case, increasing the temporal duration of the instructional stimulus would enhance acquisition of a conditional discrimination. Williams (1982; Experiment 1) found, however, that acquisition was prevented when the instructional stimulus (i. e., red or green) scheduled to occur with the trial stimulus was presented during the entire 30-sec cycle (see Figure 4B). The birds' pecking was distributed roughly equally across both positive and negative trials. In this condition the instructional stimulus preceded and overlapped the presentation of the trial stimulus. Thus, it appears that increasing the duration of the instructional stimulus actually interferes with the acquisition of the conditional discrimination.

These results suggest that temporal variables are influential in the acquisition of a conditional discrimination, but it is not yet clear in what manner. Williams (1982) demonstrated good conditional control when a simultaneous stimulus compound was employed, but not when the instructional stimulus was presented during the entire cycle duration. The failure of the long instructional stimulus to function as a conditional cue seems consistent with the findings on autoshaping. Gibbon, Locurto, and Terrace (1975) reported that autoshaping did not occur when the trial stimulus occupied 75% of the total session time. Williams' (1982) findings indicate that a comparable effect may operate for the acquisition of conditional discriminations, as the presentation of instructional stimuli for the entire cycle eliminates the effectiveness of the instructional stimulus. The lack of conditional control exerted by the instructional stimulus could be the result of the duration of the instructional stimulus (I) relative to the cycle (C). Importantly, such an account suggests that instructional control and discriminative control may be influenced by the same temporal property-the ratio of C/I.

Williams' (1982) results are consistent with an explanation that assumes the instructional stimulus (colors) was involved in two predictive relations. One involved the relation with the form cues, as the presence of the color cues predicted which forms would be followed by reinforcement. The second was between the colors and food itself. The subjects learned that colors did not predict the temporal occurrence of food, since the colors were continuously presented during C. Thus, the subjects may not have "attended" to the colors because they did not predict food. The colors were then unable to function as conditional cues for the subjects. According to this account, the instructional stimulus must have a favorable enough C/I ratio to engender conditioned responding in order to then function as an instructional cue.

If the relative duration of the cycle duration to the instructional stimulus duration is critical, then extending the duration of the cycle and instructional stimulus should have no effect on the failure of acquisition of a conditional discrimination. That is, increasing the cycle and instructional stimulus by the same factor (x2) duration does not improve the ratio of C/I. However, in a preliminary study, I investigated the effects of increasing the absolute cycle and instructional stimulus duration on the acquisition of a conditional discrimination. The procedure consisted of an autoshaping preparation in which the instructional stimulus was an illuminated red or blue light on the center key of a three-key response panel and was presented throughout a cycle duration of 60 sec. The trial stimulus was a 6-sec illumination of a white light on either the left or right side key. Blue + white-on-left or red + white-on-right was followed by 4-sec access to grain. Blue + white-on-right or red + white on left was followed by a 4-sec blackout. Therefore, whether a particular <u>position</u> (i. e., right or left) of white stimulus would be followed by food was conditional upon the presence of either a blue or red center key. A white key on the right side was followed by food, but only if the center key was red. Conversely, food followed a white keylight on the left side only when a blue keylight was present. Surprisingly, a group of pigeons exposed to these temporal durations acquired a conditional discrimination (see Figure 4C). This result is surprising because presenting the instructional stimulus for the entire cycle duration does not, itself, prevent acquisition. Consequently, the acquisition of instructional control is _not_ invariantly related to the duration of the instructional cue relative to the cycle duration. Furthermore, the results of this study suggest that a stimulus may not have to be a good predictor of food in order to function as an instructional cue. This outcome further complicates the question of which temporal variables, if any, are critical to the acquisition of instructional control.

Taken together, these studies showed that pigeons acquired a conditional discrimination within an autoshaping preparation when the instructional stimulus was presented simultaneously with the trial stimulus for a short duration of 5 sec (Williams, 1982) or preceded the trial stimulus by a long duration of 54 sec (my pilot study), yet was prevented when the instructional stimulus preceded the trial stimulus by a shorter duration of 25 sec (Williams, 1982). The discrepancy between the effects of the different instructional stimulus durations is puzzling. Traditional accounts of conditioning (e. g., Gibbon and Balsam, 1981) have relied on the duration of a stimulus event _relative_ to other stimulus events, particularly the duration of a stimulus event relative to the interreinforcement interval. It is possible, however, that a different type of relationship is involved in conditional learning. Perhaps the acquisition of instructional control depends on the duration of the instructional stimulus relative to the trial stimulus, rather than to the cycle. It should be noted that an alternative hypothesis could be developed based on the rationale that the critical variable in conditional control is the absolute duration of the instructional stimulus. An instructional stimulus may have to be of long enough duration (>25 sec) in order to provide enough information about the upcoming discriminative stimulus. If so, instructional control and simple discriminative control might require different temporal mechanisms to describe their acquisition. Whether the same ratio (C/T), or a different ratio (e. g., I/T), or the absolute duration of I, or some combination of all these variables operates for instructional control is unclear due to the mixture of results from William's (1982) study and my preliminary work.

There is reason, however, to suspect that the ratio of the instructional stimulus to the trial stimulus can influence the acquisition of instructional control. The results from my preliminary work and Williams' (1982) study suggest that a model of instructional control may be based on the relative ratio of the instructional stimulus duration to the trial stimulus duration. The evidence comes from a comparison of this ratio (I/T) in these two studies. The birds in my preliminary study, which acquired the conditional discrimination, had an I to T ratio of 10 (I/T = 60/6 =10), whereas the birds in Williams' 1982 study (Experiment 1), which did not acquire a conditional discrimination, had a lower I to T ratio of 5 (I/T = 25/5 = 5). Hence, the birds in my study, which did acquire a conditional discrimination, had a more favorable instructional stimulus to trial stimulus ratio than the birds which did not acquire a conditional discrimination.

But what about the groups exposed to the simultaneous presentation of 5 sec of the instructional stimulus and the trial stimulus? In this case, the ratio of instructional stimulus to trial stimulus (i. e., 5/5 = 1) is much lower than any other group, yet all birds exposed to this condition acquired the conditional discrimination. The findings by Holland and his associates (Ross and Holland, 1982; Holland and Block, 1983) bear on this issue. When stimulus elements within a Pavlovian feature-positive discrimination are presented _simultaneously_ they function as a configurational cue, whereas when one stimulus element _precedes_ another stimulus cue the first stimulus acquires instructional (or occasion-setting) properties. Applied to Williams' (1982) experiment in which both the instructional stimulus and the trial stimulus were presented simultaneously for 5 sec, the stimulus compound may have functioned as a configurational cue. Thus, the simultaneous presentation of stimuli in a conditional discrimination may represent a special case of configurational control in which the I/T ratio plays no role.

PURPOSE OF THE STUDY

Two main points should now be reviewed briefly. First, there is an important difference between configurational and instructional control functions of stimuli (Carter and Werner, 1978; Holland, 1983). The configurational process results in the momentary strengthening of an appropriate or unique response to each stimulus pattern whereas the instructional process results in the momentary strengthening of evocative powers of the discriminative stimulus. The demonstration of configurational control in a conditional discrimination would suggest that the function of the instructional stimulus is similar to that of the discriminative stimulus. If, however, the instructional stimulus was shown to activate the discriminative stimulus, rather than directly control responses, then a "pure" independent instructional function would be suggested. It has been shown that variations in the temporal arrangement of stimuli seem to influence the kind of control exerted by stimuli. Holland's work (1983) suggests that the simultaneous presentation of stimuli results in configurational control whereas the serial presentation of stimuli enhances instructional control.

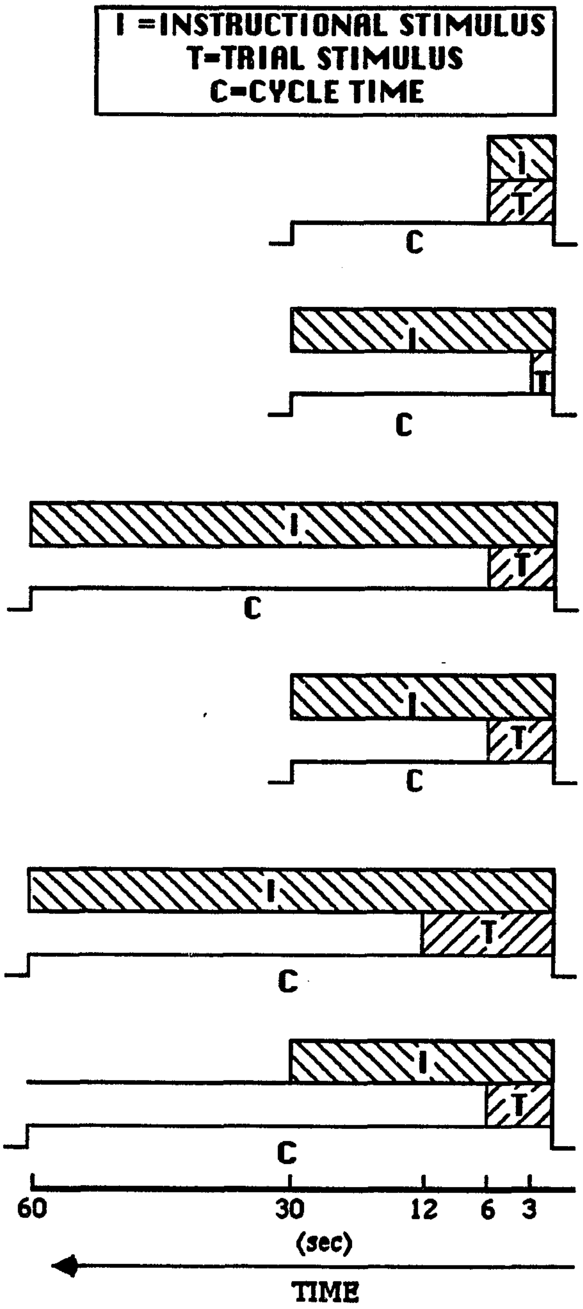
Second, it seems clear that the influential temporal property for control of responding by antecedent stimuli is the ratio of the cycle (C) to trial duration (T) (Gibbon and Balsam, 1981). However, because of the diverse results of previous experiments (e. g., Williams, 1982), it is unclear what the influential temporal property is for instructional control. I have suggested that the ratio of the instructional-stimulus duration to trial-stimulus duration may be influential. Importantly, such a finding could unify these disparate outcomes within a single model of stimulus control based on temporal factors.

The general purpose of this study was to investigate how the temporal durations of the instructional stimulus (I), the trial stimulus (T), and the cycle (C) jointly influence the acquisition of a conditional discrimination. The present study was designed to answer the following question. Is the critical temporal variable in the acquisition of a conditional discrimination the duration of the instructional stimulus relative to other stimulus events, or the absolute duration of the instructional stimulus? The answer to this question bears on the theoretical issue of whether instructional and discriminative control are influenced by the same kind of temporal property. If the absolute duration is critical then the controlling variable for instructional control may be quite different from discriminative control, which would suggest a separate process for instructional control. If, however, the relative duration is critical then the controlling variables are similar to discriminative control which indicates that the same model of stimulus control can incorporate these diverse stimulus functions.

The temporal parameters of the experimental groups will be identified throughout this paper in one of two ways. The first way is by three hyphenated numbers in which the first number represents the cycle duration, the second represents the instructional cue duration, and the third represents the trial cue duration, all in seconds. The second way is that the groups are named to indicate their I/T ratios such that a group is either a "high" ratio group, or a "low" ratio group, or a "low-C/T [control]", or a "simultaneous" group. Figure 5 diagrams the temporal arrangements of the six experimental groups of pigeons and the logic of the design is discussed below.

Figure 5. Experimental design of the six groups. I is the instructional stimulus duration indicated by the top portions of each panel and thick diagonal hatching. T is the trial stimulus duration indicated by the bottom portion of each panel and thin diagonal hatching. C is the cycle time. Groups are designated by three hyphenated numbers indicating their cycle duration, instructional stimulus duration, and trial stimulus duration, respectively. Groups are also designated by their C/T and I/T ratios. Stimulus durations are indicated by the bottom time line.

C-I-T GROUP	C/T	I/T
30-6-6	5	1
30-30-3	10	10
60-60-6	10	10
30-30-6	5	5
60-60-12	5	5
60-30-6	10	5



The top five groups constituted the central design of study with the bottom group representing a special case of conditional discrimination which will be discussed below. For Group 30-30-3, the instructional stimulus (I) was illuminated for the entire 30-sec cycle (C) and the trial stimulus (T) was illuminated for the last 3 sec of C. For Group 60-60-6, I was presented for the entire 60-sec C and T was presented for the last 6 sec of C. These two groups, Groups 30-30-3 and 60-60-6, constituted the "high" ratio groups (the I/T ratio =10). For Group 30-30-6, I was presented for the entire 30-sec C and T was presented for the last 6 sec of C. For Group 60-60-12, I was presented during the entire 60-sec C and T was presented during the last 12 sec of C. These two groups, Groups 30-30-6 and 60-60-12, represented the "low" ratio groups (the I/T ratio = 5).

This four-group subset of the design created two pairs of groups (Groups 30-30-3, 60-60-6: "high" and Groups 30-30-6, 60-60-12: "low") with the same I/T ratio but with different absolute durations of I, and two pairs of groups (Groups 60-60-6, 60-60-12 and Groups 30-30-3, 30-30-6) with the same absolute duration of I but with different I/T ratios. Accordingly, if the absolute duration of I is critical, then the pair of groups with the longer (i. e., 60 sec) instructional stimulus duration should acquire the conditional discrimination more rapidly than the pair with the shorter (30 sec) instructional duration. Alternatively, if the relative duration of I is crucial, then the pair of groups with the "high" I/T ratio should acquire the conditional discrimination faster than the pair of groups with the "low" I/T ratio.

Now note in the above groups that the I/T ratio was equal to the C/T ratio. Perhaps conditional discrimination performance is based on the C/T ratio. Subjects may require a "high" C/T ratio in order to express a discrimination. In order to rule out the C/T ratio as a critical variable in the acquisition of a conditional discrimination, a fifth group, Group 60-30-6, was employed. For Group 60-30-6 the instructional stimulus was illuminated during the last 30 sec of a 60-

sec cycle and the trial stimulus was illuminated for the last 6 sec of the cycle, and thus the C/T ratio was 10 and the I/T ratio was 5. If the I/T ratio is critical, then this group should exhibit a rate of acquisition similar to the "low" I/T groups, because it has a "low" I/T ratio. If, however, the C/T ratio is influential, then this group should acquire a conditional discrimination at the same rate as the "high" I/T groups, because its C/T is equal to the C/T ratio of the "high" I/T groups. This group was referred to as the "low-C/T [control]" group, because its I/ T ratio was comparable to the other "low" I/T ratio groups, but its "high" C/T ratio was employed to test the effects of the C/T ratio on the acquisition of a conditional discrimination. Also, if the absolute duration of the instructional stimulus is critical then this group should acquire at roughly the same rate as Groups 30-30-3 and 30-30-6.

The rationale for employing these particular stimulus durations was that they matched the ones used in Williams' (1982) and my preliminary studies, and thus provided a direct replication of the previous procedures. Williams employed a 30-sec cycle, 30-sec instructional stimulus, and a 5-sec trial stimulus parameters which prevented the acquisition of a conditional discrimination whereas my study employed a 60-sec cycle, a 60-sec instructional stimulus, and a 6-sec trial stimulus which resulted in acquisition.

Finally, a sixth group (Group 30-6-6) was exposed to a "simultaneous" condition in which the cycle duration was 30 sec and the instructional stimulus and the trial stimulus were illuminated simultaneously for the last 6 sec of the cycle. These values have been demonstrated in several previous studies (e. g., Williams, 1982) to generate acquisition of a conditional discrimination. The purpose of employing this group was to use <u>response location</u> data in order to assess the notion that stimulus combinations have different functions depending upon their temporal placement (Holland, 1983). It is important to note here that for all groups, the instructional stimulus was always presented on the center key and the trial stimuli were presented on the side keys. My attempt here was a novel test of the proposal that the simultaneous presentation of stimuli within a conditional discrimination procedure functions as a configurational cue.

I speculated that if the stimulus compound functions as an instructional cue, then the location of responding would be confined to the trial stimuli (or side keys). My hypothesis was that if the instructional stimulus, rather than directly controlling responding itself, "selects" which discriminative stimulus controls responding, then subjects' responding in the "high" and "low" I/T groups should occur only to the side stimulus key. If, however, a stimulus combination was functioning as a configurational cue, responding would be more "spread" out to the entire stimulus configuration. Pecks would occur to both the center and side keys during the stimulus combination presentation since the entire stimulus compound (center and side keys) directly controls responding. It should be noted that this notion of response location was derived from Holland's (1983) work with topographical tagging in the feature-positive discrimination. The response location measure differs from Holland's, however, in that I did not use stimuli that elicit topographically distinct responses. Thus my measure represented only a gross and convenient measure of the nature of control by stimuli. But this type of finding could be helpful in our analysis because it would make sense of the disparate results regarding the influence of temporal factors on conditional discriminations. It would, along with supporting evidence from other studies, suggest that the instructional stimulus may have different functions in simultaneous and serial conditional discriminations.

CHAPTER II

METHOD

Subjects

Twenty-four experimentally naive White Carneaux pigeons served as subjects. Birds were maintained at approximately 80% of their free-feeding weights. Throughout the duration of the study, they had continuous access to water and grit in their separate homecages.

Apparatus

Four hand-built, three-key conditioning chambers were used. Two chambers were made from modified ice chests with internal dimensions of 27 cm wide, 31 cm high, and 21 cm long. The three translucent response keys were mounted 21 cm above the floor and 8 cm apart, and could be transilluminated with red, blue, or white light. A third chamber was 35.5 cm wide, 33.5 high, and 30 cm long. The three translucent response keys were mounted 24 cm above the floor and 5 cm apart, and could be transilluminated with red, green, or white light. A fourth chamber was 38 cm wide, 38 cm high, and 52 cm long. The three translucent response keys were mounted 27.5 cm above the floor and 8 cm apart, and could be transilluminated with red, green, or white light.

The following specifications were met by all chambers. A peck with a force of at least .2 Newton was required to interrupt an electrical contact that operated recording circuits. An overhead houselight located on the ceiling near the front wall provided low-level general illumination. The houselight remained on at all times during the session except during feeder operation. Centered below the keys, 10 cm above the floor, was a rectangular opening that gave access to mixed grain when the food hopper was raised. At those times, the feeder opening was illuminated and the keylights and houselight were darkened. An externally mounted fan provided masking noise and ventilation.

For two experimental chambers, the experimental manipulations and data collection were performed by electromechanical control and recording circuits in an adjoining room. For the other two experimental chambers, the experimental manipulations and data collection were controlled by computer-driven relay circuits.

Procedure

Magazine Training. All subjects were trained to eat from the grain hopper on the first day of training. The hopper was raised when the bird was placed in the chamber and remained up until the bird ate for 30 seconds. The hopper was then lowered and raised repeatedly until the bird began eating quickly after the hopper was presented for at least five consecutive food presentations. The experimenter was able to view each bird through a one-way mirror during the session. Throughout this first session none of the response keys were illuminated.

Conditional Discrimination Training. The autoshaping procedure, with the conditional discrimination imposed from the first session, was begun on the second day of training and lasted for 18 sessions. The following notation system, minus the temporal parameters (presented below), will be used to describe the conditional discrimination procedure. The center key stimulus represents the instructional stimulus and the side key stimulus represents the trial stimulus. For the following symbols; R=red, B=blue, G=green, W=white, l=left side key, and r=right side key. A stimulus combination designated as R(W/l*) signifies a combination with a red keylight (the instructional stimulus) presented on the center key and a white keylight (the trial stimulus) presented on the left side key. The asterisk indicates a combination was followed by 3 sec access to food. A stimulus combination designated as B(W/r-)

signifies a combination with a blue keylight presented on the center key and a white keylight presented on the right key. The negative sign indicates that the combination was followed by keys darkening for 3 sec.

There were four subjects in each group. For one bird in each experimental group, the stimulus combinations were R(W/r*), B(W/l*), R(W/l-), and B(W/r-). For a second bird, the stimulus combinations were R(W/l*), B(W/r*), R(W/r-), and B(W/l-). For a third bird, the stimulus combinations were R(W/r*), G(W/l*), R(W/l-), and G(W/r-). Finally, for a fourth bird the stimulus combinations were R(W/l*), G(W/r*), R(W/r-), and G(W/l-). Positive and negative stimulus combinations were counterbalanced across birds within a group. Stimulus compound types were randomly presented, with the restriction that the same stimulus combination appear no more than three consecutive times. Sessions consisting of thirty presentations of each stimulus compound for a total of 120 stimulus compounds were conducted daily.

Subjects were randomly assigned to one of the six groups described below in terms of temporal parameters. Refer back to Figure 5 which diagrams the temporal arrangements of the six experimental conditions.

(1) Group 30-30-3: The instructional stimulus (I) was illuminated for the entire 30-sec cycle (C) and the trial stimulus (T) was illuminated for the last 3 sec of the cycle [C/T=10, I/T=10].

(2) Group 60-60-6: The instructional stimulus was presented for the entire 60-sec cycle and the trial stimulus was presented for the last 6 sec of the cycle [C/T=10, I/T=10]. These two groups, Groups 30-30-3 and 60-60-6, constituted the "high" I/T ratio groups.

(3) Group 30-30-6: The instructional stimulus was presented for the entire 30-sec cycle and the trial stimulus was presented for the last 6 sec of the cycle [C/T=5, I/T=5].

(4) Group 60-60-12: The instructional stimulus was presented during the entire 60-sec cycle and the trial stimulus was presented during the last 12 sec of the cycle [C/T=5, I/T=5]. These two groups,

Groups 30-30-6 and 60-60-12, represented the "low" I/ T ratio groups.

(5) Group 60-30-6: The instructional stimulus was presented during the last 30 sec of a 60-sec cycle and the trial stimulus was presented for the last 6 sec of the cycle [C/T=10, I/T=5]. This group represented the "low-C/T [control]" group because it had a I/T ratio equal the "low" I/T groups and a C/T ratio equal to that of the "high" I/T ratio groups.

(6) Group 30-6-6: The instructional stimulus and the trial stimulus were illuminated simultaneously for the last 6 sec of the 30-sec cycle. This group represented a "special" case of conditional discrimination in which both stimuli were presented simultaneously, instead of serially.

The comparisons of particular interest for the acquisition of a conditional discrimination were (1) Groups 60-60-6 and 60-60-12 vs. Groups 30-30-3 and 30-30-6 to see whether the absolute duration of I was critical; (2) Groups 30-30-3 and 60-60-6 (I/T's=10) vs. Groups 30-30-6 and 60-60-12 (I/T's=5) to see whether the relative duration of I was critical; and (3) Groups 30-30-3 and 60-60-6 (C/T's=10 and I/T's=10) vs. Group 60-30-6 (C/T=10 and I/T=5) to see whether the critical relative ratio was the C/T ratio or the I/T ratio. Finally, the location of responding was compared between Group 30-6-6 and all other groups to evaluate the occurrence of configurational or instructional control.

Reversal Condition. In order to assess the potency of the I/T ratio for the acquisition and maintenance of a conditional discrimination, the I/T ratios were reversed for specific groups. It was reasoned that a higher I/T ratio (i. e., 10) for groups that were slower to acquire the conditional discrimination should result in a higher level of discriminative performance, and conversely a lower I/T ratio (i. e., 5) for groups that did acquire rapidly might result in reducing conditional discrimination performance. Following the first 18 days of acquisition training, the I/T ratio for Groups 30-30-3 and 30-30-6, and Groups 60-60-6 and 60-60-12 were reversed by changing the trial durations: Group 30-30-3 had the trial stimulus illuminated for the last 6 sec of the cycle and Group 30-30-6 had the trial stimulus illuminated for the last 3 sec of the cycle, and Group 60-60-6 had the trial stimulus illuminated for the last 12 sec of the cycle and Group 60-60-12 had the trial stimulus illuminated for the last 6 sec of the cycle. Hence, Groups 30-30-6 and 60-60-12 which had an I/T ratio of 5 in the initial training phase now had an I/T ratio of 10, and Groups 30-30-3 and 60-60-6 which had an I/T ratio of 10 in the initial phase now had an I/T ratio of 5. Training on these conditions continued for 10 additional sessions.

Data Collection. Responses to the instructional stimulus key (center key) before and during the presentation of each stimulus compound, and responses to the trial stimulus key (side keys) during each stimulus compound were recorded during each session.

Response Measure. The principal response measure for this experiment was a discrimination index. Discrimination indices for each session were calculated in two steps. First, a proportion correct for each instructional stimulus (red and blue) was computed by dividing the pecks during the reinforced stimulus combination by the total pecks during all combinations of that particular instructional stimulus. For example, the proportion correct for the red instructional stimulus was computed by dividing R(W/l*), a reinforced combination of red stimulus on the center key and white on the left side key, by the total pecks during all combinations involving the red stimulus, R(W/l*) / [R(W/l*) + R(W/r-)] = Red %. Second, the actual discrimination index was obtained as the average of the proportions for the two instructional stimuli, Discrimination Index= (Red % + Blue % /2). The discrimination index was taken as being reflective of the *strength* of conditional stimulus control. When the discrimination index was greater than .50, the response rate in reinforced stimulus combinations was higher than in the nonreinforced stimulus combinations. If a subject responded to the stimulus combination independent of any instructional control, overall performance would be at .50 correct. A discrimination index of .50 constituted a lack of conditional discrimination.

CHAPTER III

RESULTS

The discrimination indices during the course of acquisition are presented first and then summary descriptions of the discrimination indices during the last three days of training are described. Observations from these data are shown to be supported statistically by a set of planned comparisons. Then discrimination indices for the four groups exposed to the reversal condition are described. Finally, descriptions of response rates late in training and location of responding are presented.

Two out of the twenty-four pigeons were not included in the following analyses because of their near zero response rate to some, or all, stimulus compounds. Bird #4327's (Group 60-60-12) response rate to all stimulus combinations dropped to near zero level following the tenth day of training, and this low level of responding occurred throughout the remainder of training. Bird #4344's (Group 60-30-6) response rate was near zero level in the presence of one instructional stimulus (blue) throughout the course of training. It is important to emphasize that the exclusion of the data from these two subjects produced smaller differences between the groups, and thus provided a more conservative comparison of the groups.

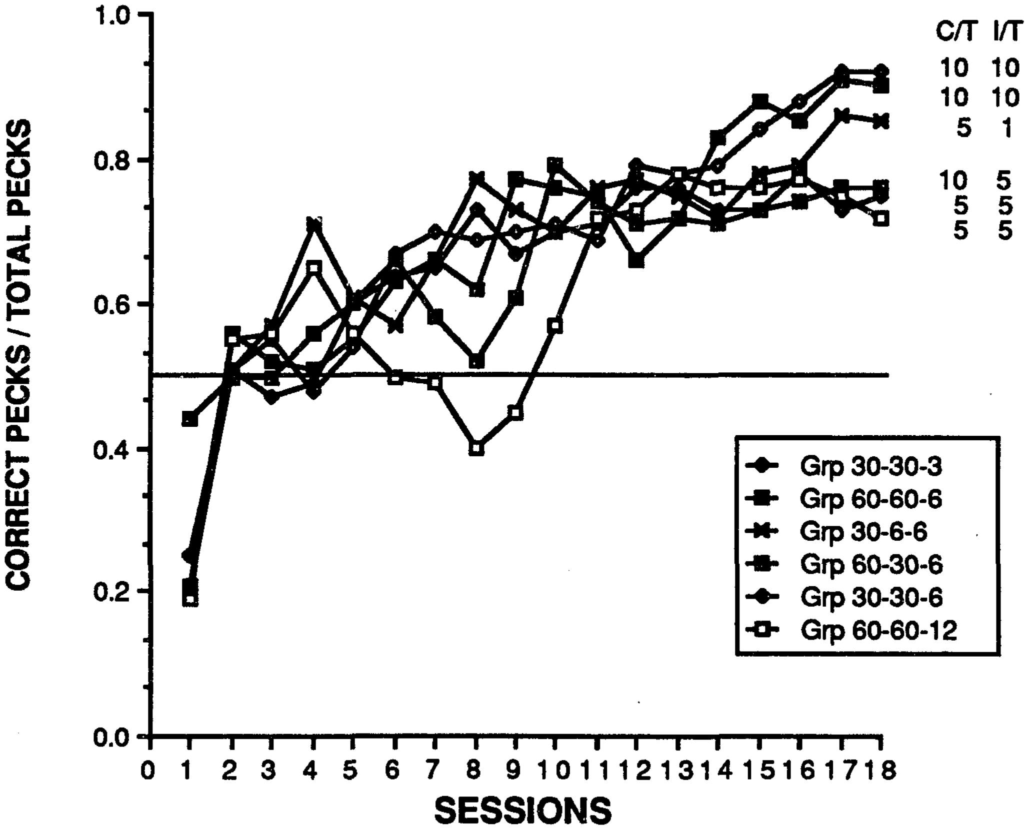
Discrimination Indices

Discrimination indices for each bird were obtained by taking the combined proportion of total pecks, summed over all keys, which occurred to each positive combination as a function of experimental sessions. A conditional discrimination was arbitrarily judged to have been acquired when a subject reached a discrimination index of .70 (i. e., approximately twice as many responses on positive trials as on negative trials).

Figure 6 summarizes the course of acquisition of the conditional discrimination for each group. All groups exhibited a discrimination index at or above 70% by the 12th day of training. The discrimination index function for Group 30-6-6 showed the first consistent deviation from chance performance (i. e., 50%) after the eighth daily session, and this function approached its asymptotic level of discrimination of around 82% after Session 16. Groups 30-30-3 and 60-60-6 showed a more gradual rise from chance performance and reached a level of 90% discrimination by the end of the 18 training sessions. The other three groups, Groups 30-30-6, 60-60-12, and 60-30-6, appeared to asymptote lower at around 75%. Group 30-30-6 showed a gradual rise from chance performance, yet only reached an asymptotic level of discrimination of around 73%. Groups 60-60-12 and 60-30-6 showed an abrupt deviation from chance performance after the eleventh session, and this function reached an asymptotic level of discrimination of around 75% for Group 60-30-6 and 70% for Group 60-60-12 by the end of training. These results show that all groups reliably demonstrated a conditional discrimination by the end of 18 days of training.

To elucidate the effects of particular temporal properties in the acquisition of a conditional discrimination, a comparison between groups was made according to the discrimination index. It should be noted that the reliability of the following trends was supported by statistical analyses, as will be documented later with planned comparisons. It is evident from Figure 6 that the two groups exposed to a high I/T ratio (10) were those which achieved the higher asymptote. This finding was supported by two aspects of these data. Groups 30-30-3 and 60-60-6, which had I/T ratios of 10, reached a discrimination index of around 90%, whereas Groups 30-30-6 and 60-60-12, which had I/T ratios of 5, achieved a discrimination index of 75%. Of special interest was that Group 60-30-6 (the low I/T [control] group) which had a C/T ratio of 10 and a I/T of 5 also achieved an asymptotic discrimination index of around 75%. However, there was one exception to the observation that the

Figure 6. Combined proportion of total pecks, summed over all keys, that were correct, averaged over subjects during conditional discrimination training.


CORRECT PECKS / TOTAL PECKS
1.0
0.8
0.6
0.4
0.2
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
SESSIONS
C/T I/T
10 10
10 10
5 1
10 5
5 5
5 5
Grp 30-30-3
Grp 60-60-6
Grp 30-6-6
Grp 60-30-6
Grp 30-30-6
Grp 60-60-12

I/T ratio had a strong influence on the asymptotic discrimination index. The "simultaneous" group (30-6-6) reached a high discrimination index of around 82% by the end of training, although exposed to a I/T ratio of 1. Data which suggest an alternative account of acquisition for the simultaneous group will be presented below and discussed in the next section.

An examination of the individual discrimination indices within each group also support the observation that the high I/T ratio resulted in a higher level of differential control. The discrimination indices summed over the last three days of discrimination training for each subject are listed in the third column of Table 2. For Groups 30-30-3 and 60-60-6, six out of eight birds reached discrimination indices close to or above 85%. Only three out of seven birds in Groups 30-30-6 and 60-60-12 were close to or at 85% accuracy, and Group 60-30-6 had only one bird which exhibited discrimination performance above 85%. Although there was variation in the individual subjects' discrimination indices within each group, a larger percentage (6/8) of birds in the high I/T ratio groups reached a high level of discrimination (i. e., >85%) than in the low I/T ratio groups (4/10).

These results show that a critical determinant in the final discrimination index achieved by pigeons in a conditional discrimination was the relative duration of the stimulus elements. Evidently the I/T ratio, not the C/T ratio, was the primary influence on the final discrimination level of a conditional discrimination.

These observations were confirmed statistically by planned comparisons. The mean discrimination indices from the last three days of training for each group were entered into a set of five planned comparisons. The mean discrimination indices of the two low I/T groups (Groups 30-30-6 and 60-60-12) did not differ significantly from each other [F (1/10) = .039, p > .25], nor did those

Table 2
Accuracy Data for Individual Subjects

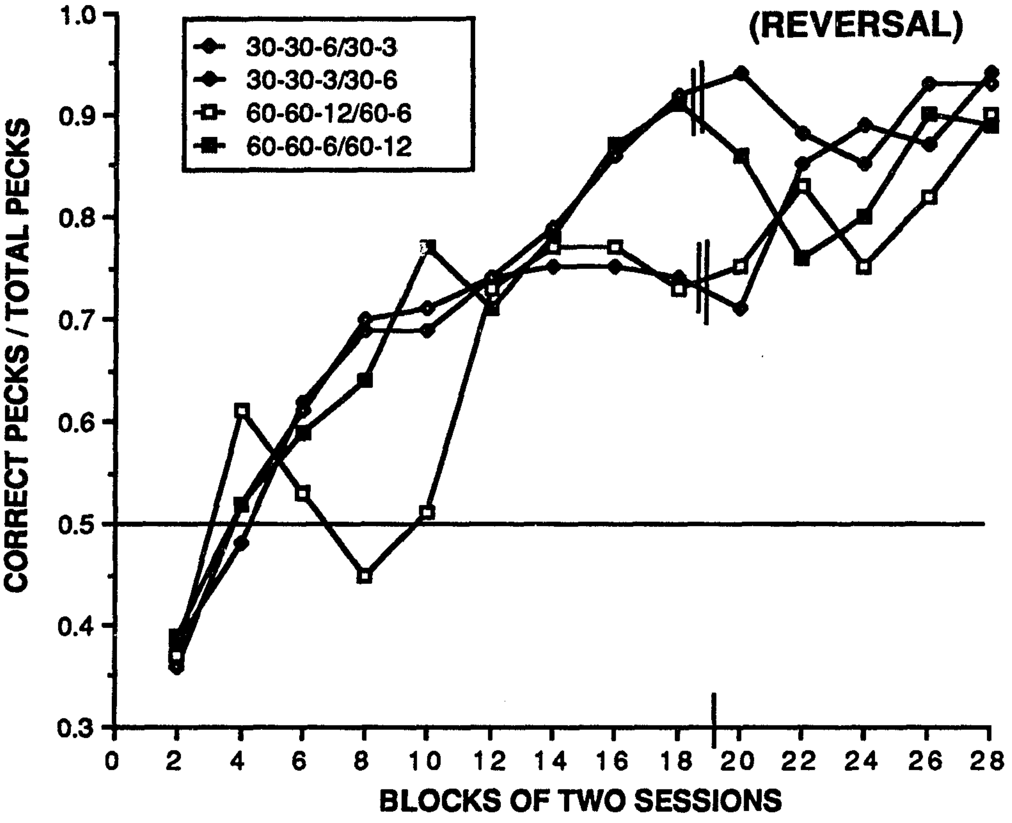
Group	Bird	Percent Correct
30-6-6	4316	.74
30-6-6	10498	.76
30-6-6	5340	.99
30-6-6	2287	.84
30-30-6	2337	.58
30-30-6	4275	.84
30-30-6	4309	.69
30-30-6	4353	.88
30-30-3	4339	.80
30-30-3	4285	.96
30-30-3	2291	.87
30-30-3	10495	.99
60-60-6	4279	.90
60-60-6	10514	.78
60-60-6	12786	.88
60-60-6	4357	.98
60-60-12	1679	.72
60-60-12	4342	.59
60-60-12	4276	.90
60-30-6	10528	.51
60-30-6	10507	.75
60-30-6	2331	.99

of the two high I/T groups (Group 30-30-3 and Group 60-60-6) [F (1/10) = .21, p > .25]. Thus the absolute duration of the instructional stimulus or the trial stimulus was not a factor in the final level of acquisition. However, the combined discrimination indices of the high I/T groups was significantly different from the combined discrimination indices of the low I/T groups [F (1/10) = 9.07, p < .025], confirming the critical role of the I/T ratio. Also, the combined discrimination indices of the low I/T groups did not differ significantly from the mean discrimination index of the low I/T [control] group [F (1/10) = .035, p > .25] whereas the mean discrimination indices of the high I/T groups did differ significantly from that of the low I/T [control] group [F (1/10) = 5.16, p < .05]. This demonstrates that the C/T ratio was not the critical factor in the final level of acquisition.

Figure 7 shows the course of acquisition for four groups, Groups 30-30-6, 30-30-3, 60-60-6, and 60-60-12, both in the initial phase and the reversal phase. (Note that the scale of the x-axis has been compressed into blocks of two sessions). The reversal phase consisted of lengthening the trial duration for the high I/T ratio groups and shortening the trial duration for the low I/T ratio groups. This figure illustrates the effect of reversing the I/T ratios for the four groups (note that the group designations refer to the initial assignment, not the conditions in effect during the reversal phase of training). When subjects in the high I/T ratio groups (Groups 30-30-3 and 60-60-6) were reversed to a low I/T ratio, a transient disruption in the discrimination index occurred between Sessions 20-24, followed by recovery to the previous high levels. Thus, changing to a lower I/T ratio did not permanently retard the discrimination once it was established.

For the subjects in the low I/T ratio groups (Groups 30-30-6 and 60-60-12), changing to the higher I/T ratio produced a noticeable change in the discrimination index, which continued over

Figure 7. Proportion of responses to the stimulus combinations that were correct, averaged over subjects during conditional discrimination training and reversal condition. Note that only four groups are designated and that group designations refer to their initial assignments.


(REVERSAL)
30-30-6/30-3
30-30-3/30-6
60-60-12/60-6
60-60-6/60-12
CORRECT PECKS / TOTAL PECKS
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
BLOCKS OF TWO SESSIONS

the 10 sessions of training. The discrimination index reached a level near that of the high I/T ratio groups by the end of the reversal phase. This reversal showed that the effect of a low I/T ratio was not permanent.

In sum, the acquisition data show that conditional discriminations were demonstrated under all conditions. All groups reached final levels of the discrimination index of greater than 70%. In other words, the temporal arrangements employed in the present study did not alter whether or not a conditional discrimination was learned at all. However, both the acquisition and reversal data show that the rate of acquisition and the final level discrimination index were influenced by the ratio of the instructional stimulus duration to the trial stimulus duration and not by the cycle to trial ratio.

Response Rates

A possibility remains that the final levels of discriminative performance were influenced strongly by rates of responding during the positive compounds. For example, a bird exposed to the high I/T (and thus high C/T) ratio may have a high rate of responding relative to a bird exposed to a low I/T ratio. A higher rate of responding in the positive compound could result in a higher discrimination index. Mean response rates for red+white positive stimulus compounds, blue (or green)+white positive compounds, and combined positive and negative compounds from the last three days of discrimination training for each pigeon are listed in Table 3. Because of the large inter-subject variability in absolute response rates (compare columns 5 and 6 across birds), there was no systematic relationship between overall rates of pecking during the compounds and the discrimination index. This impression was supported by a low correlation between the discrimination index and response rate on positive combinations for the last three days of training by subjects in the high and low ratio groups (r^2=.026).

Table 3
Response Rates for Individual Subjects

Group	Bird	(a) Resp/min on Red*	Resp/min on Blue*	Resp/min on S*	Resp/min on S-	Resp/min on I before I&T
30-6-6	4316	176.6	56.6	116.5	20.8	___
30-6-6	10498	136.3	80.0	108.1	34.4	___
30-6-6	5340	26.6	32.5	29.5	1.1	___
30-6-6	2287	161.6	90.5	126.2	45.4	___
30-30-6	2337	171.0	222.0	196.8	145.1	.15
30-30-6	4275	106.6	160.1	133.5	24.9	4.36
30-30-6	4309	155.6	23.5	89.7	38.8	.71
30-30-6	4353	37.6	10.9	24.2	3.5	.34
30-30-3	4339	71.5	122.6	97.1	24.5	.18
30-30-3	4285	104.9	28.9	66.8	2.5	.00
30-30-3	2291	68.2	25.6	46.9	7.6	.00
30-30-3	10495	19.2	160.3	89.6	0.0	.00
60-60-6	4279	169.3	126.3	147.8	16.1	.01
60-60-6	10514	27.3	16.0	21.6	7.0	.03
60-60-6	12786	50.5	22.1	36.6	5.3	.00
60-60-6	4357	68.4	15.6	42.0	.8	.00
60-60-12	1679	10.7	5.5	8.2	2.8	1.37
60-60-12	4342	18.2	10.4	14.3	13.0	.03
60-60-12	4276	26.3	30.1	28.2	3.2	.01
60-30-6	10528	37.0	13.0	25.0	23.7	.25
60-30-6	10507	109.0	40.4	74.8	25.3	.72
60-30-6	2331	208.3	158.0	183.2	1.2	.01

(a) For half of the subjects the instructional stimulus was actually green instead of blue.

Most subjects did show some individual stimulus "preference", pecking more rapidly during one stimulus combination than during the other (compare columns 3 and 4 for each bird). Sixteen of the twenty-two birds had a higher rate of responding in the presence of the red+white positive compound than in the presence of the blue (or green)+white positive compound.

Response rates to the instructional stimulus prior to the stimulus compound presentation for individual subjects are presented in the last column of Table 3. (Note that the subjects in the simultaneous group (30-6-6 were not exposed to the instructional stimulus before the presentation of the trial stimulus). The individual data show that most subjects, with two exceptions, responded very little, if at all, to the instructional stimulus during its pre-trial presentation. Subjects #4275 (Group 30-30-6) and #1679 (Group 60-60-12) responded at low rates during this period, 4.36 and 1.37 responses per minute respectively and these rates were somewhat lower than their response rates during the stimulus combination period. The majority of the subjects' responding occurred during the period in which the instructional stimulus and the trial stimulus were both illuminated. This finding shows that instructional stimuli did not directly evoked responding prior to the presentation of trial stimuli.

Response Location

The purpose of examining the location of responding during the stimulus compound period was to assess the function of the "designated" instructional stimulus within the stimulus combination. The instructional stimulus was always presented on the center key and the trial stimulus was always presented on a side key. If the center key stimulus was functioning as an "instructional" stimulus, responding should be localized on the trial key; the instructional stimulus activated the discriminative stimulus (trial key)-reinforcer relation, rather than directly controlling responses. However, if the instructional stimulus was functioning as part of a configurational cue, along with the trial cues, responding might be localized on the instructional key, or on the trial keys, or some combination of both locations. One possible outcome which would strain an instructional account is that one stimulus combination controlled responding to one key (e. g., center) and the other stimulus combination controlled responding to a different key (e. g., side). If so, then it would be expected that an analysis of overall responding should show the location of responding to be roughly equal on both the instructional and the trial key. Finally, it should be noted that in this autoshaping procedure the birds did not have to peck anywhere in order to receive reinforcement.

Figure 8 shows the mean percentage of total pecks that occurred to each key during the stimulus compound period averaged over the last three days of discrimination training (response location data for individual subjects are presented in Table 4). The four bars for each group represent the percentage of total pecks to the instructional key when the stimulus compound was followed by food (I+), the instructional key when the stimulus compound was not followed by food (I-), the trial key when the stimulus compound was followed by food (T+), and the trial key when the stimulus compound was not followed by food (T-). Pecks by the high I/T groups (Groups 30-30-3 and 60-60-6) and the low I/T groups (Groups 30-30-6, 60-60-12, and 60-30-6) were combined to examine whether the I/T ratio affected response location. Figure 8 reveals that for both the high and low I/T groups the large majority of responding during the presentation of both stimuli occurred to the trial key. In fact, less than 1% of the total pecks occurred to the instructional key for the high I/T group. It should be noted that the increased percentage of instructional-key pecks in the low I/T groups was caused by two subjects (Birds #4275 and #4309 in Groups 30-6-6). This finding shows that although instructional stimuli did exert conditional control over responding, they did not directly evoked pecking.

Figure 8. Percent of total pecks that occurred to each key during the stimulus combinations averaged over the last three days of conditional discrimination training. Four bars for each group indicate percent pecks to instructional stimulus followed by food (I+), percent pecks to instructional stimulus followed by no food (I-), percent pecks to trial stimulus followed by food (T+), and percent pecks to trial stimulus followed by no food (T-). Note that Groups 30-30-3 and 60-60-6 are combined (High), and Groups 30-30-6, 60-60-12, and 60-30-6 are combined (Low).

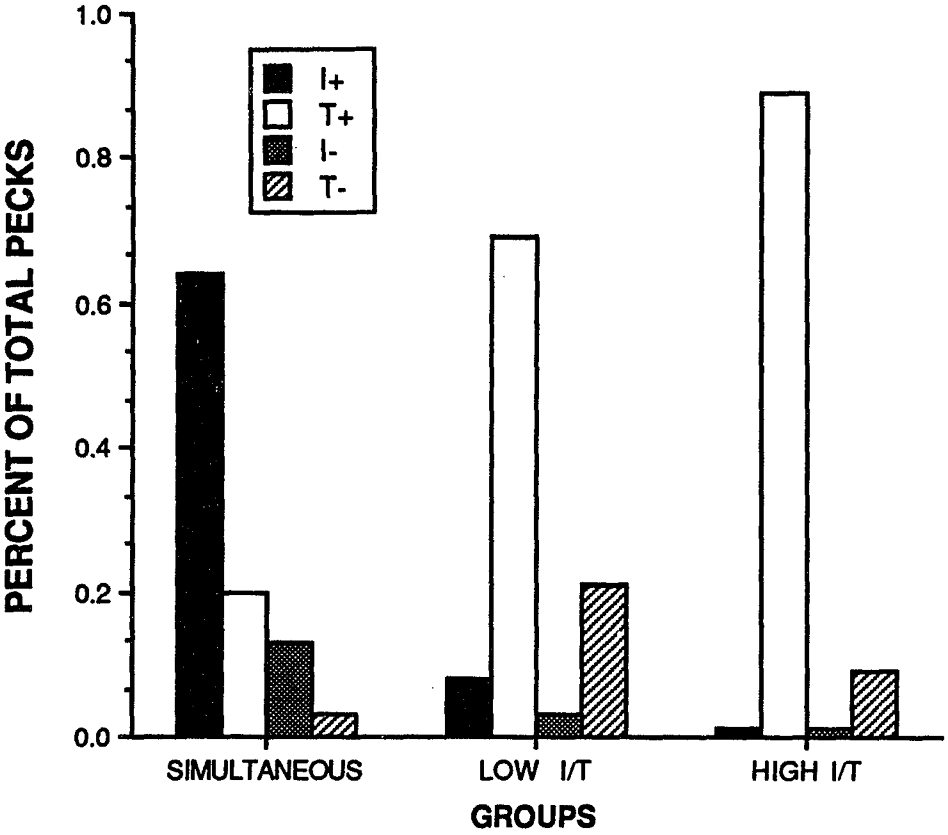

1.0
0.8
0.6
0.4
0.2
0.0
PERCENT OF TOTAL PECKS
I+
T+
I-
T-
SIMULTANEOUS
LOW I/T
HIGH I/T
GROUPS

Table 4
Response Location Data for Individual Subjects

Group	Bird	Percent of total pecks to I+	Percent of total pecks to I-	Percent of total pecks to T+	Percent of total pecks to T-
30-6-6	4316	.64	.14	.21	.01
30-6-6	10498	.47	.23	.28	.02
30-6-6	5340	.95	.02	.03	.00
30-6-6	2287	.48	.13	.26	.13
30-30-3	4339	.00	.00	.80	.20
30-30-3	4285	.00	.00	.96	.04
30-30-3	2291	.00	.00	.86	.14
30-30-3	10495	.00	.00	1.00	.00
60-60-6	4279	.00	.00	.90	.10
60-60-6	10514	.02	.03	.74	.21
60-60-6	12786	.00	.01	.88	.11
60-60-6	4357	.00	.00	.98	.02
30-30-6	2337	.00	.00	.58	.42
30-30-6	4275	.34	.06	.51	.09
30-30-6	4309	.63	.01	.06	.30
30-30-6	4353	.00	.02	.87	.11
60-60-12	1679	.00	.01	.75	.24
60-60-12	4342	.00	.01	.60	.39
60-60-12	4276	.00	.00	.91	.09
60-30-6	10528	.02	.02	.49	.47
60-30-6	10507	.00	.10	.76	.14
60-30-6	2331	.01	.00	.99	.01

For subjects in the simultaneous group, in which the stimulus events were presented coextensively, the majority (around 63%) of the total responding occurred to the instructional key and around 20% of the responding occurred to the trial key. Thus, the location of responding was more spread out to both key types. Although the birds were not required to peck any key, these results indicate that the subjects demonstrated differential patterns of response location based on the temporal arrangement of the stimulus compound. In sum, these results suggest that the "instructional" stimulus functioned as an activator of discriminative stimuli when it preceded the trial stimulus. That is, for a large majority of subjects in the low and high I/T groups, the center key stimulus functioned as an "instructor" for which discriminative cue would be followed by reinforcement. In comparison, when the "instructional" stimulus was presented simultaneously with the trial stimulus, the stimulus display functioned as a configurational cue.

CHAPTER IV

DISCUSSION

The results of the present experiment revealed three general findings about the acquisition of a conditional discrimination by pigeons in an autoshaping procedure. First, the formation of a conditional discrimination by pigeons occurred under all duration values of the instructional stimulus. Thus, the present findings fail to support Williams' (1982: Experiment 1) observation that presenting the instructional stimulus throughout the cycle prevents the acquisition of a conditional discrimination. Williams' procedure was identical to that of the present study except for one difference; the trial stimulus was either a white horizontal line or a white circle. Although it has been demonstrated that pigeons learn conditional discriminations more rapidly when trial stimuli consist of hues than when trial stimuli consist of lines or forms (Eckerman, 1975), it is hard to see why such a procedural difference would account for the total lack of a conditional discrimination in Williams' (1982) experiment.

Second, the results of the present study showed that certain features of the temporal arrangements did influence the final level of differential control by the instructional stimulus. Although a conditional discrimination was demonstrated under all conditions, the final level of the discrimination indices in training and reversal phase was affected by the duration of the instructional stimulus relative to the duration of the trial stimulus.

Third, the response location data provided suggestive evidence that two types of stimulus control (i. e., discriminative and instructional) can be distinguished in terms of a key location by the pigeon. Two types of accounts for accurate performance on a conditional discrimination are usually proposed (e. g., Carter and

Werner, 1978). The first is a configurational approach in which the stimulus compound functions as a configuration and controls an appropriate response to each configuration. It was suspected that the location of responding to a two-stimulus configuration would be distributed across both stimuli. The second type of account for successful conditional discrimination performance suggests that one stimulus functions as an "instructor" for the activation of another stimulus-response-reinforcer relation. Accordingly, the instructional stimulus would not be expected to control responding, but rather responding would occur to the stimulus controlling the response-reinforcer relation. It was assumed that this type of stimulus function emerges when stimuli within a combination are presented in a serial fashion.

Conditions for Establishing Instructional Control

The findings presented above suggest that antecedent stimuli may have at least two functions in a conditional discrimination. One function, a discriminative function, is the control over a response-reinforcer relationship. For example, a stimulus, say a white keylight, signals which particular response, a bird's keypeck, will produce food. The second function, or instructional function, is the control over a three-term, stimulus-response-reinforcer relationship. In this case, the stimulus functions to momentarily strengthen, or "gate", the ability of another stimulus to control responding. The pigeon's keypeck to the white stimulus depends on whether a red or blue keylight is present. An important question, then, is under what conditions does a stimulus acquire instructional capabilities?

One stimulus, lets say S1, can both control responding based on its predictive (e. g., temporal) relationship with the reinforcer and momentarily strengthen the ability of a second stimulus (S2) to control responding. If a stimulus combination of S1 and S2 is a valid predictor of food, S1 and S2 can compete with each other for control over the response-reinforcer relation. When they are presented simultaneously S1 and S2 are likely to become associated with each other and form a configurational cue (Rescorla, 1972). In the simultaneous case, S1 and S2 form a unitary, discriminative cue which controls the response-reinforcer relationship. However, when S1 is presented prior to S2, S2 controls responding since it is more (temporally) predictive of food. S2, in the serial case, functions as a stimulus which directly controls a response-reinforcer relationship, whereas S1 functions to gate the S2-response-reinforcer relationship. Hence, the instructional function of S1 emerges when: (a) S2 is a better predictor of the response-reinforcer relation than S1 and, (b) S1 is in a conditional relation with the S2-response-reinforcement relationship. One way to think of this process is that when S1 is "decoupled" from competing with S2 for control over the response-reinforcer relation, S1 exhibits an "higher-order" ability to control the S2-response-reinforcer relationship. The decoupling of S1 from S2 in the control over responding is directly related to the extent to which S2 is better predictor (e. g., temporally) of reinforcement. It should be noted that this decoupling process is, most likely, not an all-or- none effect. Rather the suggestion is that the instructional function of S1 is most likely to emerge when it is in a conditional relation with the S2-response-reinforcer relationship and, S2 is more predictive of reinforcement than S1.

This finding of a hierarchical signaling function based on the temporal placement of stimulus events in a compound presents an interesting parallel to Holland's (1983) results in the feature-positive discrimination. To review briefly, his experiments examined feature-positive (AX+, A-) discriminations in which one stimulus, A, was reinforced when presented in compound with a feature stimulus, X, but was not reinforced when presented alone. Holland's findings suggested that when A and X were presented simultaneously on reinforced compound trials, the more predictive positive feature, X, controlled the rats' responding. But when X preceded A on reinforced compound trials, X additionally acquired the ability to activate the A-reinforcer relation. Importantly, the results of the present study suggest similar effects of temporal arrangement may operate for higher-order control in a conditional discrimination. Studies of transfer of performance from the feature-positive discrimination to the conditional discrimination procedure may clarify this issue. It would be of particular interest to determine if discriminative performance acquired with the feature-positive procedure would transfer to a conditional discrimination procedure.

Final Levels of Discriminative Performance

The major finding from the current study was that the final level of discriminative performance was directly related to the relative duration of the instructional (I) and trial (T) stimuli. Specifically, the greater the I/T ratio, the better the accuracy achieved by pigeons.

This view was further supported by the findings in the reversal condition. The original low I/T ratio groups that were exposed to a novel high I/T ratio condition substantially improved their performance to a level that equalled that of the original high I/T ratio groups. The original high I/T ratio groups when exposed to a new low I/T ratio showed some initial disruption in their discriminative performance with a subsequent return to their previous performance. This initial decrement in performance appears to be a type of "behavioral inertia" (Hake, Azrin, and Oxford, 1967) in which discriminative behavior at a new I/T ratio has changed but is biased in the direction of the behavior at the previous I/T ratio condition. Williams (1982: Experiment 1) also ran a reversal condition following acquisition training: For one group the instructional stimuli (i. e., the color cues) were presented for the entire 30-sec cycle after they had been previously presented for only the last 5 sec of the cycle, and for another group the instructional stimuli were presented for the last 5 sec of the 30-sec cycle after they had initially been presented for the entire cycle. He also found a similar inertia-type effect during the reversal condition. When subjects in the reversal condition had the instructional stimuli on during the entire cycle, an initial transient disruption of the discrimination occurred, followed by recovery to the previous level. But the group which was presented the instructional stimulus for only the last 5 sec of the cycle showed an immediate improvement in discrimination performance.

My earlier account suggested that a stimulus within a conditional discrimination is involved in two types of stimulus-control relationships; one is with a response-reinforcer relationship and the other is with another stimulus-response-reinforcer relationship. The instructional control exerted by one stimulus (S1) reflects the combined effect of its competition with a second stimulus (S2) for control over a response-reinforcer relation as well as the higher-order control over the S2-response-reinforcer relation. S1 can simultaneously exhibit both functions, yet the degree of control exerted by each function depends on which predictive relationship is more favorable. The proposal was that S1 exerts a greater degree of its instructional function to the extent that S2 is a better temporal predictor of reinforcement than S1. In other words, if S1 is decoupled from its competitive relationship with S2 for control over responding, then the greater probability that S1 exerts its instructional control over the S2-response-reinforcer relation. From this perspective, the <u>amount</u> of decoupling influences the level of accuracy in instructional control. That is, the greater the degree to which S2 is a better predictor of food than S1, the higher the probability that S1 functions as an instructional stimulus.

The decoupling effect might typically involve stimulus type contrasts which may or may not affect expectancy levels. Some kinds of stimulus contrast may be discrete vs. diffuse, spatial discontinuities, or temporal durations. For example, consider the case in which the stimulus combination was a diffuse S1 (e. g., houselight) and a discrete S2 (e. g., keylight), rather than both S1 and S2 being discrete. According to my account a diffuse S1 would function as a good instructional stimulus, since a discrete stimulus would function as a better predictor of food. In support of this view, Williams' (1982: Experiment 6) found that presenting diffused color cues (the houselight was turned off) throughout the 30-sec cycle resulted in the acquisition of a conditional discrimination.

In the present study, the amount of difference between the temporal durations of stimulus events could have similarly influenced the decoupling of the red and blue (or green) cues from competing with the white keys for evocative control. That is, differences between stimulus durations reflected in the I/T ratios could have facilitated the decoupling of S1 from S2. The greater the I/T ratio, the larger the temporal discrepancy between the stimulus elements, the faster the decoupling occurs.

There are several findings in the serial feature discrimination literature that support this account of instructional control. First, occasion setting is acquired more rapidly if the feature cue is of a longer duration than the common element (e. g., Rescorla, 1985). Second, Holland (1986) found that the acquisition of instructional control was favored when the interval between the offset of the feature and the onset of the common element was relatively long. Third, Ross (1983) found that pre-training feature-reinforcer associations retarded, but did not prevent the occasion-setting function of the feature. Given the enhanced predictive power of the feature for food, it may have required more discrimination training for the feature to be decoupled from the common element. Finally, Lamarre and Holland (reported in Holland, 1983) found that the rate of acquisition of serial feature-negative discrimination performance was more influenced by the occurrence of an interval between the feature and common element than by the particular intervals involved. Rats that received nonreinforced compound trials comprising a 30-sec light feature followed by a 30-sec empty trace interval followed by a 60-sec noise excitator acquired the feature-negative discrimination more rapidly than rats that received 60-sec light then 60-sec noise compounds, but no more rapidly than rats that received 60-sec light separated from the 60-sec noise by a 60-sec trace interval. Importantly, the results of Lamarre and Holland suggest a ratio effect in the timing functions involved in the generation of the hierarchical stimulus control.

Simultaneous and Serial Presentation of Stimuli

I would now like to discuss the implications of a serial vs. simultaneous presentation of stimuli in a conditional discrimination. Throughout the discussion I have assumed that the simultaneous presentation of stimuli results in configurational control, whereas the serial presentation of stimuli is a condition under which an instructional function of stimuli emerges. One finding in the present study of conditional discrimination was that the location of responding was dependent on the temporal arrangement of the stimulus elements in the combinations. When the stimulus elements were simultaneous, a majority of the pigeons' responding during positive stimulus combinations was localized to the putative instructional stimulus with some responding to the trial key. For all birds, stimulus sequences were arranged such that differential responding to positive and negative combinations could not be based on any single component, since each component predicted food on 50% of its occurrences. Furthermore, when two stimuli are presented simultaneously they are both equally predictive of food, because they are the same duration. It should be clear that a configurational account does not demand that this particular pattern of response location occur. The issue here is that the particular pattern seen in the simultaneous case would be problematical for an instructional control account.

The serial presentation of stimuli, however, resulted in a large majority of pecks to the side keys with very little pecking to the center key. This pattern of responding is, then, what would be expected from an instructional approach. The lack of pecking to the instructional stimulus cannot be attributed to the pigeons simply ignoring it. If so, then the discriminative index for each bird should have been around 50%, yet discriminative performance was quite good. Additionally, it is striking that, in most cases, no responding occurred to the instructional key. It would seem likely that the "instructional" key should have acquired some secondary evocative control since it was present just before and during the trial key-reinforcement relation (e. g., Rashotte, 1981). There is an alternative account based on the configuration view that would suggest localized responding to the side key in the serial case was the result of pecking the most temporally predictive key in the positive stimulus configuration.

These data suggest that stimuli within a conditional discrimination can function in different ways depending on the temporal arrangement of the stimulus elements. A simultaneous stimulus combination functions as a configurational cue so that the compound acquires discriminative control. However, if one stimulus precedes another stimulus, it acquires an instructional function distinct from that of a discriminative function. Rather, the preceding stimulus apparently acts to gate the relation between the trial stimulus, response, and reinforcement. Clearly, one fundamental requirement for acquisition of instructional control is the presence of a conditional relation. These data further suggest that another critical condition for a stimulus demonstrating "true" instructional control is the temporal arrangement: the onset of the "instructional" stimulus must precede the onset of a stimulus-response-reinforcer relation.

Although it is difficult to see how the configurational account could be entirely ruled out, the data in the present study seem to favor an instructional account. The evidence for configurational and instructional control based on response location is tenuous, at best. The response location data are only a preliminary and suggestive attempt, whereas the topography tagging method of Holland (1977) and transfer tests (discussed below) provide much more convincing evidence for separate stimulus functions. On reflection, transfer studies would have provided stronger evidence of separate stimulus functions. Consider the case where the red (or instructional) stimulus in the serial procedure is now presented in combination with a novel yellow (trial) stimulus. If the red stimulus (in combination with the white stimulus) had functioned as a configurational cue, then discriminative performance would be expected to return to the chance level, because the white cue would not available to form the configuration. If the red stimulus acquired an instructional function, then there should be no change in performance, because the birds have learned which side key will be followed by food when red is present. Rescorla (1985), for example, using a feature-positive discrimination task reported substantial transfer of a stimulus's occasion-setting power to novel stimulus cues. The observation that serially-trained instructional stimuli did not retard discriminative performance to new trial stimuli and that simultaneously-trained instructional stimuli did retard performance would suggest that the differential transfer of instructional powers is the result of a difference in stimulus function.

Summary

There appear to be at least two independent mechanisms whereby stimuli exert control over behavior in a conditional discrimination. Antecedent stimuli may control behavior through their direct relationship with response-reinforcer contingencies, and antecedent stimuli may play an instructional function in which they momentarily strengthen stimulus-response-reinforcer contingencies. The present data seem sufficient to suggest that we need to begin acknowledging an instructional function of stimuli and devise experiments which evaluate its relationship to other hierarchical signalling functions, such as occasion setting, in addition to further elucidating its own controlling variables. It was suggested that the demonstration of instructional control was a function of a conditional relation with other stimuli and the serial presentation of stimulus events. The asymptotic level of conditional control was shown to be a function of the ratio of the instructional-stimulus duration to trial-stimulus duration. It was proposed that the controlling features of the formation and final level of instructional control may be related to the relative temporal durations of stimuli. While the specific account proposed here may be incomplete in some ways, it does provide a description of instructional control by relative time and illustrates the potential power of a temporal analysis of stimulus control.

Finally, data such as those presented here suggest some broader implications. It appears that relatively simple manipulations, such as the temporal arrangement of elements within a compound, can affect the content as well as the amount of learning. Under some circumstances, conditioned stimuli can acquire higher-order functions, like instructional control, but there has been little consideration of such stimulus functions in other areas of learning. The concept of contextual control had been defined both structurally and functionally by various researchers (e. g., Balsam, 1985). When defined structurally, context generally refers to all aspects of an experimental environment that are presented concurrently with a conditioned stimulus. When defined functionally, it is used to mean any stimulus that modulates the control exerted by other stimuli. A number of descriptions have been offered as to how the context influences behavior. Some functions of the context imply that it is just like any other cue, whereas other functions are uniquely ascribed to context, per se. Although the parallel between instructional stimuli and contextual stimuli has not been explored in detail, their actions may be similar. Both instructional and contextual stimuli can be functionally described as events in the presence of which one, rather than another, relationship holds true and, contextual stimuli usually precede conditioned stimuli in time in a manner that promotes the acquisition of instructional control.

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