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I am submitting herewith a dissertation written by Timothy L. Cleary entitled "An Investigation of Contrast Effects, Their Relationships and a Theoretical Resolution." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Psychology.

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AN INVESTIGATION OF CONTRAST EFFECTS,
THEIR RELATIONSHIPS AND A
THEORETICAL RESOLUTION

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ABSTRACT

Behavioral interactions associated with differentially reinforced stimuli, which participate in the formation of generalization gradients, are investigated.

Local contrast effects have been found to be one of the major forms of interaction in multiple schedules. A component in a multiple schedule may occur in time between two other components and may be locally influenced by either the preceding or following component.

To investigate the influence of surrounding components, subjects were exposed to a simple three component multiple schedule and local contrast due to the preceding component was found early in training, with some indication that local contrast due to the following component appeared after prolonged training. Such backward-acting contrast was less reliable and less clear than was forward-acting local contrast.

It has been suggested that local contrast may be the precipitating cause of behavioral contrast, an overall response rate interaction which can persist after local contrast has disappeared. To investigate the relation of local to behavioral contrast, a session-by-session measure of each type of contrast was made and their correlation over the course of discrimination training was studied. It

was found that the correlation of local contrast with behavioral contrast decreased over discrimination training, although behavioral contrast increased.

Three plausible theories have been advanced to account for local contrast. The two most clearly defined of these, additivity and response competition theories, were compared by examining the effect of the duration of a preceding S+ on contrast effects in a following S-. An adaptation of additivity theory, which applies the effects of sign-tracking movements, was able to account for two features of the data where behavioral competition theory could not.

The assumptions of the sign-tracking theory were investigated further by taking a measure of sign-tracking movements during a successive discrimination in which the duration of a preceding S- component was shown to have an effect on a following S+. The pattern of movement by the subjects accounted for the duration effect found.

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CHAPTER I

INTRODUCTION

The Study of Discrimination Learning

The research reported here attempts to resolve a number of questions that have arisen in the area of discrimination learning. Behavior always occurs in the presence of a specific set of stimuli and organisms usually adapt their behavior to conform to the information in the available environmental signals. Discrimination learning is the name given to the process by which this adaptation occurs. It may be studied experimentally with a number of methods; two of these are classical and operant conditioning.

Classical conditioning is based upon the fact that certain types of stimulation can evoke a measurable reflexive response, called an unconditioned response. The stimulation is called an unconditioned stimulus. When the unconditioned stimulus is preceded by a salient signal for a number of times, the signal will come to evoke the unconditioned response in some form, even when the unconditioned stimulus is not presented. The signal is then said to be a positive conditioned stimulus.

The conditioned stimulus must be a valid signal of the unconditioned stimulus for classical conditioning to be possible, valid meaning that it precedes a presentation of the unconditioned stimulus much more often than it does not. A stimulus which is presented during classical conditioning, but for the majority of its presentations does not precede the unconditioned stimulus, is a negative conditioned stimulus. Presentations of a negative conditioned stimulus evoke a reaction that is opposite to the unconditioned response. This is revealed, for example, when its presentation is superimposed upon a presentation of the positive conditioned stimulus and the conditioned response is greatly reduced (Pavlov, 1927).

In classical conditioning, discrimination learning is demonstrated by the reflexive response in the presence of the positive conditioned stimulus while the reflexive response in the presence of the negative conditioned stimulus is withheld (Pavlov, 1927). Behavior is then shown to conform appropriately to the available environmental signals.

A second major experimental method of studying discrimination is through operant conditioning. Operant conditioning relies on the fact that when certain environmental stimuli, called reinforcers, follow a definable behavior, the behavior increases in the frequency of its occurrence. Reinforcement is made contingent upon

the occurrence of the predetermined response. Stimulus discrimination is produced by reinforcing responses mostly in the presence of a specific, positive stimulus. Periods when the operant responses are mostly not reinforced may be signaled by the presence of a different, negative stimulus.

Discrimination is defined as the occurrence of a much greater proportion of operant responses in the presence of the positive stimulus than in the presence of the negative stimulus.

Proof that the organism's behavior is controlled by the presence of discriminative stimuli is obtained when the stimuli are changed in one or more ways and there is a correlated change in the organism's behavior. This relationship is experimentally demonstrated by a generalization gradient, which is a plot of a measure of responding for each stimulus of a continuous stimulus set.

For example, when pigeons are trained to respond in the presence of a 550 millimicron light, and not to respond in its absence, and are then tested on a range of different wavelengths, the greatest number of responses are made to the originally trained stimulus (e.g., Guttman & Kalish, 1956). The greater the difference between a test wavelength and the original positive wavelength, the fewer responses are made to it, and thus a gradient is formed.

A stimulus generalization gradient implies two things:
1. discrimination has formed and behavior has come under

the control of some aspect of the stimulus and 2. behavior in the presence of new stimuli may be determined by their similarity to previously encountered stimuli. Given that environmental cues guide the expression and determine the form of behavior, it is important to understand the process of discrimination learning.

The Simple Signal Recognition Model

To account for discrimination learning, experimental psychology began with the most parsimonious approach and attempted to use the behavioral principles revealed by simple conditioning paradigms to predict and explain more complex discrimination situations. The theory of discrimination and stimulus generalization of Spence (1937, 1942) followed this general approach. The attraction of Spence's theory was that it required no notions beyond simple positive stimulus conditioning, negative stimulus conditioning and stimulus generalization.

In Spence's model, termed a simple signal recognition model by Blough (1984), stimuli are said to evoke responses due to the correspondence of the internal effect that they produce with the internal effect that is produced by a trained, positive stimulus. The more similar any untrained stimuli are to the trained stimulus, the more the

correspondence that is assumed to exist among their internal effects.

On a continuum, those stimuli lying on the same dimension as a positively reinforced stimulus will evoke responding and the further they are removed from the positive stimulus, the less responding they will evoke. Conversely, those stimuli lying on the same dimension as a stimulus which inhibits responding will also inhibit responding and the further they are removed from the negative stimulus, the less they will inhibit responses.

According to the simple signal recognition model, discrimination training between two stimuli lying along the same continuum results in the establishment of an excitatory gradient around the positive stimulus and an inhibitory gradient around the non-reinforced stimulus. These gradients overlap to the degree to which the discriminated stimuli are distanced along the continuum. The tendency to respond to any stimulus along the dimension is determined by the net result produced when the inhibitory tendency for that stimulus is subtracted from the excitatory tendency. The basic assumptions of the theory have held up fairly well under vigorous scrutiny over the years, but some failings have been found. Two of these failings follow.

The first failing involves the shift in the peak of a postdiscrimination gradient that is predicted by the

theory. A peak shift refers to a greater number of responses being made to a stimulus other than the originally trained stimulus. Suppose a subject is trained to respond discriminately to two stimuli, both on the same continuum, and then is tested on a series of stimuli from the continuum. Often the greatest number of responses are made to a stimulus further removed from the originally trained negative stimulus than are made to the originally trained positive stimulus, an outcome predicted by the simple signal recognition model.

Hanson (1959) demonstrated this feature of postdiscrimination gradients and confirmed the prediction of Spence's theory. However, the theory failed to account for the obtained increase in overall response rate to stimuli around the shifted peak, compared to a gradient obtained after single stimulus training.

A second failing of the simple signal recognition model is its inability to account for dimensional contrast shoulders in generalization gradients. For example, it is common for responding to a positive stimulus which is nearby on a continuum to a negative stimulus to be greater than, not less than, responding to positive stimuli further removed from the negative, inhibitory stimulus. Malone (1975) demonstrated this effect. Two of four adjacent line tilt stimuli were presented with occasional reinforcement and two were presented in extinction. Response rate was

typically highest to the positive stimulus nearest the border with the negative stimuli and was typically lowest in the negative stimulus nearest the border with the positive stimuli. This demonstration and others (Blough, 1975; Blough & Blough, 1985; Catania & Gill, 1964; Farthing, 1974; Rowe & Malone, 1981) argue against a simple gradient summation model of discrimination and stimulus generalization. Total response strength is not a simple increasing function of responding produced by similarity to a positive stimulus algebraically summed with a simple decreasing function of responding produced by similarity to a negative stimulus.

Aspects of Discrimination Formation

Models based on a simple interaction of excitatory and inhibitory gradients must take into account some of the details of discrimination formation. Experimental work has suggested that the determinants of postdiscrimination gradients are much more complex than that implied by just a summation of excitatory and inhibitory influences on response systems (cf. Mackintosh, 1974).

Local (Transient) Contrast

It appears that the control exerted by a stimulus depends not only on the reinforcement history in the presence of the stimulus, but on the sequence of stimuli

within which a stimulus is presented. Malone and Staddon (1973) showed that response rates during the presentation of a stimulus could be inversely related to the average response rates controlled by the immediately preceding stimuli, an effect that was termed local contrast.

Pigeons were presented eight line tilt stimuli with reinforcement accompanying only a vertical line tilt and extinction accompanying another seven. When two or more schedules of reinforcement are presented in sequence, each in the presence of different stimuli, the procedure is called a multiple schedule (Ferster & Skinner, 1957). The combinations of stimuli and reinforcement schedules are the components of the multiple schedule. Each of the components is usually presented for a fixed amount of time before a change to another component is made, but this need not always be the case.

In Malone and Staddon's (1973) study, after responding stabilized in each of the components, the response rate to a given stimulus depended on its similarity to the vertical positive stimulus and upon the average response rate in the preceding stimulus. A stimulus could produce negative contrast in a following component if the average response rate in the following component was lower or it could produce positive local contrast if the average response rate in the following component was higher.

Positive local contrast may appear as a pattern of responding within a component, with elevated responding at the beginning, while negative local contrast often appears as depressed responding at the beginning of the component.

Local contrast has been found to be a function of the stage of discrimination. It can occur in the early stages of training and disappear when discriminated responding stabilizes. For this reason, it is sometimes referred to as transient contrast (i.e., Nevin & Shettleworth, 1966).

In transient contrast, the effect of a change in reinforcement in one schedule may affect an interacting, unchanged schedule only when the changed schedule precedes it. Thus, Boneau and Axlerod (1962), using VI schedules, showed that S+ component responding was greater following an S- component than it was following another S+. This sequential contrast effect can disappear after a few discrimination sessions. O'Brien (1968), for example, found transitory contrast in human subjects that disappeared after ten discrimination sessions. Transient contrast can also occur with FI schedules (Staddon, 1969).

Local contrast is affected by the duration of the preceding S- component. Bernheim and Williams (1967) showed that when rats ran in a running wheel during two components of food reinforcement, the longer a preceding high-reinforcement-frequency component, the greater the contrast effect on a following low-reinforcement-frequency

component. A duration effect was also found by O'Brien (1968) with longer durations of S-. The longer durations of S- produced greater contrast. For pigeon subjects and a broader range of S- durations, Wilton and Clements (1971) reported the same duration effect.

Transient contrast has been found to depend upon the discriminability of the component stimuli. In Bernheim and Williams experiment (1967), positive contrast was not found when the stimuli for the S+ and S- components were from different modalities, but was found when the component stimuli were both from the auditory modality. Negative contrast was found to be greater when the stimuli were from the same modality as well. Malone and Staddon (1973) reported greater contrast with more similar line tilt stimuli in a maintained generalization procedure.

A closer examination of sequential effects during discrimination learning reveals that at early stages of a discrimination, similarity to the preceding stimulus can influence responding to the currently presented stimulus. Hinson and Malone (1980) found that during the first several weeks of training, response rates tended to be relatively depressed the more similar the presented stimuli were to the immediately preceding stimulus. The effect, or effects, was termed local dimensional contrast.

Contrast and Generalization

A stimulus generalization gradient is the main measure of stimulus control (cf. Rilling, 1977) and it consists of a plotting of a response measure against an ordered series of stimulus values. The sequence of presentation of stimuli during discrimination training, however, affects the responding to each stimulus through the effects of local contrast and dimensional contrast. So it would appear that the study of local contrast effects is important in the understanding of stimulus control. And, as pointed out above, understanding the control of behavior by environmental cues is vital to the study of behavior.

Contrast effects have also added complications to the view of schedule interactions held by many. Ferster and Skinner (1957) demonstrated that in a two component multiple schedule, with one component on a variable interval reinforcement schedule and with the other component on a fixed interval reinforcement schedule, the response pattern associated with single variable interval schedules developed during the variable interval component and the response pattern associated with single fixed interval components developed during the fixed interval component. They therefore reasoned that the effect of a reinforcement schedule was essentially unaffected by other, successively-presented schedules, in so far as the pattern of responding was concerned.

Behavioral Contrast

But at least one interaction during multiple schedule training soon received notice. Reynolds (1961a) demonstrated a clear interaction in overall response rates during multiple schedule performance, an effect he called behavioral contrast [after Skinner, 1938]. After equal reinforcement in the components of a two-component multiple schedule, he altered the reinforcement density in one component and the response rate in the other component changed in a direction opposite to the change in response rate in the altered component. If response rate in the unaltered component went up as reinforcement frequency in the altered component went down, it was termed positive behavioral contrast. If response rate in the unchanged component went down as reinforcement frequency in the changed component went up, it was known as negative behavioral contrast.

An interaction in response rates occurring among components of a multiple schedule was reported research before 1961. Herrnstein and Brady (1958) showed that response rate in an FI schedule went up if the shock-to-shock interval during an alternating avoidance component was shortened. An interaction in response rates during extinction after a multiple VI 3 VI 9 minute schedule was reported by Gollub and Urban (1958). The ratio of response rates in VI 3 to those in VI 9 increased in an extinction

phase following the acquisition of stable multiple schedule responding.

Behavioral contrast is affected by a number of variables. Positive behavioral contrast has most often been observed with pigeon subjects, but it has also been found with rat subjects (Bernheim & Williams, 1967; Mackintosh, Little & Lord, 1972; Pierrel & Blue, 1967; and Wertheim, 1965) as well as with humans (O'Brien, 1968; Waite & Osborne, 1972).

The type of response required is another condition that affects the occurrence of behavioral contrast. When pigeons are required to press a foot pedal instead of pecking a wall key, positive behavioral contrast is not obtained during discrimination training (Hemmes, 1973; Westbrook, 1973, but see McSweeney, 1978, 1983).

Changes in a component of a multiple schedule, other than reinforcement frequency changes, may produce contrast. Richards (1972) varied the delay of reinforcement available to pigeon subjects in one component of a multiple VI 1 VI 1 minute schedule and found behavioral contrast with longer delays. Lattal and Griffin (1972) found contrast in a multiple schedule of free-operant avoidance with rat subjects when bar presses in one of the components was punished with shock. Differentially reinforcing a low rate of response in one component (DRL) can produce contrast in an interacting VI component (Reynolds & Limpo, 1968).

Timeouts and blackouts can also produce behavioral contrast in an interacting VI component (Sadowsky, 1973).

Although the typical demonstration of behavioral contrast is with multiple VI schedules, behavioral contrast has been reported with fixed-interval schedules (Reynolds & Catania, 1961; Staddon, 1969), with variable-ratio schedules (Reynolds, 1961b) and with variable-time schedules (Bloomfield, 1967).

The magnitude of positive behavioral contrast in an unchanged component reaches a peak with a few training sessions after a change in an interacting component. Some researchers have found a decline from this maximum contrast effect with continued training (Bloomfield, 1966; Pear & Wilkie, 1971; Selekman, 1973), while others have not (Hearst, 1971).

Since Reynolds only employed two components in strict alternation, the definition of behavioral contrast did not specify that any particular transition between the components needed to occur. But when the transitional relationships are focused upon, local contrast effects are found and they should be seen as part of the interaction occurring between multiple schedule components. Local contrast as described thus far is a function of the prior transition between differentially-signaled and differentially-reinforced components, since the average response rate controlled by the preceding component

predicts whether response rate in a presented component is elevated or depressed (Malone & Staddon, 1973). But a contrasting effect on response rate in a component due to an interaction with an impending component has also been reported. We turn now to this type of contrast.

Impending Contrast Effects

Buck, Rothstein and Williams (1975) reported a contrast effect in a currently-presented component that depended on the reinforcement density of the following component. When the following component provided less frequent reinforcement, response rate in the preceding component showed an increase, especially toward the end of the component. This type of positive contrast effect due to a following extinction component had been previously reported (Pliskoff, 1961 1963; Wilton & Gay, 1969). A short, fixed, sequence of components was used. If contrast is due to an impending component, then the transition between components cannot be the precipitating cause. Instead, for the upcoming transition to have an effect, some form of expectation or anticipation of the transition on the subject's part needs to be assumed.

Because a preceding transition between stimuli and reinforcement schedules is an objective event, while a subject's anticipation of an impending schedule transition

is not directly observable, contrast of the prior transition type would be the more straightforward phenomenon to study. And the evidence for this type of contrast is plentiful. However, evidence that impending transitions between components of different reinforcement densities do have a contrast effect on behavior has been occasionally reported and should not be ignored. For example, Williams (1981, experiment 2) reported this effect. A three component multiple schedule was used. For narrative purposes, the components in sequence will be called A, B and C. Components A and C were always assigned a variable interval three-minute schedule. Component B was assigned a variable interval one-minute schedule during the first condition of the experiment. Component A was therefore followed by a component of three times its reinforcement density while component C was preceded by the more densely reinforced component.

The results showed that for an average of the first ten sessions, response rate in component C was more depressed than response rate in component A, indicating that the contrast effect produced by component B as a preceding component (i.e., local contrast) was dominant. The pattern of response rate in component C also showed the greater depressive effect at its beginning, just after the offset of component B. However, an average of sessions 31-40 showed that component A had become more depressed

than component C, indicating that the contrast effect of component B as a following component was dominant. Also, the depressive effect in component A was slightly greater at the end of the component, just before the onset of component B.

A second condition was carried out in which the reinforcement schedule in component B was reduced to variable-interval six-minutes, making its reinforcement density half of that in components A and C. In this condition, response rate in component C barely increased, while response rate in component A increased dramatically, so that it became greater than response rate in component C, based on an average of sessions 21-30. The indication was that contrast acted backwards from component B to enhance component A more so than it acted forward to enhance component C.

Williams stresses this evidence for the importance of the effect of the transition to come, but other researchers have found evidence that the prior component is responsible for contrast (Arnett, 1973; Malone & Staddon, 1973; Nevin & Shettleworth, 1966; Rachlin, 1973; and Spealman, 1976). Are the rate of response changes which characterize local contrast due to the effect of the preceding transition or due to the effect of the transition into the component to come? Or, are they due to both? The question is very similar to that of whether the typical fixed interval

pattern is due to the effect of the reinforcement which had just occurred or is it due to an anticipatory reaction to the reinforcing event to come. The question of the interpretation of fixed interval responding has been answered by acknowledging the existence of both forward and backward acting influences (Dews, 1970). Local contrast probably has both forward and backward acting influences as well. Chapter 2 of this dissertation reports two experiments which attempt to examine the evolution of these two types of influences on local contrast.

The Relation of Local to Behavioral Contrast

Response rate changes due to local and backward-acting contrast may lead one to wonder if these changes could account for the overall contrast effect known as behavioral contrast. One mechanism for this possibility was suggested by Marcucella and MacDonall (1977). They looked at the interresponse time distribution of pigeons' pecks in an unchanged component of a multiple random interval 60-second, random interval 60-second schedule when one of the components was changed to extinction. The reinforced interresponse times in the unchanged component tended to be shorter and the total distribution of interresponse times shifted toward shorter intervals. The authors suggested, following Mackintosh (1974), that the new reinforcement

distribution which emphasized short interresponse times was the result of positive local contrast. Once established, the microcontingencies represented by the reinforcement of short interresponse times served to maintain the shifted distribution, even though local contrast effects may have no longer been present.

The authors further showed that when the extinction component was reinstated to a random interval 60-second schedule, very long interresponse times were selectively reinforced in the changed component and, by induction, there was a shift in interresponse times in the unchanged component toward longer intervals. The result was the phenomenon of negative behavioral contrast.

The mechanism suggested by Mackintosh and by Marcucella and MacDonall implies that local contrast is only part of the process that produces behavioral contrast, microcontingencies between IRT's and reinforcement are also part of the process. Indeed, there is evidence to suggest that local contrast cannot account completely for overall behavioral contrast. Chapter 3 will review this evidence and will report an experiment which examines the correlation between local and behavioral contrast in light of the possibility that local contrast may be a precursor of behavioral contrast, but does not completely account for it.

Theories of Local Contrast: Pavlov

Intermixed with specific questions about contrast effects are theoretical formulations which have been proposed to account for local contrast. Chapters 4 and 5 will review three theories that have so far been advanced and will attempt to resolve them. The three main theories that have been proposed are: 1. Pavlov's, 2. behavioral competition theory and 3. additivity theory.

Pavlov's description of induction during classical differentiation training represents, in effect, a description of local contrast effects. A list of the properties of induction which he derived from experimental results have clear analogies with the properties of local contrast as reported in more modern times (Malone, 1976; Malone & Rowe, 1981).

Pavlov's translation of the induction effects into spreading cortical fields has not been influential, partly because it has been impossible to find a physiological basis for complex discrimination formation. But his views of the nervous system in terms of its analyzing and synthesizing functions and their interactions may be applied to local contrast, as was suggested by Nevin and Shettleworth (1966). However, a theory of local contrast needs to be more clearly defined in order to sort out the

many contradictory proposals advanced to explain the local contrast experimental results that have been obtained in recent times. Behavioral competition and additivity theories are more explicit and hopefully one of them will provide an explanation of local contrast.

Theories of Local Contrast: Behavioral Competition

For example, behavioral competition theory (Hinson & Staddon, 1978; Iverson, 1978; Staddon, 1982) is an account of local contrast which focuses on the presence of competing response tendencies (as did Pavlov's theory). To understand behavioral competition theory, it is necessary to separately classify a subject's behavior during an intermittent reinforcement schedule into interim and terminal responses.

Terminal responses are those that are supported by a scheduled reinforcing event and upon which the reinforcing event may be made contingent. Interim responses are those for which there is a tendency for expression that is independent of the scheduled reinforcement. In Staddon's (1982) behavioral competition model, terminal and interim responses have the following relationships: 1. occurrence of one type of response suppresses the other type of response in proportion to the rate at which the first type of response occurs and 2. in a simple variable interval

schedule, the collective expression of terminal and interim responses consumes the total interval time. From these two principles, a principle of diminishing returns is derived in which the ability of one type of response to interfere with the expression of the other type of response is inversely related to the first type's rate of expression.

To explain behavioral contrast, the events which produce it are considered in terms of the competition between terminal and interim responses. When the scheduled reinforcement density in one component of a multiple schedule is decreased or set to extinction, the terminal responses which are supported by that reinforcement decrease their rate of expression, allowing more interim responses to be made during that component. As the number of interim responses increases in the changed component, their ability to interfere with terminal responses in the unchanged component diminishes, due to the diminishing returns principle, and the number of terminal responses in the unchanged component goes up. Of course, the increase in terminal responses has a suppressive effect on interim responses, which are inhibited. The effect is greater the greater the rate of terminal response that is achieved. Eventually, an equilibrium is reached in which the rate of terminal responses is greater in the unchanged component and the rate of interim responses is greater in the changed

component, as compared with their rates before the scheduled reinforcement was reduced.

Notice that the two principles of competition for time and diminishing returns can produce effects which operate in opposite directions. For example, decreasing scheduled reinforcement reduces the number of terminal responses. The eliminated responses can then no longer compete, so that reduces the competition to be contended with by interim responses. But the terminal responses which do remain increase in their individual ability to interfere, so that increases the competition to interim responses. The eventual level of competitiveness reached is on the basis of a dynamic equilibrium.

Evidence of this process was presented by Hinson and Staddon (1978). Two groups of rats were conditioned to lever press for food on a multiple variable interval, variable interval schedule. One group had a running wheel in their chamber while the other did not. The schedule was changed to a multiple variable interval, extinction schedule and the result was that the group with the running wheel increased their rate of lever pressing and decreased their rate of wheel running in the variable interval component. During the extinction component, they decreased their rate of lever pressing and increased their rate of wheel running.

The group without the wheel showed a much higher rate of lever pressing during the baseline condition, so that when one component was set to extinction, response rate in the unchanged component went up, but not with as great a contrasted difference from baseline as the wheel group.

The inverse relation between changes in rates of lever pressing and wheel running in both the changed and unchanged component may be said to reflect the hypothesized competition processes. The process may be described as follows: Lever presses were reduced in the extinction component, lowering the competition with wheel running. As wheel running in the extinction component increased, its ability to be competitive in the variable-interval component decreased, so lever pressing in that component increased. The fact that contrast was greater for the group with a major competing response available may be taken as support for the idea that contrast is a function of competing responses.

Not only do overall response rate changes between terminal and interim responses have an inverse relationship to each other, but their local patterns of response rate may also have an inverse relationship. Iverson (1978, Experiment 3) reinforced wheel running with food in a multiple variable interval, extinction schedule and recorded exploratory activity as well as wheel turns. During presentations of the variable interval component,

wheel running rate was greatest, and exploring rate was least, at the beginning of the component. During the beginning of the extinction component, wheel running was least, and exploring rate was at its peak. The inverse interplay between a terminal and an interim response was seen in local rate changes during component presentations as well as in overall rate changes.

Hinson and Staddon (1981) have also presented evidence for the diminishing returns principle of behavioral competition theory. One way of expressing the diminishing returns principle as applied to interim responses is to say that the performance of an interim response not only immediately suppresses terminal responses, but also suppresses the competitiveness of the interim responses occurring thereafter. By increasing the opportunity for the expression of interim responses, the competitiveness of following interim responses should be reduced, and this reduction should be revealed by an increase in terminal responses when an opportunity for their expression follows.

They preceded a variable interval 30- second component with an extinction component of either 30 seconds, 60 seconds, or 90 seconds duration. The response rate in the variable interval component became highest after the longest extinction component, in keeping with what a diminishing returns principle would predict. The result of

a higher number of terminal responses after a long extinction interval was presumably due to the diminished ability of exhausted interim responses to compete in the reinforced component.

The diminishing returns principle should also apply to terminal responses as well as interim responses. If the duration of a VI component is varied while the duration of an extinction component is held constant, longer VI components should increase the opportunity for terminal responses to be expressed. When an extinction component follows, the competitiveness of terminal responses should be diminished and a greater number of interim responses should occur. An increase in interim responses should suppress the number of terminal responses during the fixed-duration extinction component. Response rate should be lowest after the longest reinforced component duration and should be highest after the shortest duration, if the diminishing returns principle is to apply to terminal responses. Chapter 4 reports the results of such a procedure and discusses their implication.

Theories of Local Contrast: Additivity

A second explicit account of contrast effects is known as additivity theory. Additivity theory was developed by a number of investigators (Hearst & Jenkins, 1974; Gamzu &

Schwartz, 1974; Rachlin, 1973; and Schwartz & Gamzu, 1977) and, although their accounts vary in details, their basic proposition is that contrast is due to the addition of elicited responses to a baseline of operant responses. The phenomena of autopecking is assumed to be evidence that such elicited responses exist.

Autopecking was first described formally by Brown and Jenkins (1968), who were extending some work reported by Skinner in 1948. Skinner placed food-deprived pigeons in a Skinner box and delivered food every X seconds. Certain behaviors began to appear and to be repeated even though the delivery of food was not contingent on any of these movements. To Skinner's procedure, Brown and Jenkins added a signal light which came on 8 seconds before food delivery and they soon found pecking directed to the signal light. The signal light at first increased the birds' activity. Then, with more pairings, the birds would approach the signal light and eventually began pecking at it. An average of 40 pairings was needed for the first peck. The authors termed these events autoshaping and the elicited pecks were called autopecks. Autoshaping has been found in other species, such as laboratory rats, dogs and chickens (see Hearst and Jenkins, 1974 for a review).

Autopecking has come to be included within a general class of effects, collectively known as sign-tracking. Sign-tracking is behavior directed toward or away from a

stimulus as a result of the predictive relationship of the stimulus to the occurrence or non-occurrence of a reinforcing event. Wasserman, Franklin and Hearst (1974) provided a demonstration of this type of behavior. Two response keys were located on the left and right half of one wall of an experimental chamber. A pivoted floor allowed the experimenters to determine whether a subject was standing on the left or right half of the chamber floor. When pigeons were exposed to a positive contingency between the illumination of a key and the subsequent delivery of grain, they approached and pecked the lighted key, which was the result expected from an autoshaping procedure. But in addition to this result, when the birds were switched to a negative contingency, they spent most of the lit key time on the side opposite the key. Other groups of pigeons showed that backward pairing and presentations of the lit key by itself did not produce the tendency to withdraw. The relationship between an illuminated key and the delivery of food controlled the positioning of the birds within the chamber.

The control was further illustrated by varying the predictive relationship of the lit key to food presentation (Hearst & Franklin, Experiment 1, 1977). When a signal indicated the absence of higher frequencies of grain deliveries, withdrawal from the signal was greater and occurred with fewer trials. Withdrawal from a signal of

nonreinforcement was a direct function of the difference between the probability of reinforcement during the absence of the signal and the probability of reinforcement during the presence of the signal. In addition, the withdrawal effect increased as more trials were accumulated.

The ability of a predictive signal to control the directed actions of a subject was shown to be possible without the direct participation of the subject in the reinforcing event (Browne, 1974). One group of food-deprived pigeons was allowed to observe illumination of a pecking key followed by activations of a grain magazine, but was denied access to either by a clear plexiglass wall.

Another group of pigeons observed the activation of the magazine only when the key was unlit. The wall was then removed and the birds were exposed to an autoshaping procedure. Those pigeons which observed a positive contingency between the keylight and grain presentation approached and pecked the key more often and with fewer trials than those pigeons which observed a negative contingency.

Another finding which Hearst and Jenkins (1974) categorized as sign-tracking is the feature positive effect. The feature positive effect is the learning of a feature positive discrimination more rapidly than the learning of a feature negative discrimination (Jenkins & Sainsbury, 1969, 1970). A feature positive discrimination

uses as a signal for food availability a stimulus display which contains a distinctive feature, while the signal for food non-availability is the same display without the distinctive feature. In a feature negative discrimination, the signal for food non-availability contains the distinctive feature. The defining characteristic of "distinctiveness" is left to subjective measures. Although pecks to any part of the positive display were counted as operant responses, pigeons tended to peck at the distinctive feature when it was positive and tended to peck away from the distinctive feature when it was part of the negative display. Furthermore, if the distinctive feature was part of a negative display, the subjects learned to not respond during the negative display only with great difficulty.

The predictive relation of the distinctive feature to food availability controls whether pecks are directed toward it or away from it, a situation very similar to the whole-body withdrawal or approach of a subject from or to signals of food non-availability or availability. The birds tend to direct their behavior toward that feature which has the highest positive correlation with a reinforcer.

Since sign-tracking is evoked only when there is a differential predictor of a reinforcer, a multiple schedule in which each component has the same schedule of

reinforcement would not evoke any sign-tracking. But when the reinforcement schedule in one of the components is reduced or set to extinction, the signals for the other components become differential predictors of food and should elicit autopecks. These autopecks should presumably add onto the existing baseline of operant pecks. This notion is the basis of the strong version of additivity theory (McSweeney, Ettinger & Norman, 1981).

That responses controlled by the relationship between a stimulus and a reinforcer can be considered separate from the responses controlled by the relationship between a response and a reinforcer is shown by omission procedures (Williams and Williams, 1969). An omission procedure is the same as autoshaping but with the added condition that any peck at the illuminated key will prevent a scheduled magazine operation from occurring. Pigeons will peck less often under this type of contingency, but some pecking is still maintained. Since autopecking is directly set in opposition to operant pecking, it is assumed that the pecks still emitted under the omission procedure are due to a stimulus-reinforcer relation and are separable from operant pecks, that is, pecks due to any response-reinforcer contingency.

Other evidence that autopecks are separate from operant pecks comes from studies using two pecking keys. On one key, responses must be made for reinforcement to

occur and on the other key, stimuli which signal the reinforcement conditions are projected, but responses to this key have no effect on reinforcement delivery. When a multiple variable-interval, variable-interval schedule is changed to a multiple-variable interval, extinction schedule, an increase in responses occurs only on the signal key, where presumably autopecks, but not operant pecks, would be drawn (Keller, 1974).

Given the evidence for sign-tracking behavior, its separability from operant behavior and the fact that in the procedure which produces behavioral contrast, component stimuli change from non-differential to differential cues, additivity theory is a plausible account for the response rate increase known as positive behavioral contrast. But the strong form of additivity theory, which is only concerned with the summation of responses to a manipulandum, does not explain negative behavioral contrast. Negative behavioral contrast is a depression in response rate when an accompanying component has its reinforcement rate raised. For strong additivity theory to apply, a baseline of operant pecks would have to be summed with elicited "negative pecks", whatever they might be. Schwartz, Hamilton and Silberberg (1975) recognized the difficulty that negative behavioral contrast posed for additivity theory.

However, an expansion of additivity theory from just autopecks to the more molar behavior of sign-tracking could explain negative behavioral contrast, as well as some features of local contrast. The original impetus for exploring sign-tracking withdrawal, rather than elicited approach, was to find a measurable reaction which would differentiate a negatively correlated predictor from a random non-predictor (Hearst & Jenkins, 1974). A demonstration of non-autopecking did not distinguish between a signal which was a non-differential predictor from one which was highly predictive of food non-availability (i.e., an inhibitor). Both types of signals produced an absence of autopecks. Autopecks, or rather their absence, therefore cannot be assumed to function in a behavioral reaction to a negatively-correlated signal and this is the major downfall of strong additivity theory. Sign-tracking, however, appears as a reaction to a negatively-correlated signal. An adaptation of additivity theory which depends on sign-tracking behavior in general, rather than specific autopecks, may be the best account for contrast. Such an adaptation of additivity theory may be termed a Pavlovian process/additivity theory (PP/AT).

A Comparison of Behavioral Competition and PP/AT

Behavioral competition theory and PP/AT are similar in that both explain changes in a terminal response, such as key pecking in the pigeon, by reference to auxiliary responses. In the case of the Pavlovian process/additivity theory, the auxiliary responses are sign-tracking movements. The auxiliary responses of behavioral competition theory are much broader in scope because they include any behavior not directly maintained by the reinforcing event of the terminal response. Therefore, sign-tracking movements may be included within the range of the interim responses of behavioral competition theory and, indeed, they would be indistinguishable from the exploratory behavior reported by Iverson (1978) as a representative of an interim response. The PP/AT theory proposed here may, in a sense, be considered a specific interpretation of behavioral competition theory, where the range of interim responses is limited to sign-tracking movements only.

But there is another difference between the two theories which will prove to be crucial for the understanding of the results of an experiment reported in chapter IV. The difference is the manner in which each theory explains the facilitation of terminal responding by the action of its auxiliary responses. PP/AT explains the

facilitation directly by pointing to the bi-directionality of sign-tracking behavior. It can either appear as movement away from a predictor of the nonoccurrence of a reinforcing event or toward a predictor of a reinforcing event, in which case it would enhance any response toward the predictor.

Behavioral competition theory, on the other hand, explains the facilitation of terminal responding by invoking a decrease in competitiveness of the auxiliary responses. The decrease may be by either or both of the two mechanisms described above. According to the theory, any occurrences of the competing interim responses should reduce their competitiveness and facilitate the occurrence of terminal responding. According to the Pavlovian process/additivity theory, the balance between approach and withdrawal tendencies determines whether terminal responding will be facilitated or depressed and their balance depends on temporal factors.

Chapter IV tests directly the assumptions of response competition theory and PP/AT by looking at the spread of the effect of a variable duration positive component on a fixed duration negative component. Chapter V further tests the assumptions of PP/AT by measuring sign-tracking withdrawal movements during the development of the effect of a variable duration negative component on a fixed duration positive component.

CHAPTER II

APPEARANCE OF LOCAL AND IMPENDING CONTRAST IN SIMPLE MULTIPLE SCHEDULES

One of the challenges in exploring discrimination learning is to explain adequately the phenomenon of contrast, in both its overall and local forms and both in its positive and negative directions. The task is especially difficult because the processes underlying overall behavioral contrast may be largely independent of those underlying local contrast. The relationship of behavioral to local contrast will be discussed further in Chapter III. Also adding to the difficulty is the distinct possibility that negative contrast is not a simple reverse image of positive contrast, but may depend on different factors from those controlling positive contrast (c.f., Mackintosh, 1974).

A final complication in the study of contrast is that local contrast may be derived from both forward- and backward-acting influences. It is to this possibility that we now turn. In a multiple schedule, a component consists of a presentation (usually for a constant duration) of a salient stimulus in conjunction with a given reinforcement schedule. When components correspond to differing

reinforcement densities, their stimuli come to control different probabilities of response--a process that is known as discrimination learning. Since components are sequentially presented, it is possible for the preceding component to have a local effect on responding during a component's presentation. In this case, local refers to the close position in time that the preceding component holds in relation to the affected component.

But the following component also holds a position close in time to the component and it is possible that it can, if anticipated, have a local effect as well. If the local effect is positive contrast, then responding will be elevated by a local component which controls lower average response rates. If the local effect is negative contrast, then responding will be depressed by a local component which controls higher average response rates.

In addition, the local effect may be seen within the temporal pattern of responding during a component's presentation. Positive local contrast is seen by elevated responding in the initial segments of presentation. Depressed responding in the initial segments would indicate negative local contrast. If the local component occurs after the affected component, then elevated responding in the final segments of its presentation would indicate positive contrast of a backward-acting type and depressed

responding in the final segments would indicate negative backward-acting contrast.

It is possible for forward-acting local contrast to occur when the components of a multiple schedule are both predictably and unpredictably presented, while backward-acting contrast, on the other hand, may occur only if the upcoming component is anticipated. A simple, repeating sequence is therefore required and some final, steady state of discrimination learning needs to be obtained before backward-acting contrast can reasonably be expected to be found.

The evidence for forward-acting local contrast is overwhelming (e.g., Arnett, 1973; Malone & Staddon, 1973; Nevin & Shettleworth, 1966; Rachlin, 1973; and Spealman, 1976), but there is strong evidence for backward-acting contrast as well. An experiment by Williams (1981) was described in Chapter I in which these backward-acting effects were seen.

A study of backward-acting contrast effects, such as Williams (1981), suggests that these influences represent the prevailing component interaction in any eventual steady-state product of discrimination training, given a simple and predictable sequence. Thus, Williams refers to an average of the last ten sessions in a condition to show a backward-acting contrast effect, even though he did find a preceding component effect (local contrast) appearing in

data averaged over the first ten sessions of the first condition. But he does not view local contrast effects as an important aspect of the final steady-state product, since these effects were transient (as is often the case).

But some researchers have emphasized the performance of individual subjects occurring over time and have sought orderly changes in the patterns of the individual's behavior. The fact that commonly reported and orderly aspects of a discrimination process can prove to be transitory under simple discrimination procedures and/or prolonged discrimination training is hardly seen as a cause to dismiss them.

Local contrast as an aftereffect of an immediately preceding component is a point in question. As has been discussed in the introduction, these effects can vary in their magnitude and persistence depending on several factors, but they are clearly an aftereffect of the transition from the preceding component. The characteristics of the preceding component determine the contrast effect in the component that follows (Blough, 1983; Catania & Gill, 1964; Hinson & Staddon, 1981; McLean & White, 1981; Malone & Staddon, 1973; Nevin & Shettleworth, 1966; Rachlin, 1973). Most of the procedures in the above studies used unpredictable sequences of component presentations, so that the subject could not anticipate the component to come. One could not expect to

find a backward-acting effect, although local contrast effects dependent upon the preceding component were found.

Williams typically has employed multiple schedules comprised of four or fewer components paired with easily discriminable stimuli appearing in a fixed and repetitive sequence. His results argue for the dominance of the component transition to come, while other researchers have found only contrast depending on the immediately preceding component, albeit using methods which would preclude any anticipation of the component to follow. To study the relative influence of both prior and impending types of local contrast effects, it may be best to use simple, recycling multiple schedules and examine the evolution of the patterns of local response rates as a discrimination is forming. Components signaled by easily discriminable stimuli in a fixed sequence would favor the rapid appearance and disappearance of prior component local contrast (Malone and Rowe, 1981) and would make possible the effects produced by the impending component.

The experiments reported below used pigeon subjects, which were presented with simple three-component multiple schedules arranged in a fixed sequence and recycled after a blackout period. The components were signaled by easily discriminable colors projected on a pecking key. It was expected that under these conditions, transitory local contrast effects would appear early in training and

backward-acting contrast effects would appear later in training.

Experiment I

This experiment included two conditions and two groups of pigeons. In the first group, a recycling multiple schedule comprised of three components associated (respectively) with variable-interval 60-sec, variable-interval 15 sec and extinction was used. Each three-component sequence was separated by blackout periods, in which the chamber was darkened and no stimulus appeared on the key. Of primary concern was the pattern of responding appearing in the variable interval 15-sec component. Local contrast produced by the prior low reinforcement density component (VI 60-sec) should appear as elevated responding during the initial part of the VI 15-sec component, with a pattern of decreasing response rate during the component. If backward-acting contrast produced by the following extinction component were to appear, it should appear as a pattern of increasing response rate throughout the component and with elevated responding in the latter part of the component.

In the second condition, a recycling multiple schedule of three components associated with variable interval 15-sec, variable interval 60-sec and variable interval 15-sec,

in that order, was used. Of main interest was the pattern of responding during the middle, variable interval 60 second component. Local contrast produced by the prior VI 15-sec component would appear as depressed responding during the initial part of the component, with a pattern of increasing response rate throughout. Backward-acting contrast, if it should occur, should produce depressed responding during the latter part of the component, with a pattern of decreasing response rate throughout the component's presentation.

Method

Subjects. Four male White Carneaux pigeons (condition 1) and four Silver King pigeons (condition 2), all with varied experimental histories, were maintained at approximately 80% of their free-feeding weights during the experiment. The pigeons were of the species Columba livia.

Apparatus. The experimental chamber was a 33 x 26-cm aluminum and Plexiglas box placed within a 61 x 61 x 92-cm sound-and-light shielding enclosure. An opaque 1.9-cm response key was centered 24 cm above the floor and 14 cm above the center of a 5.5 x 5.5-cm food magazine opening. A 1.1-W houselight centered on the ceiling of the chamber provided illumination. During food magazine operation, three-second access to mixed grain, a 6-W light illuminated

the feeder area. Stimuli were projected on the response key by an inline digital display unit using 6.3V, 1.6-W bulbs. A ventilation fan and white noise generator masked extraneous noises and programming and recording equipment was located in a nearby room. Room temperature remained at approximately 70 degrees Fahrenheit during the experiment.

Procedure for condition 1. After one session of key training, four subjects were placed on a three-component multiple schedule. For Birds 68 and 90, a red key was presented with VI 60-sec in effect. This was followed by an orange key paired with a VI 15-sec schedule, and that was followed by a green key, present for one minute in extinction (EXT). After these three one-min components, a one-min blackout (BO) occurred. During this time, the key was unlit, as was the houselight, and reinforcement was not available. The sequence repeated seven times per session. Birds 93 and 95 received similar treatment, but VI 60-sec appeared with a green key, and EXT appeared with a red key. Data were collected for 42 sessions, conducted 6 days/week.

Procedure for condition 2. After one session in which keypecking was reinstated with from 10 to 20 autoshaping trials, four different birds were placed on a different multiple VI schedule in which a fixed sequence of three components recycled. For birds 1 and 51, green was projected on the key for one minute while a VI 15-sec reinforcement schedule was in effect. This was followed by

one minute of red on the key, accompanied by VI 60-sec. The keylight during the third component was green, again accompanied by VI 15-sec. These VI components were followed by a one-minute BO period during which the key was unlit, the houselight was turned off, and reinforcement was not available. This sequence repeated four times during each session. For Birds 60 and 72, red was projected on the key during VI 15-sec and green was on the key during VI 60-sec. This continued for 39 sessions and the subjects were run six days a week.

Results

Condition I: VI 60 \ VI 15 \ EXT. Figures 1-4 show responding for Birds 68, 90, 93 and 95, respectively, during successive 15 sec segments of the VI 15-sec component, which was preceded by the VI 60-sec component and was followed by extinction (VI60 VI15 EXT). The response rates were averaged over successive three-session periods. Birds 68 and 93 showed positive local contrast at some point during the first 3 blocks.

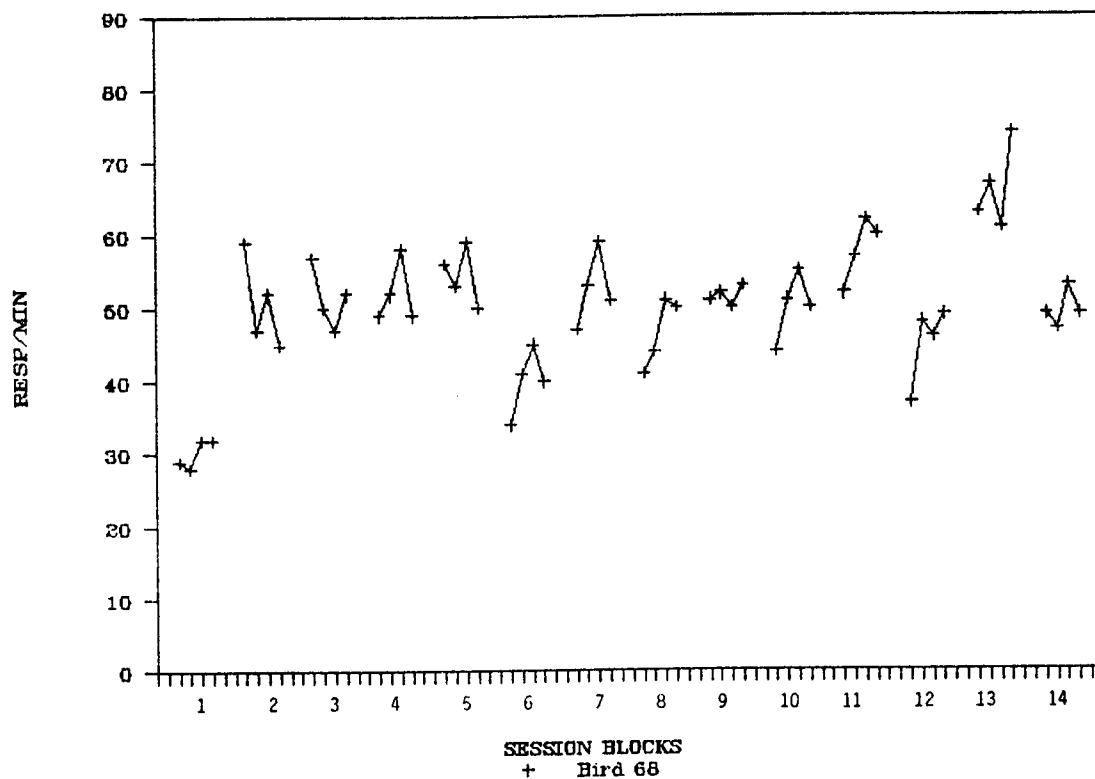


Figure 1. Response rates for Bird 68 during successive 15-sec quarters of the VI 15-sec component in Condition 1. Data were averaged over successive three-day blocks.

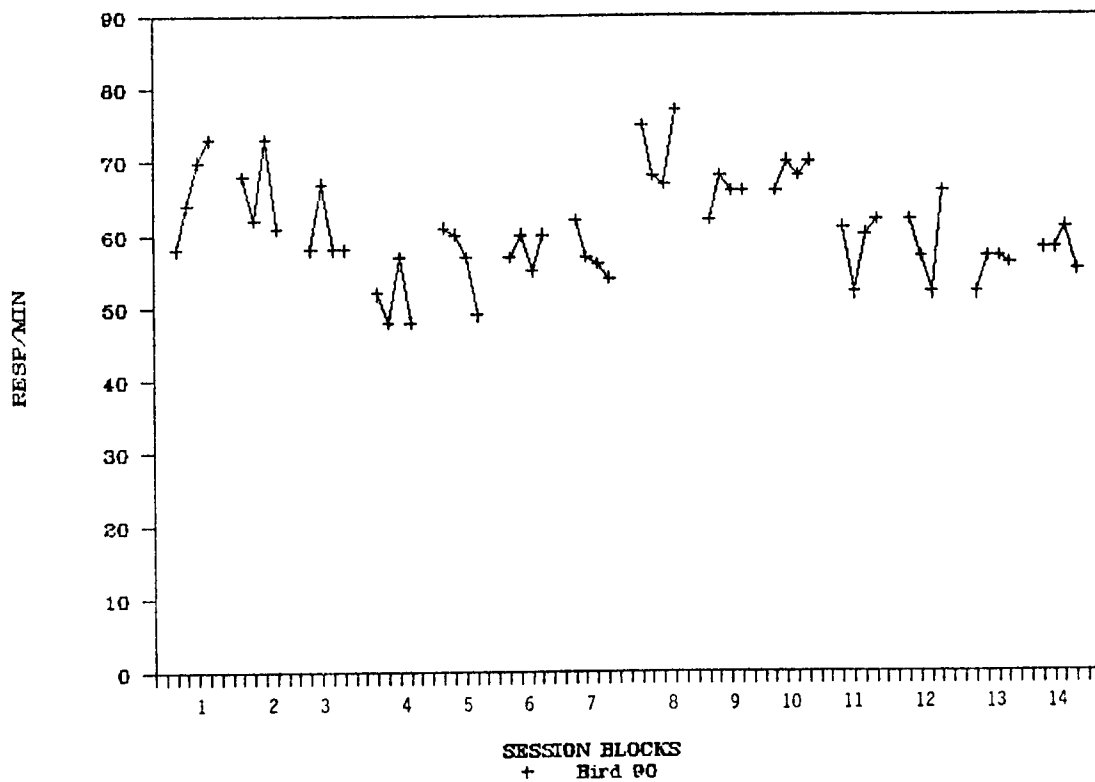


Figure 2. Response rates for Bird 90 during successive 15-sec quarters of the VI 15-sec component in Condition 1. Data were averaged over successive three-day blocks.

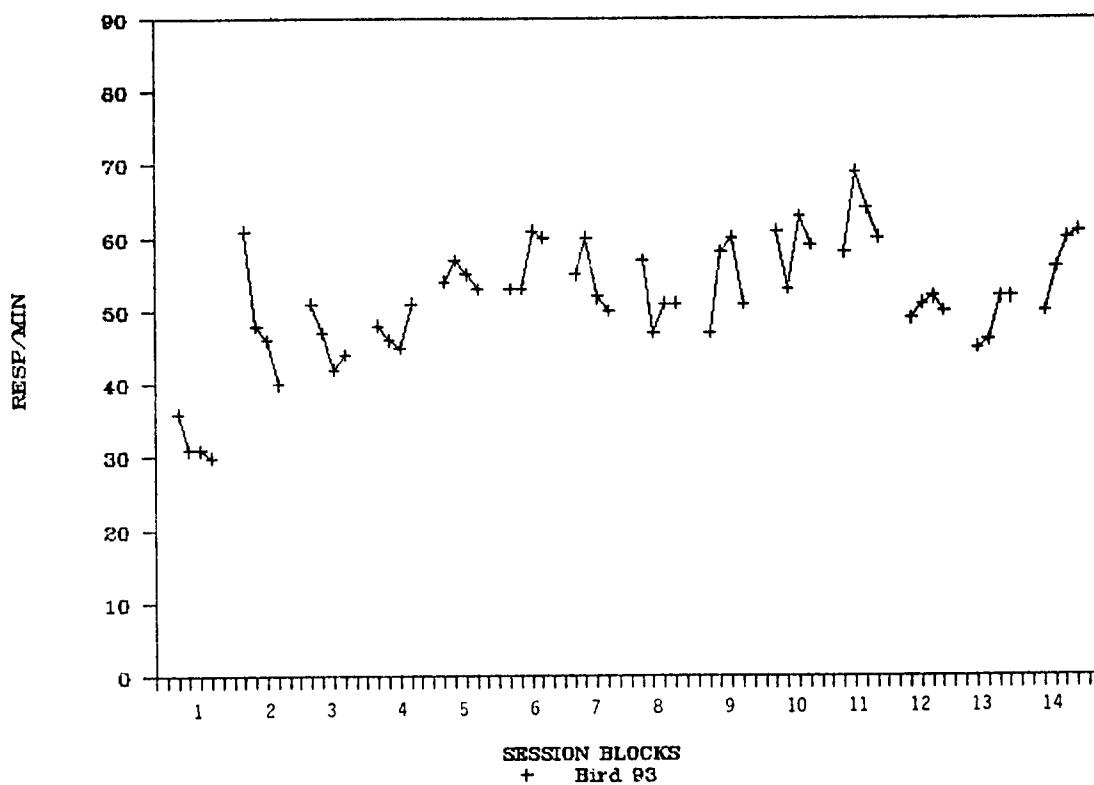


Figure 3. Response rates for Bird 93 during successive 15-sec quarters of the VI 15-sec component in Condition 1. Data were averaged over successive three-day blocks.

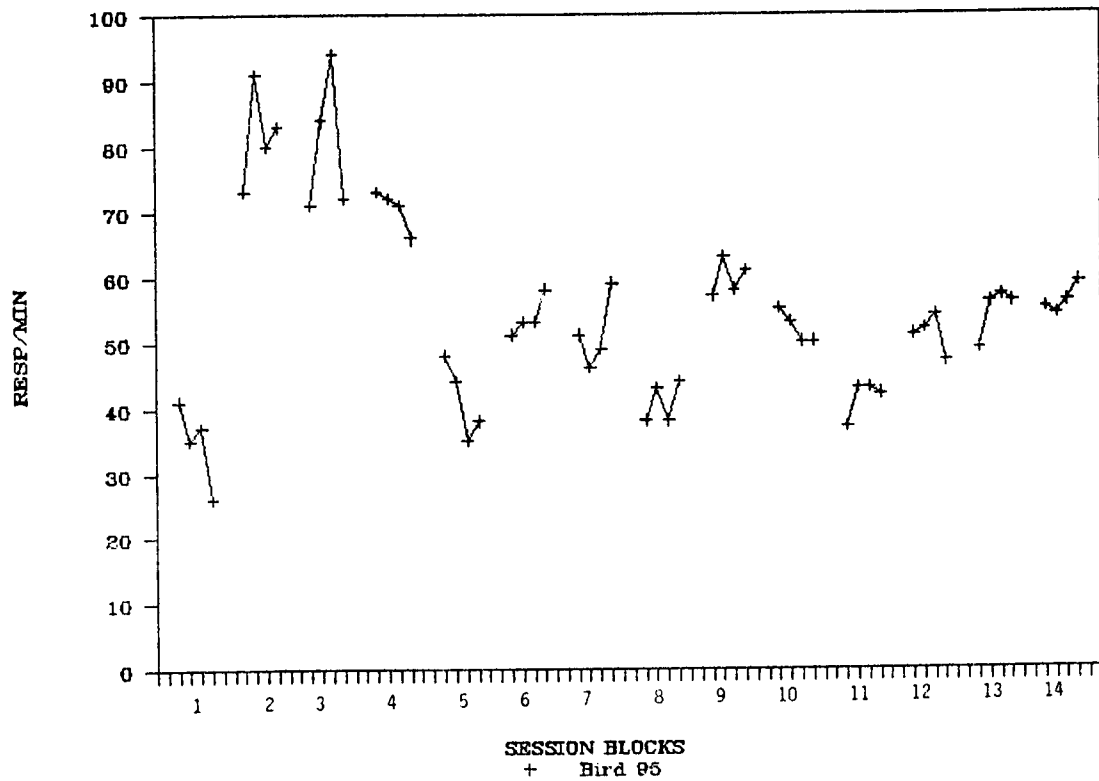


Figure 4. Response rates for Bird 95 during successive 15-sec quarters of the VI 15-sec component in Condition 1. Data were averaged over successive three-day blocks.

Elevation in the first 15 seconds of the VI 15 sec component was presumably due to the prior low-reinforcement component. Bird 95 showed positive local contrast for the first block of three sessions only and Bird 90 showed no consistent patterns.

Those birds which showed positive local contrast early in training showed the opposite pattern after prolonged training. Birds 68 and 93 showed a pattern of increasing response rate during the middle VI component. This is seen over the last 9 blocks for Bird 68, and over the last 3 blocks for Bird 93. Bird 95, which showed a decreasing pattern for only the first block of sessions, showed an increasing pattern late in training for only the last 2 blocks. Bird 90 again showed little variation in response pattern.

Figures 1-4 suggest that local contrast may not simply fade away, but may change from sensitivity to the prior component into a type of contrast with sensitivity to the impending component. Figure 5 compares the response rate in the first and last six individual sessions of training, where the two forms of local contrast patterning seemed most pronounced.

Early in training, Birds 68 and 93 showed most responding during the first 15 sec of the middle VI 15-sec component for most of the first 6 sessions. Bird 95 showed

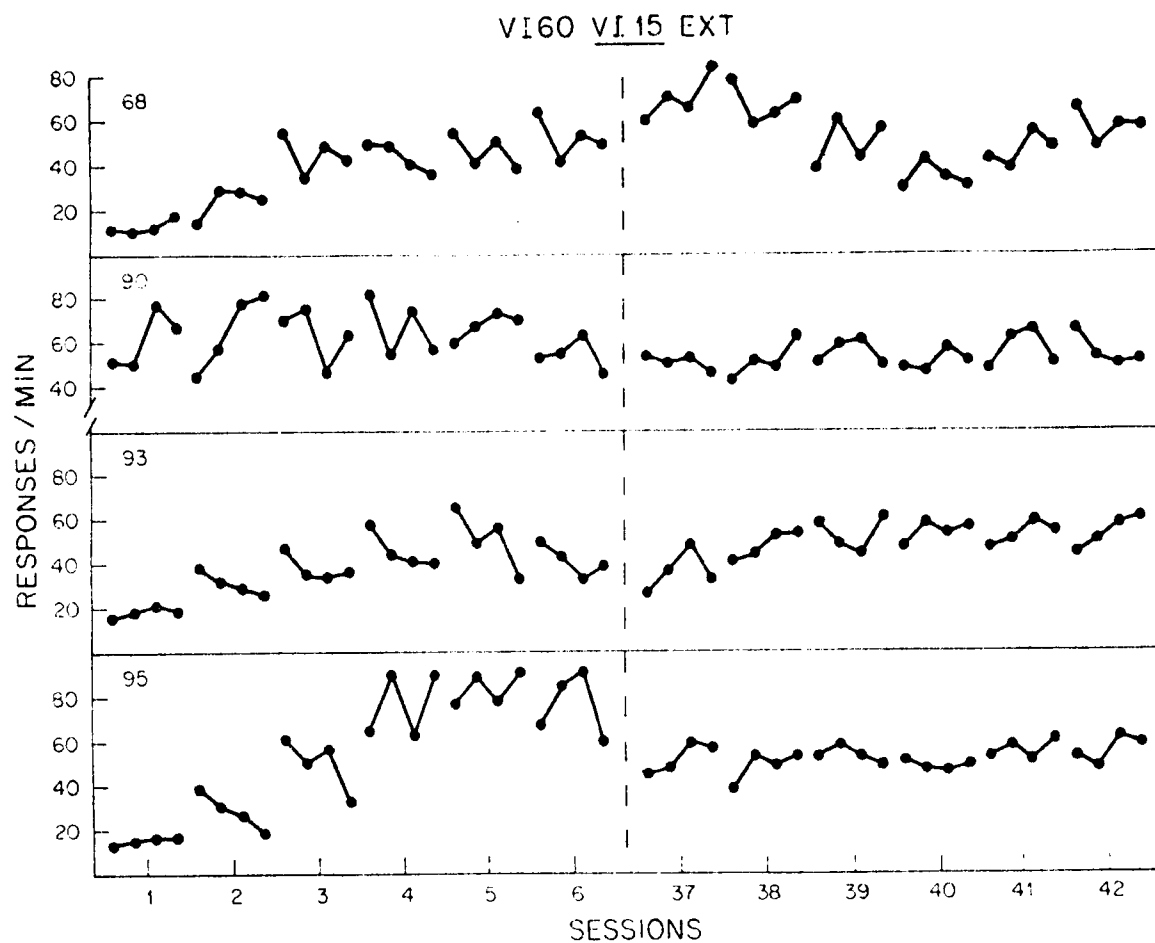


Figure 5. Response rates for each subject during successive 15-sec quarters of the VI 15-sec component in Condition 1. Data represent the first and last six individual sessions.

this pattern for 2 of the first 6 sessions and Bird 90 showed it for 1 of the first 6 sessions.

Late in training, Birds 93 and 95 showed an elevation in responding during the last 15 sec of the component's presentations.

Condition 2: VI 15 \ VI 60 \ VI 15. Figures 6-9 show responding for Birds 1, 51, 60 and 72, respectively, during the middle component of a VI 15 sec, VI 60-sec, VI 15-sec recycling sequence. The VI 60 sec component was both preceded and succeeded by a component in which reinforcement was available four times as frequently. If local contrast occurred, responding in the middle component should show strong negative local contrast, appearing as a pattern of depressed response rate in the first 15 sec of the component's presentation. If backward-acting contrast occurred, the middle component should show depressed responding at the end of its presentation.

The data, shown in alternate three day blocks in Figures 6-9, indicates that all four birds produced a pattern of depressed response rate in the initial segment of the component's presentation. This was true throughout the 39 sessions for Birds 1 and 51. Only a hint of backward-acting contrast effects appeared during the last block of sessions for Bird 72, which also showed the least

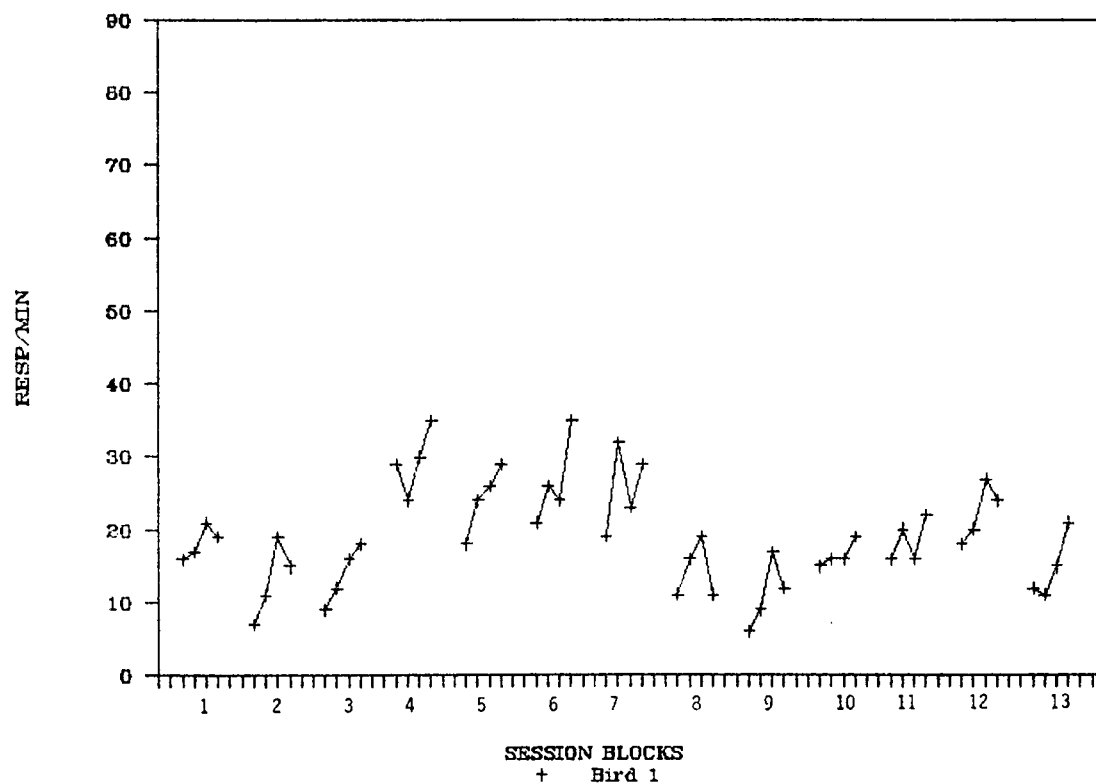


Figure 6. Response rates for Bird 1 during successive 15-sec quarters of the VI 60-sec component in Condition 2. Alternate three-day averages are shown.

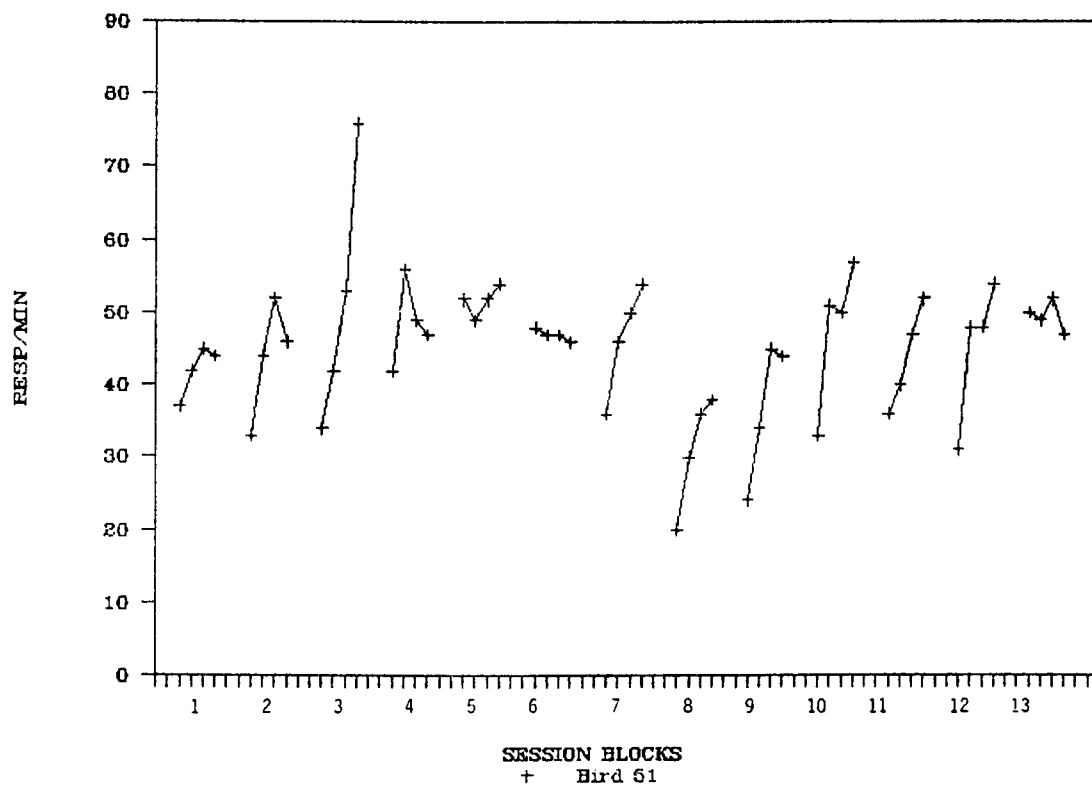


Figure 7. Response rates for Bird 51 during successive 15-sec quarters of the VI 60-sec component in Condition 2. Alternate three-day averages are shown.

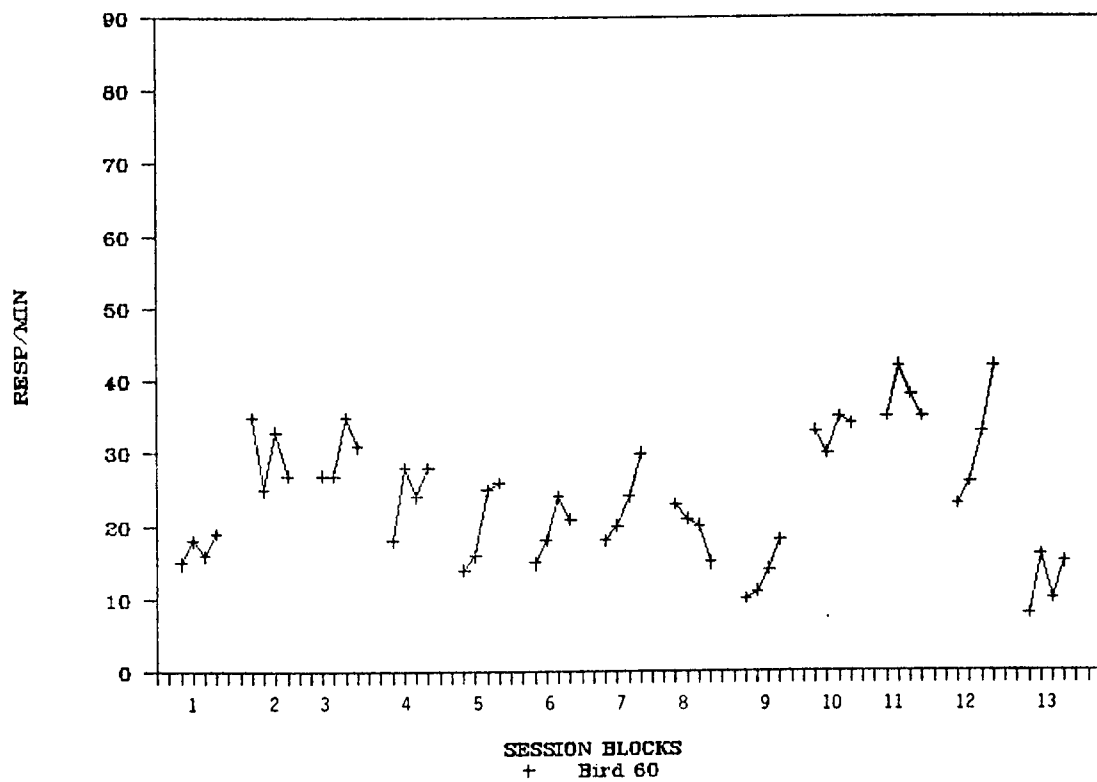


Figure 8. Response rates for Bird 60 during successive 15-sec quarters of the VI 60-sec component in Condition 2. Alternate three-day averages are shown.

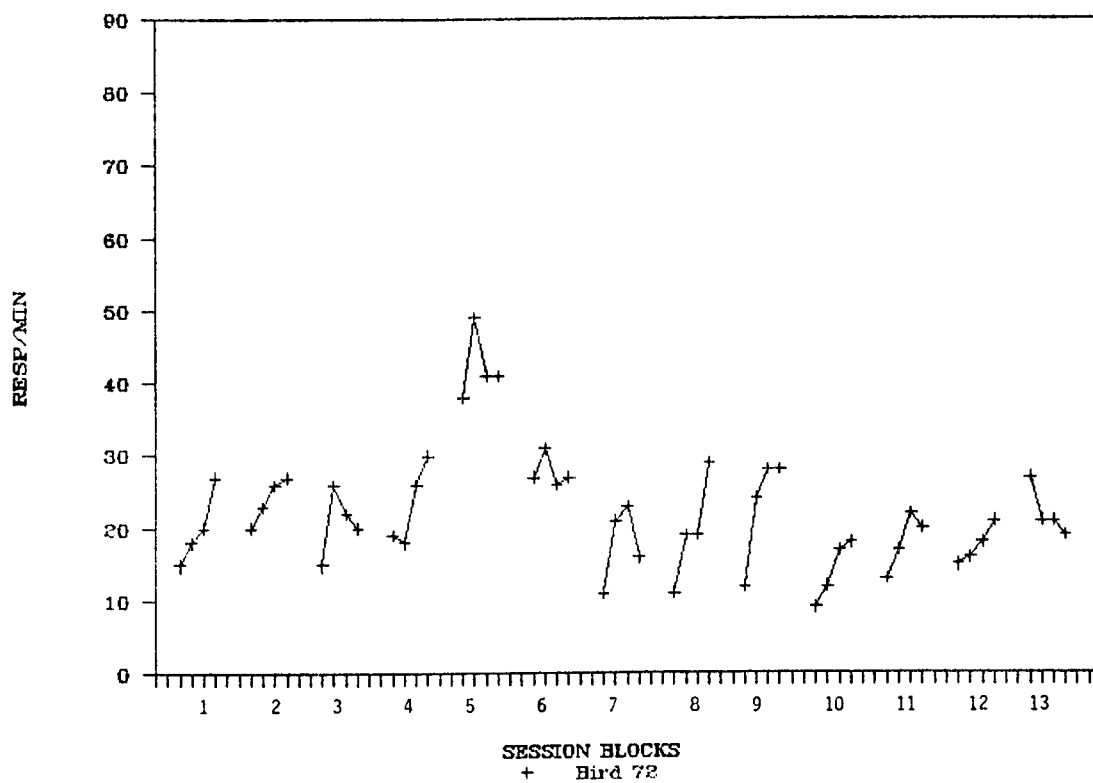


Figure 9. Response rates for Bird 72 during successive 15-sec quarters of the VI 60-sec component in Condition 2. Alternate three-day averages are shown.

orderly patterns throughout. Local contrast predominated and the only surprising feature of the data was its persistence over such a protracted period. Since the sequence was so predictable and the number of components so few, one might expect local contrast to disappear fairly quickly.

If within-component response patterns changed from patterns indicating sensitivity to the preceding component to patterns indicating sensitivity to the following component, a comparison of the first few sessions to the last few sessions of the condition should confirm it. Figure 10 shows average response rates during the first and last six individual sessions.

Depression in response rate is seen in the first 15 sec of presentation for most of the first 6 sessions for all of the birds. In the last 6 sessions, a depression in the final 15 sec of the component's presentation is found in 2 of the 6 for Bird 1, in 4 of the 6 for Bird 51, in none of the last 6 for Bird 60 and in 3 of the 6 for Bird 72. So there were some indications of backward-acting contrast in the last 6 sessions of training for 3 of the subjects.

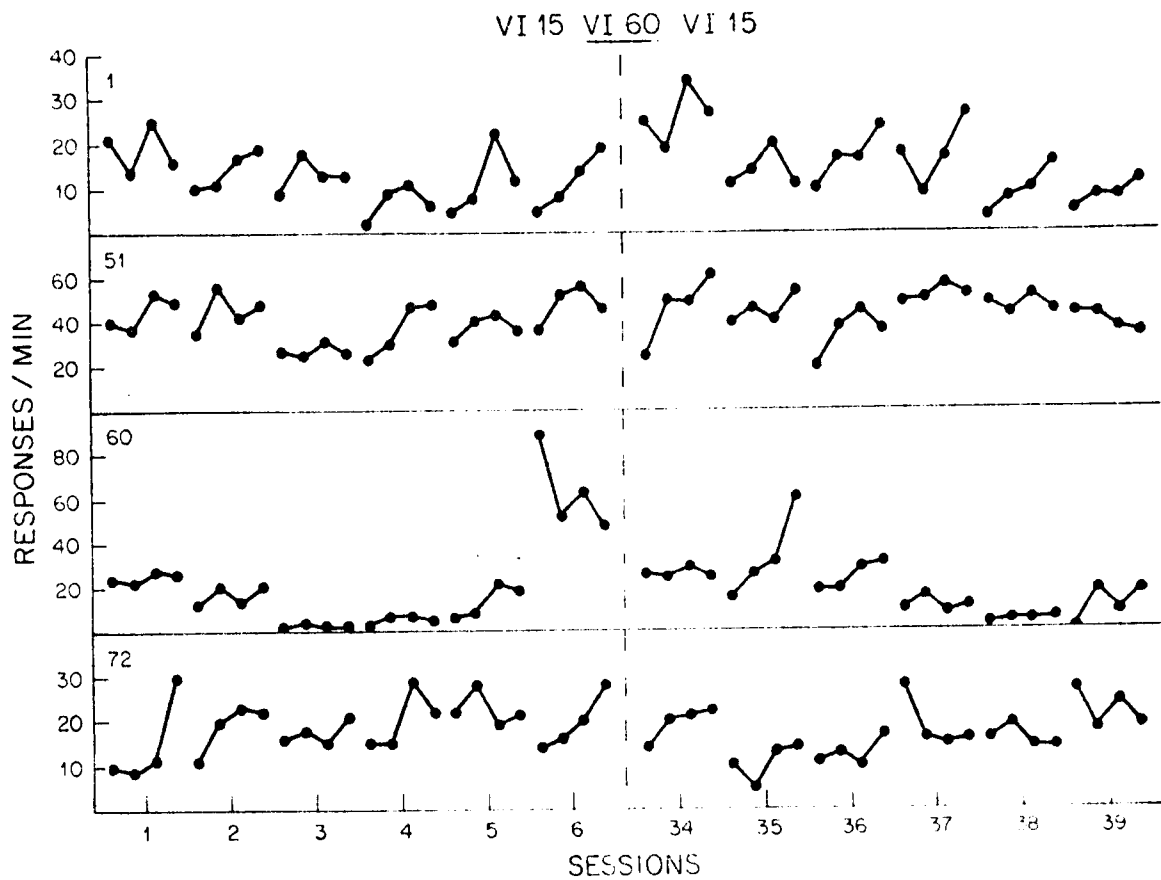


Figure 10. Response rates for each subject during successive 15-sec quarters of the VI 60-sec component in Condition 2. Data represent the first and last six individual sessions.

Discussion

Under the simple conditions employed in Experiment I, both local contrast and backward-acting contrast were expected to appear. In each condition only three components were used and these appeared in a fixed, recycling sequence isolated by blackout periods. The evidence for the possibility that the component-to-come exerts a controlling effect was found in Experiment I, where initially positive local contrast in a middle component was produced by a preceding component. This pattern of decreasing response rate was subsequently replaced by a pattern of increasing response rate in some of the subjects.

Experiment II

It may be impossible to "isolate" simple multiple-schedule triads by inserting between them a blackout period, even if the blackout period is treated as a component in its own right. Since blackouts may have affected preceding and following components in unknown ways, the second experiment employed the simple VI 60, VI 15, EXT sequence of Condition 1, but without BO periods intervening.

Method

Subjects. Two White Carneaux and one Silver King pigeon with varied experimental histories served, maintained at approximately 80% of their free-feeding weights. The Silver King had served in Experiment I, Condition 1, twelve months earlier.

Apparatus. The apparatus of Experiment I was used.

Procedure. As in the first experiment, a three component multiple schedule was used and it was identical with that used in Condition 1, except that BO periods were not inserted between cycles. One-minute presentations of a red key appeared with VI 60-sec reinforcement, followed by one minute of VI 15-sec appearing with an orange key, followed by one minute presentations of a green key accompanied by EXT. The sequence repeated seven times per session. Thirty-six sessions were run, conducted six days a week.

Results and Discussion

Figures 11-13 show response rates, for Birds 57, 74 and 95 respectively in the middle VI 15-sec component for each

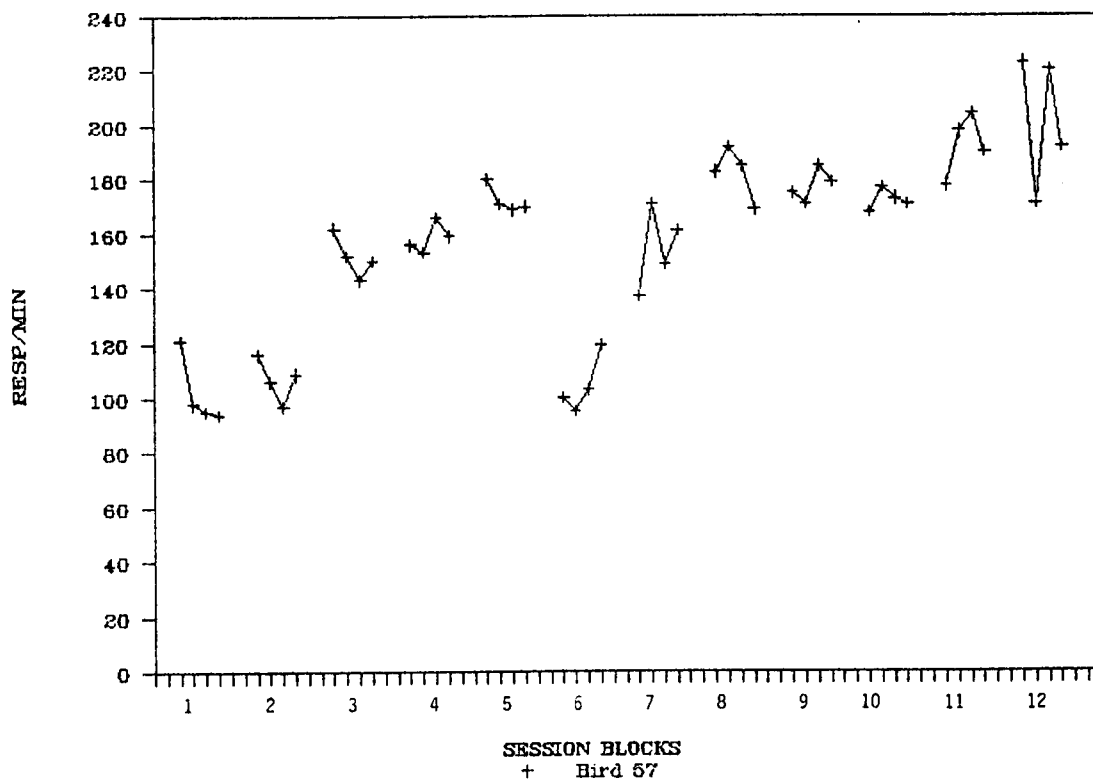


Figure 11. Response rates for Bird 57 during successive quarters of the VI 15-sec component in Experiment II. Data were averaged over successive three-day blocks.

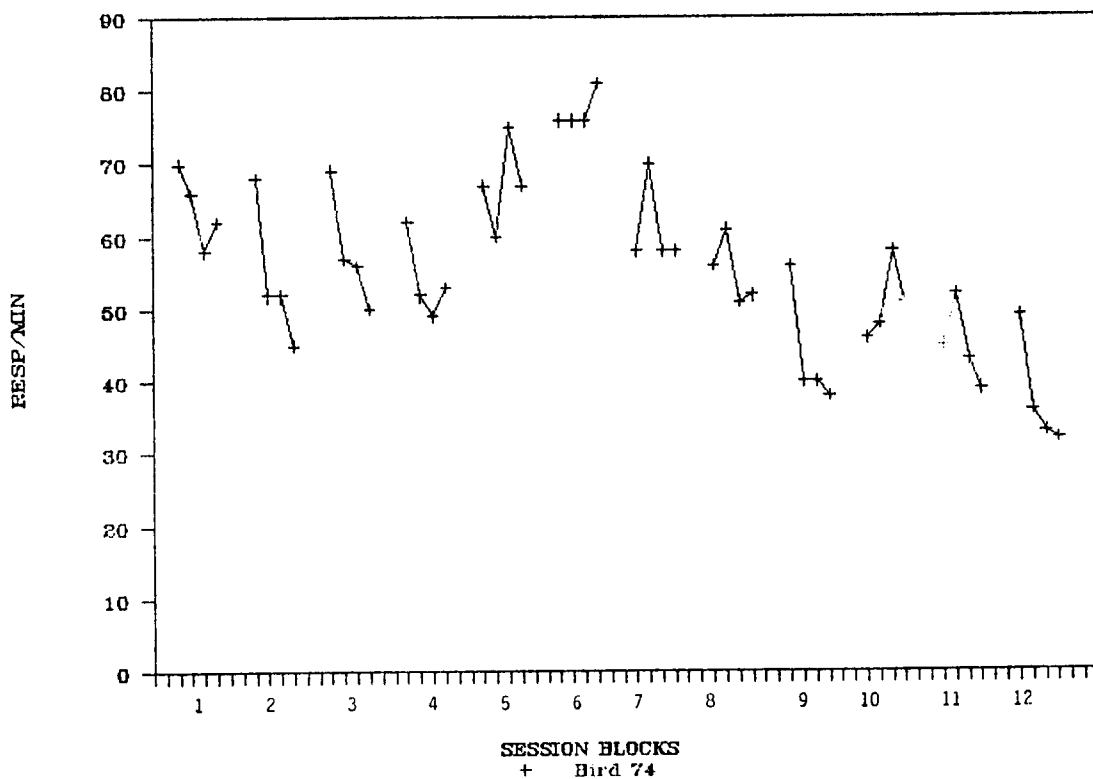


Figure 12. Response rates for Bird 74 during successive quarters of the VI 15-sec component in Experiment II. Data were averaged over successive three-day blocks.

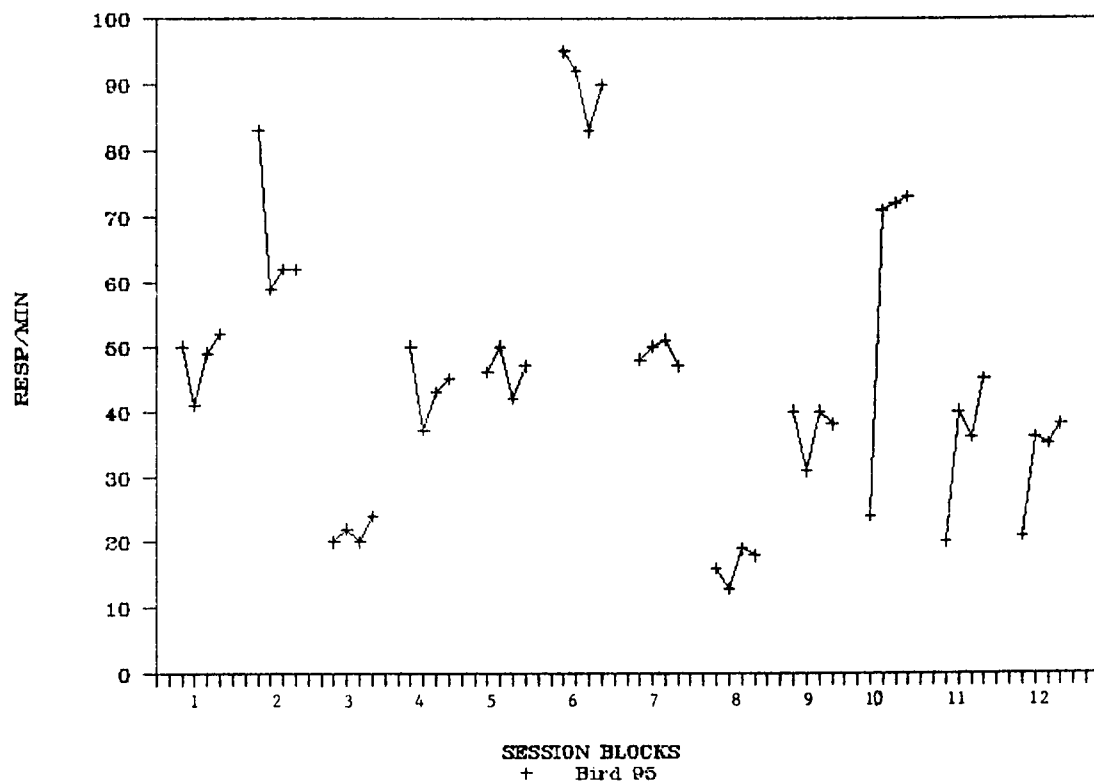


Figure 13. Response rates for Bird 95 during successive quarters of the VI 15-sec component in Experiment II. Data were averaged over successive three-day blocks.

15 second subinterval of its presentation. The data are given in blocks of 3 sessions over the course of training.

An elevation in response rate in the first 15 seconds of presentation was seen in the first 3 blocks for all of the birds. A depression in response rate in the last 15 seconds of presentation is seen in the last 2 blocks for Bird 74. For Bird 95, there is an elevation in response rate in the last segment of the component's presentation during the last 3 blocks. As in condition 1 of experiment I, a contrast effect due to the preceding component was seen early in training. Whether there is a blackout period separating the recycling components appears not to be relevant to this outcome. For at least one of the subjects, Bird 95, a contrast effect due to the following component was indicated late in training.

General Discussion

The pattern of within-component responding has been emphasized here, but as has been pointed out elsewhere (e.g., Malone & Rowe, 1981), that is not the only, or the best, means for identifying local contrast. Often local contrast appears more reliably as differences in overall response rates within components, produced by different preceding components. An adequate demonstration of local contrast requires the comparison of response rates during a

given component when it is preceded by other components and when it is preceded by itself. Thus a pattern of response rate often implies local contrast, but does not do so invariably. The simple sequence of components used here did not allow for comparison of a component preceded by other components with the component preceded by itself. An interpretation of the results should be seen in this light.

A look at local response rates during a multiple schedule discrimination procedure reveals that there are local interactions among the components of a multiple schedule. If one temporal position (either before or after) produced the greater interacting effect, then multiple schedule interactions would be temporally asymmetric. Buck, Rothstein and Williams (1975) argue that multiple schedule interactions are temporally asymmetric in their final steady-state product, with anticipatory contrast produced by the component-to-come being the dominant factor.

But an opposing point of view was proposed by Rachlin (1973). He suggested that the signal value of a component's stimulus was maximized at the beginning of a component's presentation. Therefore, the preceding component produced the greater interacting effect by maximizing the signal value of a component's stimulus at its beginning. Multiple schedule interactions were

considered to be temporally asymmetric, but with the asymmetry weighed in favor of the preceding component.

A concern with the interaction of surrounding reinforcement contexts on the effect of a given reinforcement schedule has resulted in concentration on steady-state, post-discrimination performance. There is another point of view, however, that considers the importance of the process of discrimination formation in multiple schedule interactions, particularly local contrast, since local contrast is a reliable accompaniment of discriminations (Malone, 1976).

Local contrast research has depended on the use of random presentations of positive and negative components. The reason for this procedure is that the response rate in an positive component when it occurs after a negative component may be compared to when it occurs after itself, and reliance on a pattern of within-component responding as the sole measure of local contrast may be avoided. This procedure is not favorable to the finding of any anticipatory contrast effects, as Williams (1983) has justifiably pointed out.

The procedure for producing anticipatory contrast is to present simple, repeating sequences of components, so that a discrimination performance may be quickly obtained.

In condition 1 of experiment I, an elevation in response rate in the first segment of the middle component's

presentation was found during the first six sessions for three of the four subjects in the condition. In experiment II, three other subjects were run in the same condition, except without a blackout period, and an elevation in the first segment of the middle component was found for these three subjects.

Such an elevation of response rate in the initial segment of the rich component's presentation when it follows a poor component represents local contrast of the forward-acting type. An elevation in the final segments of the middle component in this condition was found in three of four subjects in experiment I and for one of three subjects in experiment II. Local contrast effects were more evident than were backward-acting effects. When anticipatory effects did occur, they were less clear than were effects due to the preceding component.

In condition 2 of experiment I, a depression in response rate in the initial segment of the middle component indicated local contrast and such an effect was found throughout most of the experiment for all of the subjects. A depression in response rate in the final segment of the middle component would have indicated backward-acting contrast in this condition, but such an effect was not evident.

This study supports the position that the context of reinforcement is temporally asymmetric with the preceding

component producing a greater interaction than the following component. But perhaps a more valuable outcome of this finding is that anticipatory contrast effects did appear to some extent in the conditions of these experiments, along with local contrast. Therefore, their importance in the process of discrimination formation needs to be considered, at least in the type of discrimination in which the component-to-come can be anticipated.

CHAPTER III

THE RELATION OF LOCAL TO BEHAVIORAL CONTRAST

In the previous chapter, local contrast was assessed as the pattern of response rate within a component, but it was pointed out that it often appears more reliably as differences in the overall rate of response in a component when preceded by components associated with different reinforcement frequencies. For example, positive local contrast would be exhibited if the overall response rate in a component were higher after a preceding extinction component, compared to its response rate when preceded by itself or by a component with a comparable reinforcement value. Terrace (1966) demonstrated that during a simple discrimination between two colors, one associated with a variable interval 60 sec schedule (S+) and the other associated with an extinction schedule (S-), the response rates during the presence of S+ were higher following a presentation of the extinction component than they were following a presentation of itself. The same type of finding was reported by Pavlov (1927, Lecture XI) when a CS- preceded a CS+. Thus, these were demonstrations of positive local contrast.

In Terrace's study, the average response rate in S+ could be compared with an average baseline rate, taken before an extinction schedule was introduced. Behavioral contrast as a schedule interaction between overall response rates, in the sense in which Reynolds (1961) defined behavioral contrast, was therefore measured. By doing so, Terrace was able to answer the question as to whether local contrast was a necessary condition for the existence of behavioral contrast.

He found that the positive local contrast effect of the preceding extinction stimulus tended to disappear after prolonged training, even though an overall response rate elevation above baseline still remained. Terrace's findings have generally been confirmed (Mackintosh, Little & Lord, 1972; Malone, 1976; Nevin & Shettleworth, 1966). Apparently, overall behavioral contrast does not require the continuation of a local contrast effect. But, as with many questions concerning contrast phenomena, the answer is usually not so simple.

Although overall behavioral contrast does not appear to depend on the continuation of a local contrast effect, an important relationship between local contrast and behavioral contrast may still exist. As discussed in Chapter I, the molecular analysis of negative behavioral contrast by Marcucella and MacDonall (1977) indicated how such a relationship may develop. In their analysis, a

local contrast effect changes the relative frequency of specifically reinforced interresponse times and so therefore influences response rate. The influence may remain even if the local contrast effects disappear. It should be noted that, although their analysis used local contrast to explain the development of behavioral contrast, they were not specific in explaining why local contrast occurs.

To better understand contrast effects, it would be helpful to follow the course of behavioral contrast, by separate measures as much as is possible, to see if there is a strong correlation between the measures and to assess the time course of their relationship. In Terrace's (1966) study, local contrast was measured by the difference between the response rate to the positive stimulus when it was preceded by the negative stimulus compared to its response rate when it was preceded by itself. This difference diminished in the middle of the twenty training sessions and faded by the eighteenth session. The behavioral contrast effect appeared as the difference in the average response rate to the positive stimulus compared to a prediscrimination response rate. Average response rate to the positive stimulus also decreased in the middle of the twenty sessions and during session eighteen.

Although behavioral contrast lessened, it was still substantial since the average response rate in the positive

stimulus was almost twice that of the prediscrimination baseline phase. The increase in response rate due to local contrast was insufficient to account for the large increase in response rate appearing as behavioral contrast. The same conclusion applies to the data in Malone (1976, Figure 2). But, nevertheless, there is the indication in Terrace's results that local and behavioral contrast were in part correlated.

One of the problems with correlating behavioral contrast with local contrast is that the magnitude of the behavioral contrast effect, as measured in a procedure such as Reynolds (1961), is the difference between the average response rate in S+ during the discrimination phase minus the average rate in the same component during the nondiscriminatory baseline phase. The baseline average remains a constant during the discrimination and becomes further removed in time and training from the current discrimination sessions as the training phase progresses.

Local contrast, on the other hand, is typically measured as the difference in response rate in S+ when it follows an S- and the response rate in S+ when it follows itself or another S+. The measure is based on session-by-session recordings of response rate and doesn't involve averages from any past baseline phase.

Might there be a more appropriate measure of behavioral contrast based on current, session-by-session

recordings of response rate with which local contrast could be correlated?

In fact there may be a way of measuring behavioral contrast session-by-session. Positive behavioral contrast is that increase in response rate in an unaltered component of a multiple schedule when reinforcement is reduced in a previously positive component. It is not necessarily due to the transition from a negative to a positive component.

Now consider a three component multiple schedule in which two of the components are positively reinforced and one is presented in extinction. One of the positive components is sometimes directly preceded by the extinction component and the other positive component is never directly preceded by the extinction component. For narrative purposes, the positive component which is sometimes preceded by the extinction component will be called A, the positive component which is never preceded by the extinction component will be called B and the extinction component will be called C.

Local contrast may appear in this situation as an increase in response rate in component A when it is preceded by component C, as compared to when it is not directly preceded by C.

In addition, an increase in component A may be found when it is not preceded by component C, relative to the other positive component B. Such an increase would be a

contrast effect that would not be directly attributable to an S- to S+ transition and would represent behavioral contrast. Component B would, in effect, act as a session-by-session baseline with which to measure behavioral contrast in component A when it is not preceded by the extinction component.

By tracking separate session-by-session measures of local and behavioral contrast, the nature of the correlation between the two types of contrast may be investigated. A precursor theory of the origin of behavioral contrast would predict that the appearance of local contrast would accompany or precede the appearance of behavioral contrast. It would also predict that the correlation may fade in later stages of discrimination training, indicating an increasing independence of behavioral from local contrast. The experiment reported here tests these predictions.

Method

Subjects

One Silver King, one White Carneaux and two Tumbler pigeons, all with varied experimental histories, were maintained at approximately 85% of their free-feeding weights.

Apparatus. The experimental chamber was a 33 x 26-cm aluminum and plexiglas box placed within a 61 x 61 x 93-cm sound and light shielding enclosure. An opaque 1.9-cm response key was centered 24 cm above the floor and 14 cm above the center of a 5.5 x 5.5-cm food magazine opening. A 1.1-W houselight centered on the ceiling of the chamber provided illumination. During food magazine operation, three second access to mixed grain, a 6-W light illuminated the feeder area. Stimuli were projected on the response key by an inline digital display unit using a 6.3-V, 1.6-W bulb. The floor was raised 5 cm for the tumbler pigeons. A ventilation fan and white noise generator masked extraneous noises and programming and recording equipment was located in a nearby room.

Procedure. Each bird was started with one day of key training, which consisted of operation of the food hopper until the subject approached and fed. The magazine operation was then discontinued until a peck on the response key occurred. After several more pecks and reinforcements, a VI 30-sec schedule of reinforcement ran for 30 minutes.

On the second day, the birds were placed on a three component multiple schedule. For narrative purposes, the components are termed A, B, and C. Component A was presented with a VI 30-sec reinforcement schedule.

On the second day, the birds were placed on a three component multiple schedule. For narrative purposes, the components are termed A, B, and C. Component A was presented with a VI 30-sec reinforcement schedule. Intervals comprising the schedule were based on the method of Fleshler and Hoffman (1962). Component B was also presented with a VI 30-sec schedule. For the first 11 sessions of the experiment, component C was presented with a VI 30-sec reinforcement schedule and then switched to extinction for the next 32 sessions.

The sequence of presentation of each component was random except for three qualifications: (1) component B never followed component C, (2) component C never followed component B and (3) no component was presented more than three times in succession. In the sequence so generated, component A occurred 57 times, B occurred 38 times and C occurred 33 times. With component durations of 30 seconds, a session lasted 64 minutes.

Component A was presented with red projected on the response key for birds 90 and 78, with green for birds 65 and 94 and with orange for bird 99. Component B was presented with red for birds 94 and 99, with green for bird 78 and with orange for birds 90 and 65. Component C was associated with red for bird 65, with green for birds 90 and 99 and with orange for birds 78 and 94. Sessions were conducted six days a week for 43 sessions.

Results

Baseline

After 11 sessions of baseline training, in which responding in each component was equally reinforced, there was little difference in response rate between the components, except for birds 78 and 99. Figure 14 shows response rate for each component, averaged over two-session blocks, during the baseline and discrimination periods for birds 90 and 94. The baseline and discrimination stages are separated by a vertical dashed line. The last 10 sessions of baseline are shown in 2 day blocks. Figure 15 shows the same for birds 99, 65 and 78. In the baseline stage, Bird 78 showed a higher response rate in component B and bird 99 showed a higher response rate in component C. Response rates declined in all components over the baseline period for all birds except 78.

Discrimination

On the 12th session, discrimination training was begun in which the VI reinforcement schedule was changed to extinction. The figures illustrate behavioral contrast in that response rate in the positively reinforced component (A) preceded by the extinction component (C)

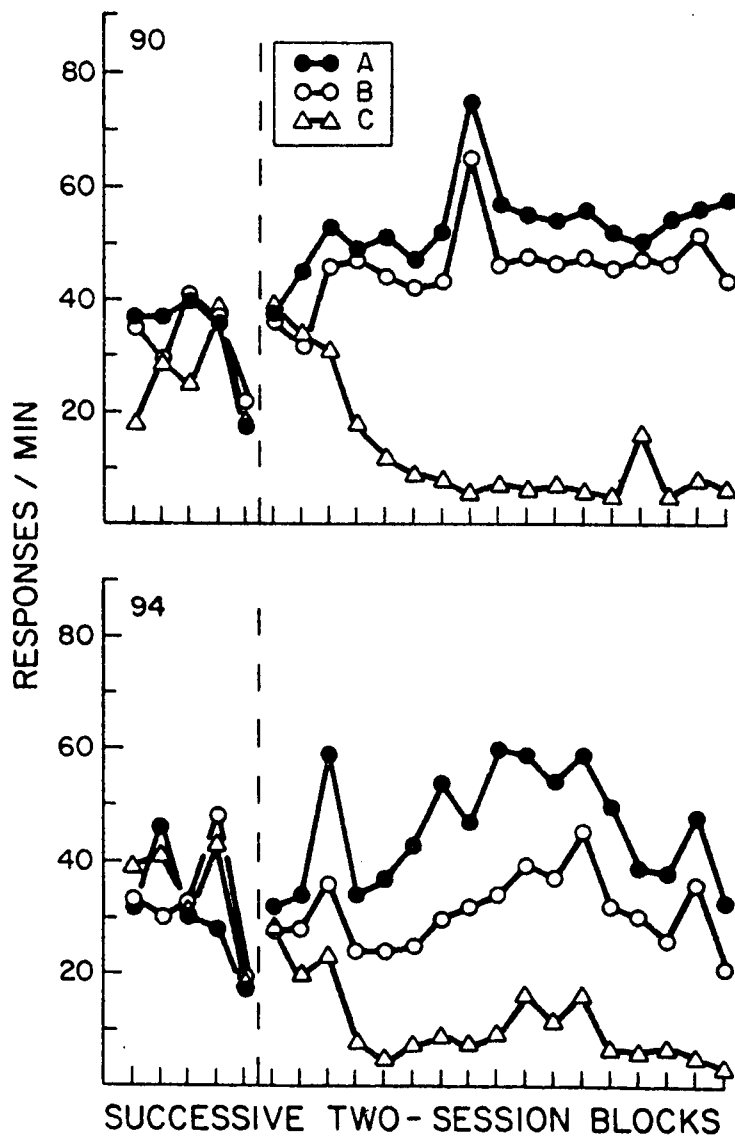


Figure 14. Average resp/min for Birds 90 and 94 during each component. The data are reported in successive two-session blocks. Baseline and discrimination stages are separated by a vertical dashed line.

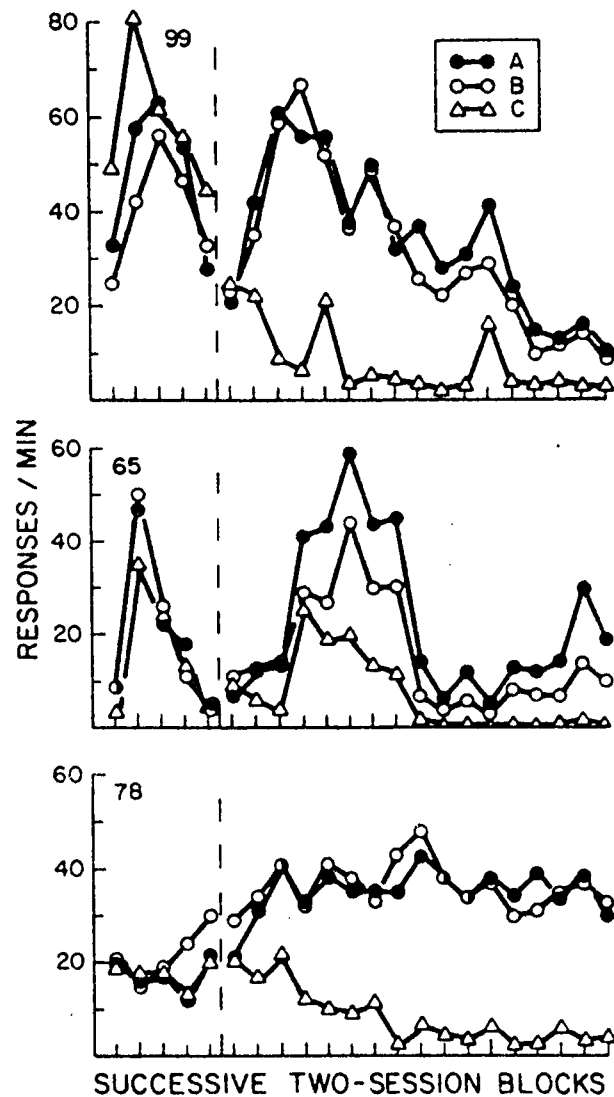


Figure 15. Average resp/min for Birds 99, 65 and 78 during each component. The data are reported in successive two-session blocks. Baseline and discrimination stages are separated by a vertical dashed line.

increased as response rate in the extinction component decreased. Furthermore, the increase in response rate in A exceeded that of B, a positively reinforced component never preceded by C. This was true for birds 90, 94 and 65. For bird 99, response rate in both A and B increased to about the same degree. Beginning at discrimination session 17, response rate in A did become slightly higher than response rate in B for bird 99. For bird 78, response rate in A never became appreciably higher than response rate in B. Birds 65 and 99, the tumbler pigeons, decreased in response rate over the discrimination sessions, perhaps reflecting the difficulty in maintaining the deprivation level of these small birds.

To illustrate local contrast, Figures 16 and 17 show response rate in A when it occurred immediately after C and its residual, response rate in A when it did not occur after C. The data are again given over successive two-session blocks. Response rate in B is also shown. Figure 16 depicts the results for bird 90 and 94 while Figure 17 depicts birds 99, 65 and 78.

For all birds except 78, the results indicate that response rate in A was higher at some point in the discrimination phase when A immediately followed the extinction component. For bird 90, the difference appeared and peaked by discrimination sessions 15-16 and faded by

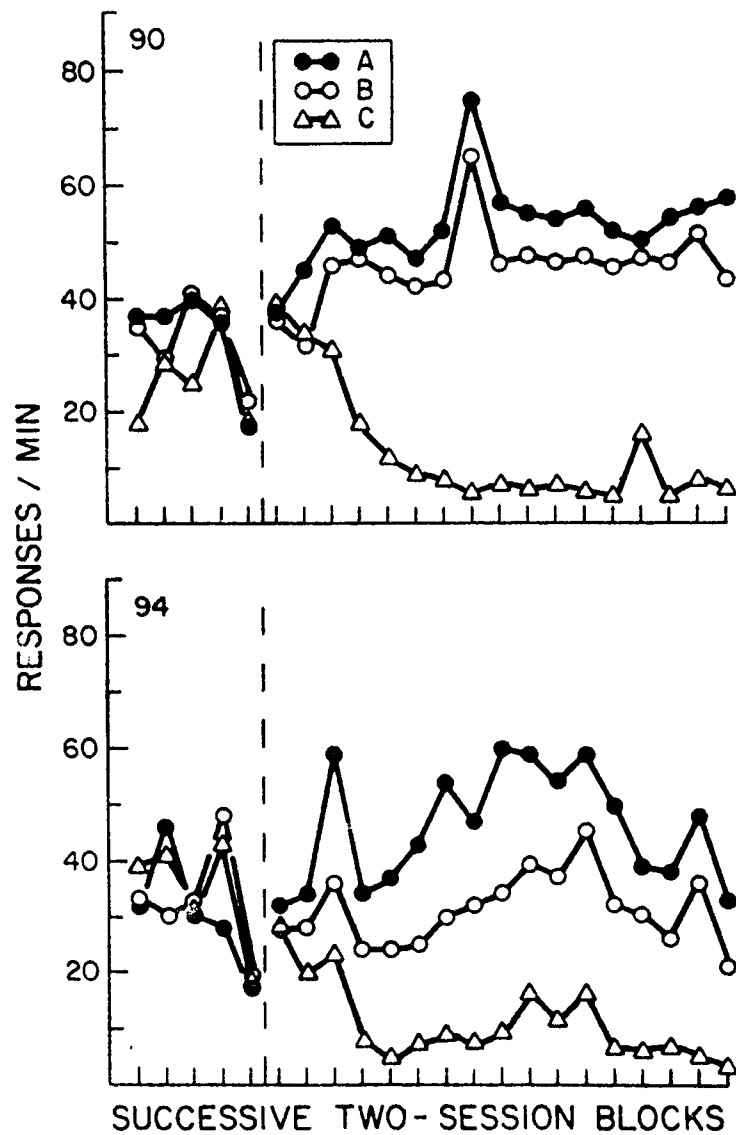


Figure 16. Average resp/min during the positive components for Birds 90 and 94. Response rate in component A, both when it occurs after component C and when it occurs after itself or component B, is shown. Also shown is response rate in B. The data are reported in successive two-session blocks.

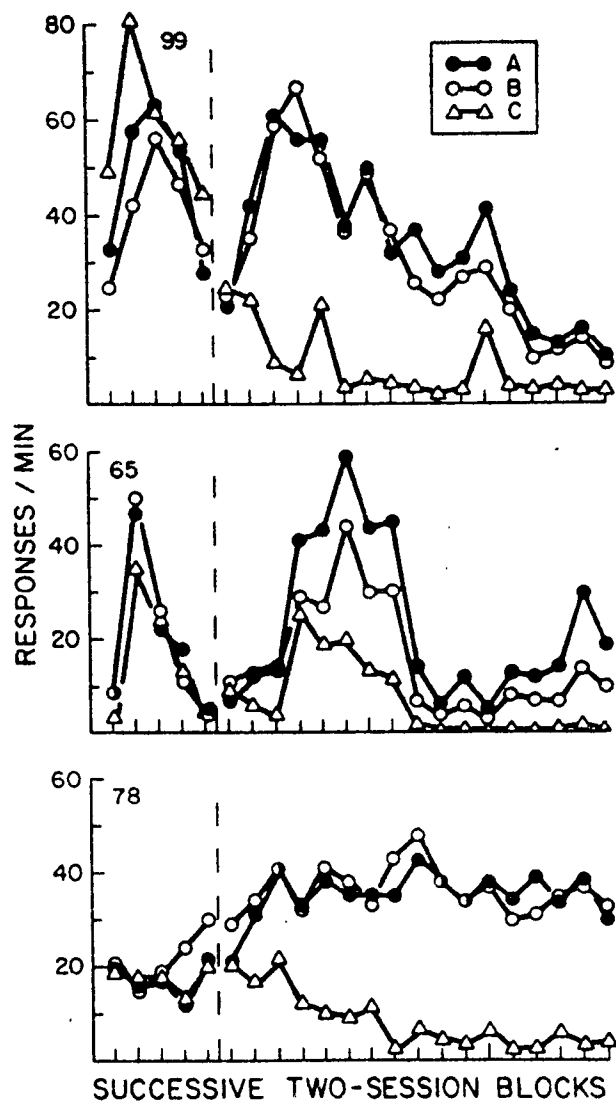


Figure 17. Average resp/min during the positive components for Birds 99, 65 and 78. Response rate in component A, both when it occurs after component C and when it occurs after itself or component B, is shown. Also shown is response rate in B. The data are reported in successive two-session blocks.

sessions 27-28. For bird 99, the difference appeared and faded by sessions 11-12. The difference between A after C and A not after C did not appear until sessions 5-6 for bird 65 and declined through sessions 17-26, but increased during the last four sessions. For Bird 94, a large difference appeared and peaked by sessions 23-24.

One question to be addressed by this study was the correlation between behavioral contrast and local contrast. Table 1 shows both a behavioral contrast measure and a local contrast measure for each session of the discrimination phase. The behavioral contrast measure is the average response rate in A minus the average response rate in B and the local contrast measure is the response rate in A after C minus the response rate in A when not after C. The discrimination phase is divided into two blocks of 16 sessions each, with the average behavioral and local contrast measure for each block and the product moment coefficient of correlation between the measures for each block given.

While the average measure of behavioral contrast increased over sessions for 4 of the 5 birds, the average measure of local contrast decreased for 3 of the 5 birds. All birds showed a decline in the positive correlation between the two measures from the first block of discrimination sessions as compared to the second block.

TABLE 1

CORRELATION OF BEHAVIORAL AND LOCAL CONTRAST MEASURES

SUBJECTS											
90		94		99		65		78		Avg.	
Behv. Local		Behv. Local		Behv. Local		Behv. Local		Behv. Local		Avg.	
Day	Cont.	Cont.	Cont.	Cont.	Cont.	Cont.	Cont.	Cont.	Cont.	r	
	(r/m)	(r/m)	(r/m)	(r/m)	(r/m)	(r/m)	(r/m)	(r/m)	(r/m)		
1	-3.4	9.2	8.7	2.5	4.0	1.5	-1.7	0.0	-7.3	-6.5	
2	3.5	13.5	4.9	9.2	1.2	8.7	0.6	1.7	-5.5	-2.0	
3	20.8	3.5	7.2	9.7	10.4	12.8	-1.7	5.0	0.9	-2.7	
4	2.4	8.8	31.3	25.0	-1.6	32.8	-0.6	4.3	-4.0	-4.0	
5	11.2	11.2	14.5	5.0	5.6	12.8	-0.6	-1.2	5.8	0.3	
6	2.4	3.2	16.0	14.5	-14.6	8.8	-5.4	4.8	2.2	-1.8	
7	2.4	10.2	4.0	-5.0	-7.9	3.7	30.5	43.0	-0.8	2.0	
8	8.8	5.8	8.4	5.8	-0.9	11.7	1.2	0.7	-2.0	-1.0	
9	3.9	1.8	17.2	0.7	9.1	4.8	29.3	41.3	-3.9	4.8	
10	4.4	-10.3	9.4	10.8	3.1	-2.1	13.1	30.3	-4.2	-4.5	
11	3.9	3.2	26.9	31.7	-1.3	3.0	16.9	25.2	-0.7	1.0	
12	5.3	-0.2	25.4	25.3	-2.3	-5.0	13.6	15.7	2.2	-0.3	
13	11.2	0.5	20.9	26.7	4.2	-4.5	12.1	17.2	1.5	-0.5	
14	4.1	9.7	16.8	30.0	-2.9	5.1	7.4	7.2	-8.2	-3.0	
15	21.4	20.7	12.8	33.0	-5.5	5.5	20.4	13.8	-7.9	-4.3	
16	13.8	2.8	22.4	24.7	11.1	2.8	10.2	14.2	-4.2	-1.7	
Avg.	7.3	5.8	15.4	15.6	0.8	6.4	9.1	13.9	-2.3	-1.5	
r	.19		.69		-.06		.91		.47		.54
17	7.4	-4.3	28.3	31.8	13.1	5.3	3.6	4.7	-6.5	-2.2	
18	11.6	6.3	16.7	34.0	1.3	5.3	1.2	1.2	-1.1	0.3	
19	4.7	3.2	23.2	28.2	12.1	1.7	2.8	2.3	0.4	-2.7	
20	7.0	-1.5	21.3	23.0	5.1	4.3	6.9	3.7	-1.6	4.3	
21	9.2	-1.8	13.4	33.2	5.9	1.2	3.5	3.0	1.9	0.7	
22	10.8	12.5	16.4	31.7	15.1	-4.8	2.3	-0.2	2.3	5.0	
23	7.3	0.3	12.5	36.5	10.7	0.2	1.3	2.3	0.4	3.3	
24	7.5	5.0	15.6	20.8	4.5	0.5	6.3	10.8	1.9	0.2	
25	7.4	12.7	20.3	23.5	3.7	2.2	5.8	-2.5	7.2	-0.5	
26	8.3	6.0	8.4	19.8	7.9	1.2	3.6	-3.3	9.3	-2.5	
27	-1.1	-0.8	8.4	26.8	2.5	0.2	7.7	-2.0	6.9	3.7	
28	10.2	0.2	6.2	18.2	0.2	1.7	3.8	-0.5	-1.8	-2.3	
29	5.7	0.5	16.8	38.8	2.5	8.5	10.8	13.5	0.0	-1.5	
30	7.6	-4.2	8.7	27.5	-5.6	3.8	19.2	24.7	0.5	-1.5	
31	3.8	5.0	15.5	33.0	3.4	0.2	9.1	2.3	2.1	1.3	
32	16.2	1.0	17.9	22.2	0.9	5.2	3.4	0.2	-2.1	3.7	
Avg.	7.7	2.5	15.6	28.1	5.5	2.3	5.7	3.8	1.2	0.6	
r	.17		.23		-.45		.79		.04		.20

Table 1 indicates that the correlation coefficient between behavioral contrast and local contrast measures, which was positive for 4 of the 5 birds, decreased as discrimination training progressed. The average correlation coefficient (found by using a Fisher's z transformation) for the first half of discrimination sessions was .54 and a one-tailed test to determine if this value was significantly different from zero showed significance ($df=14$, $t=2.40$, $\alpha=.05$). The average r for the second half of the discrimination sessions was .20 and a one-tailed test showed that it was not significantly different from zero ($df=14$, $t=0.76$, $\alpha=.05$).

Discussion

Pigeons were presented a three component multiple schedule with components appearing in an unpredictable order. After a baseline period in which all components were associated with reinforcement, a discrimination period followed in which one of the components was associated with extinction. Of the remaining two positive components, one was at times directly preceded by the extinction component and one was not.

For most of the subjects, response rate in the positive components rose during the discrimination phase. The difference in response rate between the positive

component sometimes immediately preceded by an extinction component minus the other positive component, never immediately preceded by an extinction component, was taken as a measure of behavioral contrast. This measure tended to increase over the discrimination period.

In addition, the response rate in the positive component when it followed the extinction component minus the response rate in the component when it did not directly follow the extinction component was taken as a measure of local contrast. As found by Terrace (1966), this measure of positive local contrast tended to decrease over the discrimination period. Also, the positive correlation of the measures of local and behavioral contrast was found to weaken from an early block of discrimination sessions to a late block. The present results are in agreement with Marcucella and MacDonall's analysis in that independence of the measures for behavioral and local contrast increased as discrimination training progressed.

One of the difficulties posed by the suggestion that behavioral contrast is dependent on local contrast is that there is evidence that behavioral contrast often remains when local contrast has faded. Indeed, the present study found that behavioral contrast became more independent of local contrast, even as behavioral contrast was increasing.

For the majority of subjects, the average measure of behavioral contrast increased over discrimination sessions,

while the average measure of local contrast decreased. The disassociation of the local and behavioral contrast measures can be seen in their product moment correlation as it decreased in its positive value over discrimination sessions for all of the subjects. Precursor theories such as Mackintosh (1974) and Marcucella and MacDonall (1977) are attractive because an interacting relationship between local and behavioral contrast may be established without the requirement that local contrast remain in order for behavioral contrast to continue. A precursor theory may therefore be the most viable view of the relationship between behavioral and local contrast.

CHAPTER IV

LOCAL CONTRAST AND COMPONENT DURATION: A RESOLUTION OF THE THEORIES OF LOCAL CONTRAST

As discussed in the introduction, contrast effects are found to be reliable aspects of discrimination. There are four types of contrast: behavioral contrast, local contrast, backward-acting contrast and local dimensional contrast. Defining characteristics and evidence for each type was given in Chapter I. Chapter II looked particularly at the conditions that produce backward-acting contrast and at the presence of local contrast in those conditions. Chapter III looked at the correlation between overall behavioral contrast and local contrast. In this chapter, two of the main theories of local contrast will be compared and, hopefully, resolved.

Local contrast is found when transitions are made between multiple schedule components of different frequencies of reinforcement (Nevin & Shuttleworth, 1966; Malone & Staddon, 1973). Positive local contrast, for example, appears as increased responding during the presentation of a positively reinforced component when it is preceded by an extinction component, as compared to its response rate when preceded by itself.

Positive local contrast may also appear as a pattern of responding within a positive component, with elevated responding at its beginning when preceded by an extinction component. However, response rate may be inversely related to the average response rate in a preceding component without the pattern of responding being affected.

Additivity theory was reviewed in Chapter I and there it was argued that a strict interpretation of the theory could be liberalized to include the elicitation of the more molar sign-tracking behavior, rather than being restricted to only autopecks.

A Pavlovian process/additivity theory (PP/AT) would overcome the difficulties of strict additivity theory and would apply Pavlovian processes to local contrast effects in a credible way. PP/AT would be "additive" in the sense that both Pavlovian and operant factors are involved, not in the sense that there is a literal adding of Pavlovian and operant responses. Its application to local contrast would include the following assumptions:

(1) During operant successive discrimination training (multiple schedules) classically-conditioned responses may be elicited by positive and negative stimuli. The Pavlovian responses evoked need not be topographically similar to the operant responses. They may appear as approaches to and withdrawals from the manipulandum. Approach to S+ means that operant responses are apt to be

directed toward it and withdrawal means that responding to S- is less likely to occur.

(2) These responses are strongest at or shortly after the transitions among stimuli associated with different frequencies of reinforcement, as suggested by Rachlin (1973). Their strength diminishes with time since stimulus transition.

These assumptions account for positive local contrast as the result of Pavlovian conditioned approach responses, especially at the transition from an S- to an S+, superimposed on a baseline of operant responding. Negative local contrast is accounted for by the withdrawal produced by a transition from an S+ to an S- superimposed upon an operant baseline.

The temporal course of withdrawal tendencies also would explain the effect of variable durations of an S- on a following S+. As discussed above, longer S- durations produce higher response rates in a following S+. A reason for this effect may be that conditioned withdrawal tendency peaks at the transition into an S- and dissipates throughout the component. A short S- would therefore end with a higher level of withdrawal tendency than would a longer S-. Consequently, responding in a following S+ would be less disrupted after a long S- than after a short S- component. By this means, PP/AT agrees with response

competition theory concerning the effect of a variable duration S-.

The effect of a variable duration S+ on a following fixed duration S- would also be predicted by a Pavlovian process/additivity theory, in agreement with response competition theory. Long duration positive components would allow time for any approach tendency, which is assumed to peak close to the transition from an S- to an S+, to dissipate. Shorter positive components may not allow enough time, with the result that after short S+'s, there may be remaining a substantial tendency to approach the signal, which is translated into a higher operant response rate to S-.

Response competition and PP/AT are the two most promising accounts for local contrast. Both can account for positive and negative local contrast and both can account for the effect of variable durations of S- and S+ components on following components. They do so by referring to an auxiliary response which influences a baseline of operant responses. Response competition refers to competing interim responses whose exact nature is often undefined. PP/AT refers to sign-tracking movements whose characteristics have been studied in some detail.

Hearst and Franklin (1977) found that approach and withdrawal tendencies increased as discrimination training continued. Since the effect of variable durations of

preceding S- and S+ components on a following component is assumed to be a function of the time for approach and withdrawal tendencies to subside, PP/AT would predict that a variable duration effect would increase from an early stage of discrimination training to a later stage.

But in Hinson and Staddon's study, the duration effect increased from early to late stages of training for only one of the three birds reported. It would be worthwhile to look at this variable more closely, since it is crucial in evaluating the plausibility of PP/AT. The results may help to assess the relative merits of the two most promising accounts of local contrast.

Method

Subjects

Three male Silver King and one male White Carneau pigeons, with varied experimental histories, served. All were reduced to 85% of their free-feeding weights, where they were maintained throughout the experiment. Bird 95 became ill after 12 sessions and its data are reported up to that time.

Apparatus

The experimental chamber was a 45.5 x 40.5 x 14-cm plywood box, placed inside a larger sound attenuating chamber. Stimuli were provided by a Grason-Stadler inline projector mounted immediately behind a transparent response key. The key was centered 20.3 cm above the floor and 12.5 cm above the 5 x 5-cm food magazine aperture. A 6-W red houselight was on continuously, except during the 3-sec food magazine operations, which provided access to mixed grain. A ventilation fan and white noise generator masked outside noises and programming and recording equipment were located in an adjoining room.

Procedure

Keypecking was established with a brief autoshaping procedure. A vertical (90-deg) line orientation appeared on the key for ten seconds, followed by a 3-sec magazine operation and a 30-sec intertrial interval. Ten such stimulus-food pairings were given each day for three days.

Following each autoshaping period, food was available according to a VI 30-sec schedule for 30 minutes. Intervals comprising the schedule were based on the method of Fleshler and Hoffman (1962).

Each subject was then exposed to from 12 to 36 sessions in which 30-sec presentations of the vertical line were accompanied by EXT and presentations of the 60-deg line were accompanied by a VI 30-sec reinforcement schedule. Presentations of the two stimuli alternated, with those of 60-deg (S+) lasting either 15, 30 or 45 seconds. Each of the three S+ durations appeared 15 times in a quasi-random order and each session thus comprised 45 minutes. Sessions were conducted six days per week. Birds 74, 83, 93, and 95 were run 36, 32, 28 and 12 sessions respectively.

As has been previously noted (e.g., Malone & Rowe, 1981), local contrast is properly assessed against a baseline of stimulus-preceded-by-itself. Here, where the independent variable was S+ component duration, such a procedure was impractical, because it would require the occasional doubling of S- duration, adding a second variation of component duration. Since the magnitude of local contrast could be assessed by comparing responding after different S+ durations, lack of such a baseline was not a real concern.

Results

Duration Effect

Figures 18, 19, 20 and 21 show response rate/minute for each bird in the first 15 seconds of the negative component, both when it occurred after a 45-sec S+ and when it occurred after a 15-sec S+.

If the effect of the longer preceding S+ components is to decrease response rate in a following S-, these two sets of points should be significantly different. A one-tailed paired-comparison t-test confirms that response rate over the discrimination sessions was significantly higher during S- after a long (45-sec) S+ than after a short (15-sec) S+ for Birds 74, 93 and 95 ($n=36$, $t=5.01$; $n=28$, $t=3.26$; $n=12$, $t=2.23$; respectively) at a .05 level of significance. The two sets of points were not significantly different for Bird 83 ($n=32$, $t=.688$).

Increase in the Duration Effect Over Training

The magnitude of sign-tracking movements has been shown to increase with continued discrimination training (Hearst & Franklin, 1977). If, as PP/AT assumes, the duration effect is due to sign-tracking movement, it would

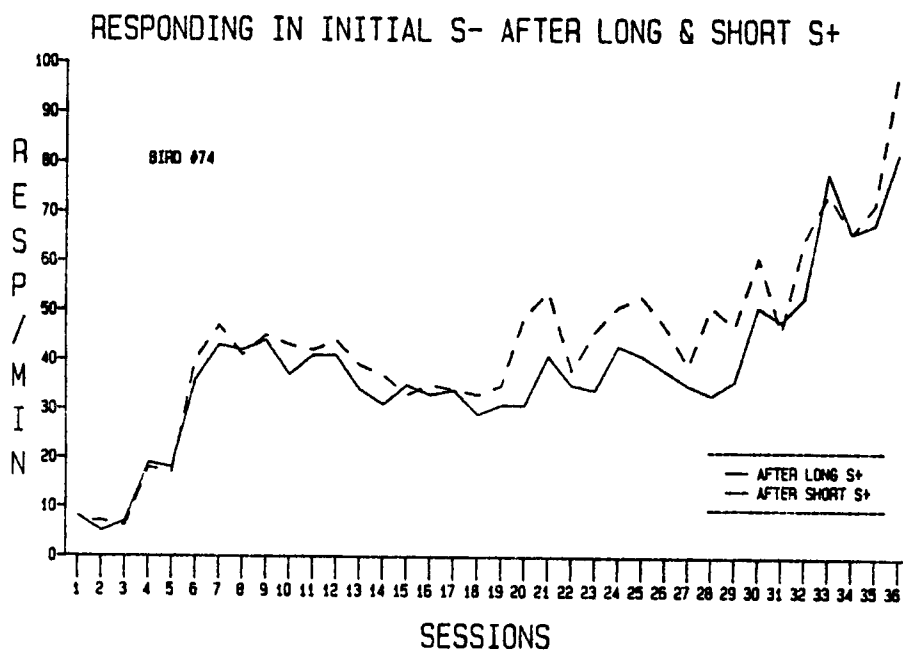


Figure 18. Average response/min in each session for Bird 74 during the first 15 seconds of the S- component, both after the 45 second (long) and the 15 second (short) S+.

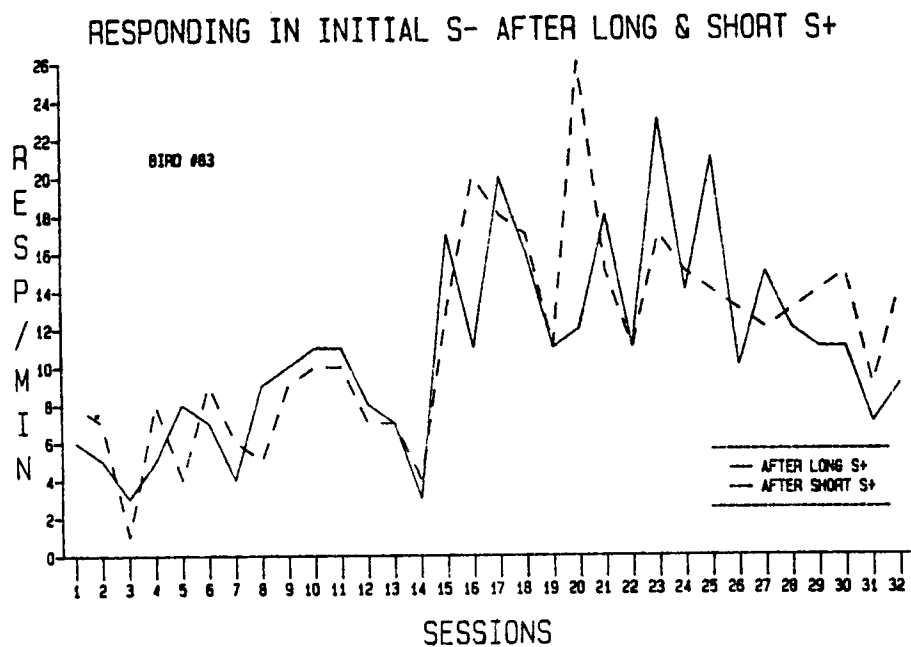


Figure 19. Average response/min in each session for Bird 83 during the first 15 seconds of the S- component, both after the 45 second (long) and the 15 second (short) S+.

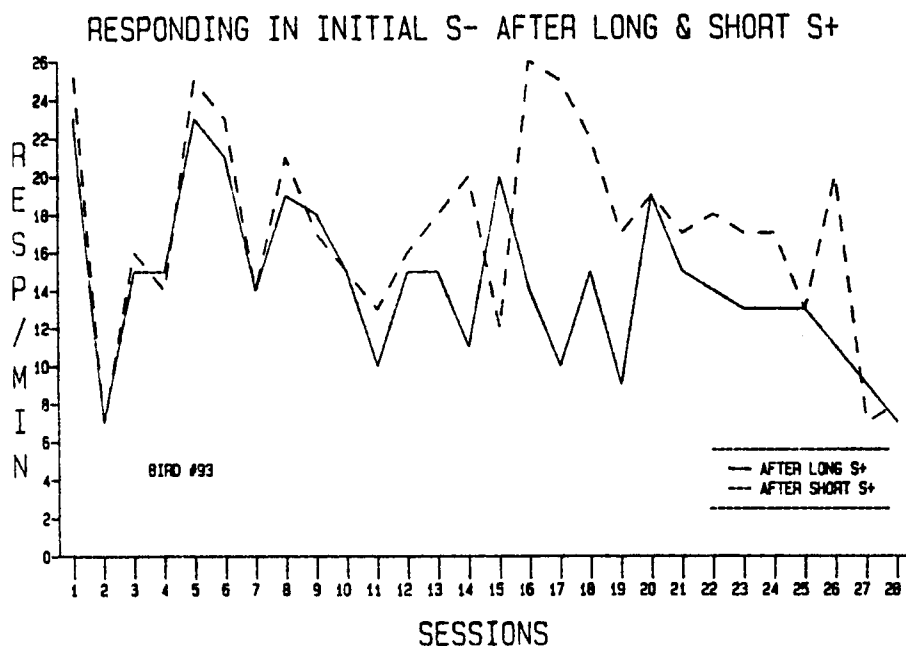


Figure 20. Average response/min in each session for Bird 93 during the first 15 seconds of the S- component, both after the 45 second (long) and the 15 second (short) S+.

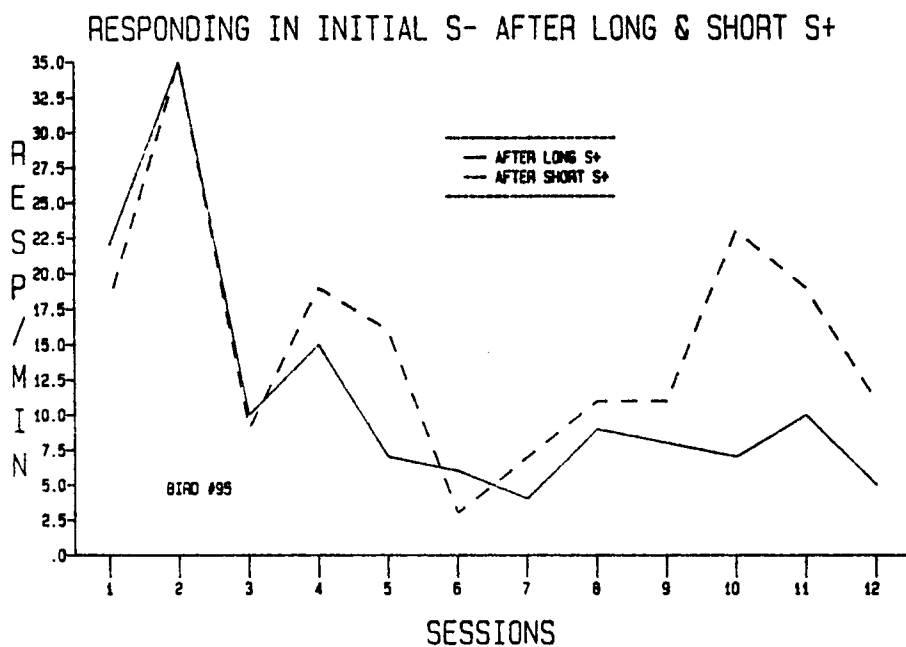


Figure 21. Average response/min in each session for Bird 95 during the first 15 seconds of the S- component, both after the 45 second (long) and the 15 second (short) S+.

be reasonable to expect the duration effect to also increase in magnitude over the discrimination sessions.

For each bird, Figures 22, 23, 24 and 25 depict the magnitude of the effect of S+ duration on the following S-, both for the first half of the discrimination sessions (early) and for the last half (late). The magnitude of the duration effect was calculated by subtracting average response/minute during the first 15 seconds of S- following a long S+ from average response rate in the first 15 seconds of a S- following a short S+.

As can be seen, the duration effect tends to be greater during the second half of the discrimination sessions than during the first half for Birds 74, 93 and 95, but not for Bird 83.

Discussion

Three of the four subjects in the study showed an effect of the duration of a preceding S+ on terminal responding in a following fixed-duration S-. The same three subjects also showed an increase in this effect as discrimination training progressed. The magnitude of positive local contrast in a positive component of a multiple schedule is directly related to the duration of a preceding S- component (Wilton & Clements, 1971; Hinson &

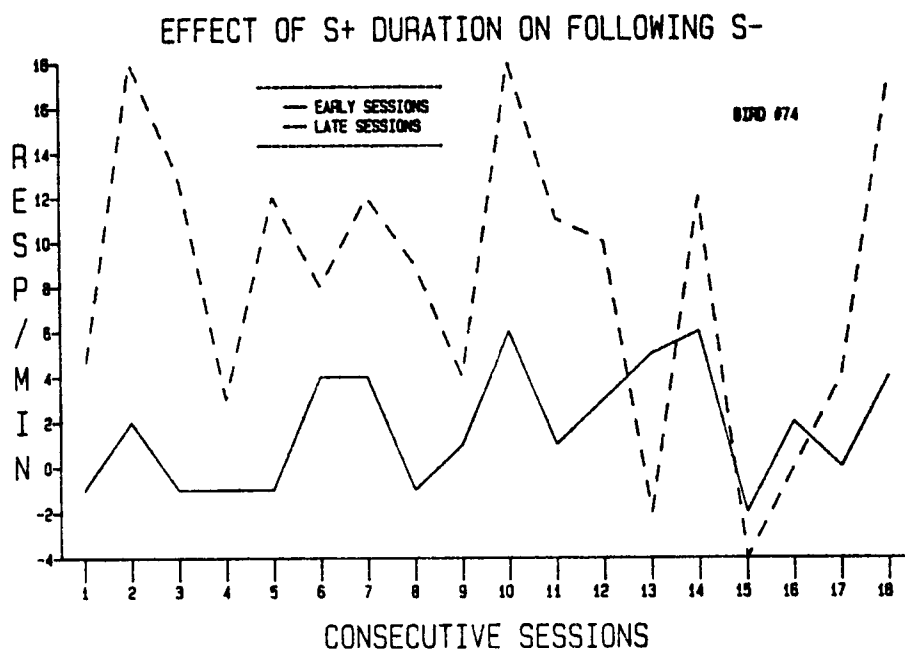


Figure 22. The magnitude of the effect of 45-sec (long) versus 15-sec (short) S+'s on responding in a following S- for Bird 74. The effect magnitude is given in consecutive sessions for the first half of discrimination training (early and the last half (late). See text for the method of calculation of the effect magnitude.

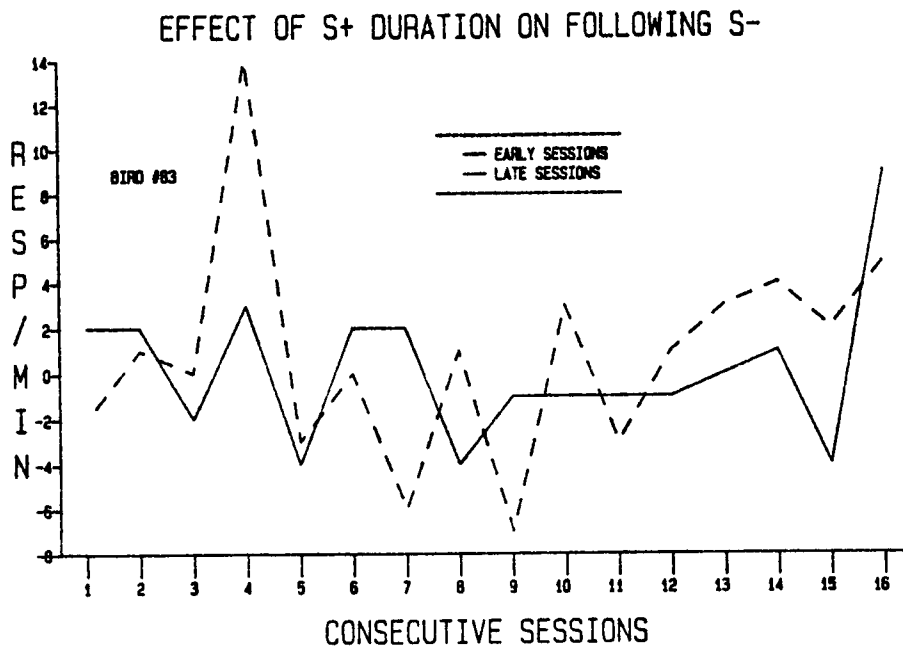


Figure 23. The magnitude of the effect of 45-sec (long) versus 15-sec (short) S+'s on responding in a following S- for Bird 83. The effect magnitude is given in consecutive sessions for the first half of discrimination training (early) and the last half (late). See text for the method of calculation of the effect magnitude.

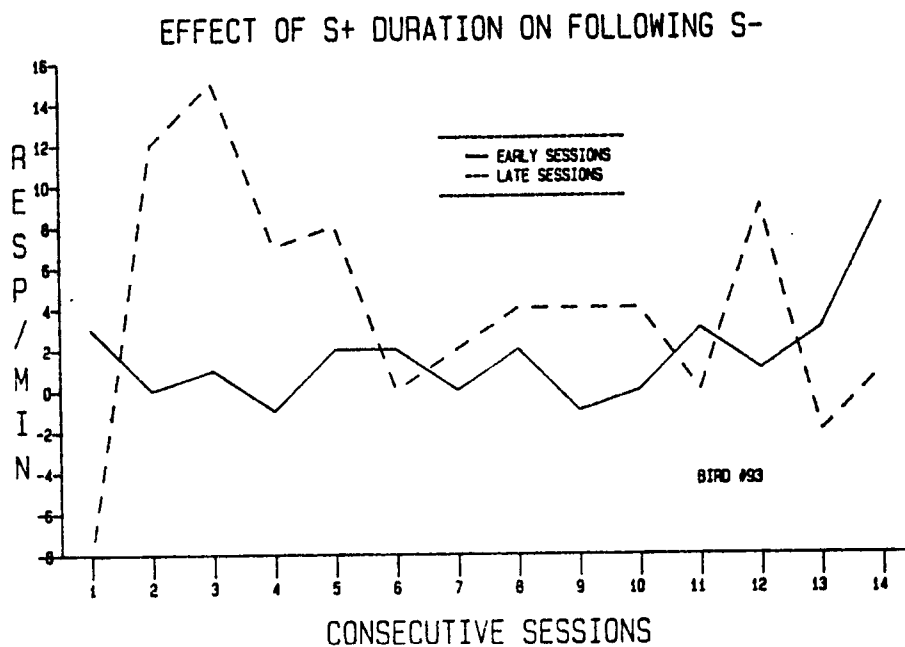


Figure 24. The magnitude of the effect of 45-sec (long) versus 15-sec (short) S+'s on responding in a following S- for Bird 93. The effect magnitude is given in consecutive sessions for the first half of discrimination training (early) and the last half (late). See text for the method of calculation of the effect magnitude.

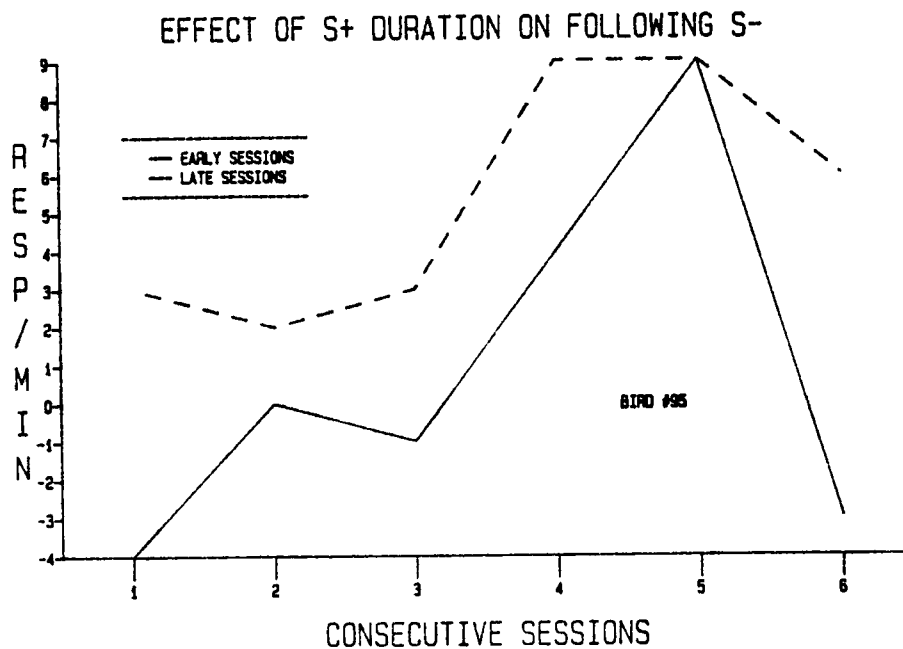


Figure 25. The magnitude of the effect of 45-sec (long) versus 15-sec (short) S+'s on responding in a following S- for Bird 95. The effect magnitude is given in consecutive sessions for the first half of discrimination training (early) and the last half (late). See text for the method of calculation of the effect magnitude.

Staddon, 1981; Malone & Cleary, 1986). It is higher after longer durations of a preceding extinction component. The development of S- duration effects on the magnitude of positive local contrast has been presented as an example of the principle of diminishing returns as derived from response competition theory (Staddon, 1982).

However, a Pavlovian process/additivity theory can account for the direct relationship between magnitude of positive local contrast and duration of a preceding extinction component as well. It can also account for other aspects of S+ response patterning when the duration of a preceding S- component is varied while response competition theory cannot (Malone & Cleary, 1986).

The present study showed that the effect of the duration of a preceding S+ on negative local contrast increased as discrimination training continued. This result would not be predicted by response competition theory, but would be expected according to PP/AT. The approach and withdrawal movements assumed by PP/AT to operate to produce local contrast effects have been shown to increase in strength as discrimination training progresses. Such an increase would be expected to magnify the disparity between the effect of long versus short durations of S+ on the magnitude of negative local contrast.

If the evidence from the present study had indicated that the duration effect did not increase or if it decreased during discrimination training, it would greatly weaken a liberal adaptation of additivity theory as a plausible account of local contrast, but would have left response competition theory unaffected. Nevertheless, the evidence from the majority of the subjects indicated that the duration effect did increase with progressive training.

Since the two theories do not have an equivalent power to explain this result, it becomes clear the PP/AT is a more adequate account of local contrast.

As mentioned in Chapter I, PP/AT may be considered to be a form of response competition theory if response competition theory is limited to a specific type of interim response, that response being sign-tracking movement. The two principles of response competition theory are: (1) reinforcement for one type of response suppresses the other type of response in proportion to their rates of occurrence and (2) in simple variable interval schedules, the reinforced response and interim responses take up the total time (Staddon, 1982). Signal responding and withdrawal conform to the first principle in that any tendency to withdraw from the signal will suppress signal responding, while any time spent signal responding will reduce any measure of withdrawal from the signal. The second principle could also be applied to the simple situation

presented to the subjects of this experiment; key pecking and movement within the chamber could conceivably consume their total time. The language and principles of response competition theory are not that divergent from PP/AT if interim behavior is limited to only sign-tracking movement.

There has been a recent attempt to modify response competition theory so that it applies to only one class of behavioral contrast called "competitive contrast" (Dougan, McSweeney & Farmer-Dougan, 1986). In their research, it was found that a measured interim response would increase behavioral contrast only if there was a high probability of the interim response's occurrence. Behavioral contrast, in fact, decreased if the opportunity for a low probability interim response was introduced. The authors concluded that response competition principles applied only in the case of an alternative response which had a high probability of occurrence.

Their conclusion is in line with what is being expressed here, that response competition principles may be applied to contrast effects if the type of interim response assumed by the theory is limited to one type of high probability response, in the case of PP/AT that being sign-tracking movement.

CHAPTER V

LOCAL CONTRAST AND SIGN-TRACKING

An account for local contrast based upon a Pavlovian process/additivity theory was presented in Chapter IV. Since this chapter will report a study designed to test that account, it may be worthwhile to summarize how it deals with some of the features of local contrast. A more complete discussion of the Pavlovian process additivity/theory may be found in Malone and Cleary (1986).

The within-component response rate pattern which typifies local contrast is one feature addressed by the theory. The positive pattern, for instance, is one where there is elevated responding in the initial segment of an S+'s presentation when it directly follows an S-. The approach tendency is assumed by PP/AT to be strongest at the transition from a differential predictor of non-food to a differential predictor of food (Rachlin, 1973; Hearst & Franklin, 1977). The facilitation of keypecking behavior by approach movement is assumed to be the basis for the increase in response rate.

But note that according to PP/AT, a tendency-to-approach may be opposed by a tendency-to-withdraw. The

tendency-to-withdraw is assumed to be strongest at the transition from a predictor of food to a predictor of non-food and it is assumed to take time to subside. Thus, a short duration S- may deliver into a following S+ a substantial level of unsubsidized tendency-to-withdraw, which can result in a depression of signal-responding behavior. Response rate in an S+ following a short S- would therefore be lower than response rate in an S+ following a long S-. Such an effect of variable durations of an S- is consistently found (Wilton & Clements, 1971; Hinson & Staddon, 1981; Malone & Cleary, 1986).

Conversely, PP/AT predicts that the shorter a preceding S+ component, the higher the response rate in a following fixed-duration S- component, an outcome found in Chapter IV. This is because a tendency-to-approach is also assumed to require time to subside after peaking at the transition into a component. When an S+ is short, it can end at a moment when there is still a strong, unsubsidized tendency-to-approach. The following S- response rate is consequently higher compared with the case where a longer S+ allows the tendency-to-approach time to subside.

The S+ and S- within-component patterns of responding typical of local contrast and the difference in local contrast magnitude due to variable durations of preceding S+ and S- components are two features of local contrast explained by PP/AT. A final feature to be discussed is the

impermanence of local contrast effects and their occasional reversal to induction effects after prolonged discrimination training (Pavlov, 1927; Malone, 1976).

According to a Pavlovian process/additivity theory, a pattern of high response rate immediately after a transition from an S- to an S+ may occur early in training because the tendency-to-approach peaks near the transition.

But induction is a depression in responding in the initial segment of an S+ after a preceding S-. A contrast pattern may be reversed into an induction pattern by the following process. Early in training, responding in an S+ is relatively unaffected by any tendency-to-withdraw being delivered into the component by the preceding S-. However, as training progresses, the tendencies to approach and withdraw become stronger and take longer to subside (Hearst & Franklin, 1977). At some point, it would be expected that a tendency-to-withdraw initiated during a preceding S- would come to encroach into an S+. The result would be a reduction in the pattern of high response rate early in the S+ component and may eventually result in a pattern of induction. Local contrast effects would therefore appear impermanent and would be more impermanent with shorter duration components.

PP/AT depends on sign-tracking behavior (as approach/withdrawal movement in space) to explain the above mentioned features of local contrast. Yet, in previous

studies of the effect of variable durations of preceding components, sign-tracking movements were not directly measured. The present study examined response rates in two alternating S-/S+ components of a multiple schedule in which there were two different durations of the S-. The distance of the subjects from the wall containing the signal key was recorded every fifth second during two S+ and two S- presentations each session. The temporal course of sign-tracking movements within a component's presentation were then examined to see if they offer a plausible explanation of local contrast effects, as assumed by PP/AT.

Method

Subjects

Two White Carneaux and one Silver King pigeons, all with varied experimental histories involving the discrimination of line orientations, served. The birds were maintained at 85% of their free-feeding weights during the experimental period.

Apparatus

A plywood box, 66 x 32 x 42 cm (L x W x H), with a wire-mesh top, served as an experimental chamber. Black strips of tape across the top marked distances inside the box. A false wall was mounted 18 cm from one end of the chamber and behind the false wall a grain magazine and inline stimulus projector were mounted. The projector was mounted 2 cm behind a transparent pecking key, 2 cm in diameter, centered 28 cm above the floor and the magazine was mounted behind a 6-cm square opening whose top was centered 15 cm above the floor.

The projector, a Grason-Stadler model E45801, produced a 0.2-cm wide black line on a white background of either 45 degrees or 60 degrees orientation, relative to the horizontal. The projector used 6.3 V, 1.6-W bulbs. Reinforcement consisted of 3-sec access to mixed grain and the feeder opening was illuminated by a 6-W light above the feeder area. General illumination was provided by florescent lighting in the experimental chamber room.

Recording and controlling equipment was located in an adjacent room from which a 0.25-sec Sonalert signal could be heard by an observer in the experimental chamber room. The Sonalert signal was produced every 5 seconds, starting at the beginning of each experimental session.

Procedure

After one day of key training, as described in Chapter III, a two component multiple schedule was presented to the subjects. One of the components was associated with a VI 30-sec reinforcement schedule, based on the method of Fleshler and Hoffman (1962), and a 45 degree line orientation was projected on the pecking key. The other component was associated with extinction and a 60 degree line orientation. The VI component (S+) and the extinction component (S-) alternated 30 times each experimental session.

The duration of the S+ was always 30 sec while the duration of the S- was either 20 sec or 40 sec. The sequence of presentations of the S- durations was randomly determined with two qualifications: (1) no more than 3 durations of either type were allowed to occur in succession and (2) there were 15 of each type of duration in a session. Each session consisted of 15 short S- presentations, 15 long S- presentations and 30 S+ presentations.

At the start of the 30th component presentation, an observer entered the room containing the experimental chamber and began recording the position of the subject's head upon the occurrence of every Sonalert signal. Positions were classified as being between 0 to 8 cm, 8 to

16 cm, 16 to 24 cm, 24 to 32 cm or 40 to 48 cm from the false wall, as gauged by the black strip markings on the wire-mesh top of the chamber. If the center of the bird's head was exactly beneath a strip, it was classified in the position closer to the false wall.

Position recordings were made for the next four component presentations, which included two more positive components, a 40-sec extinction component and a 20-sec extinction component. Recordings were made for the same segment of the session sequence each day, i.e., from the 31st to the 34th component presentation. At the end of the 34th component presentation, the observer left the experimental chamber room. Birds were run 4 days a week for 20 sessions. Bird 95 was discontinued for one month between sessions 14 and 15, due to a December vacation period.

Results

Duration Effect

Figures 26, 27 and 28 show, for Birds 60, 74 and 95 respectively, average responses/minute during the first 10 seconds of the S+ component, both when it occurred after the 20-sec S- and when it occurred after the 40-sec S-. Initial response rate in S+ tended to be higher after the

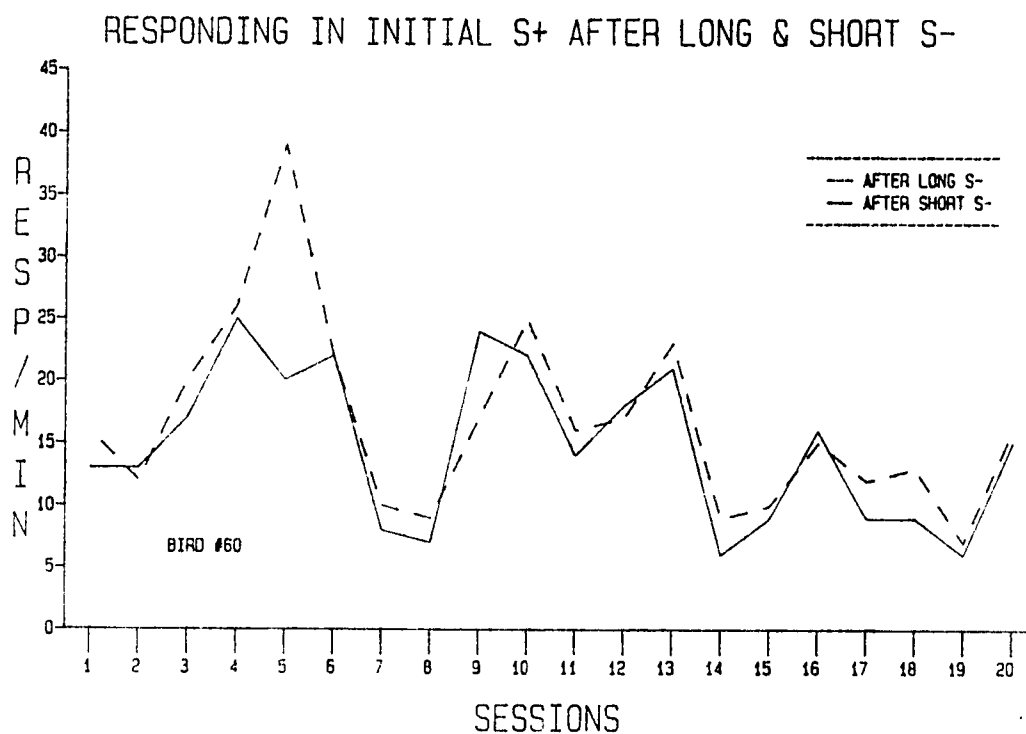


Figure 26. Average response/min for each session in the first 10 seconds of the S- component, both when it occurs after a long (40-sec) and a short (20-sec) S- for Bird 60.

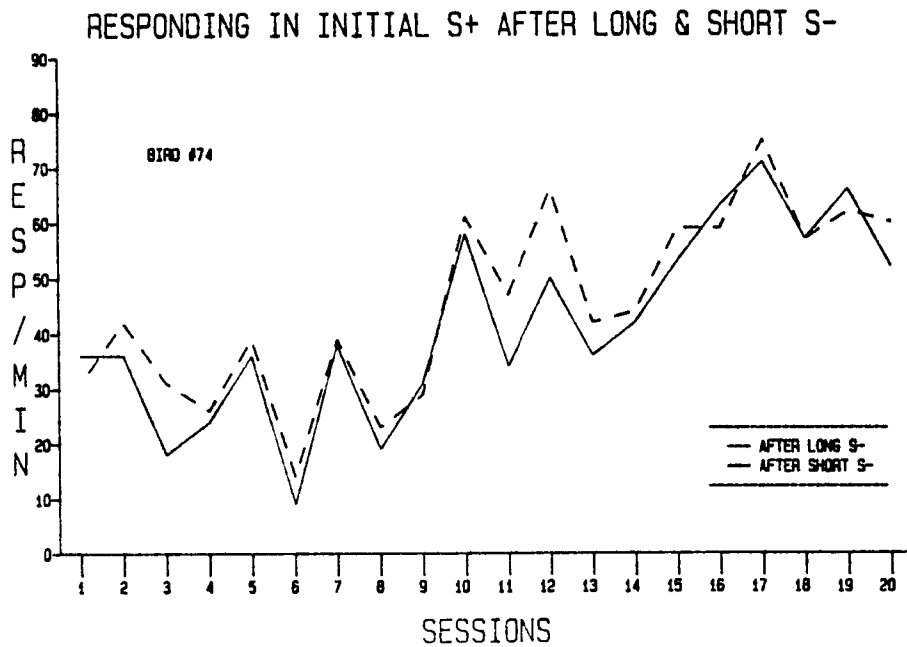


Figure 27. Average response/min for each session in the first 10 seconds of the S- component, both when it occurs after a long (40-sec) and a short (20-sec) S- for Bird 74.

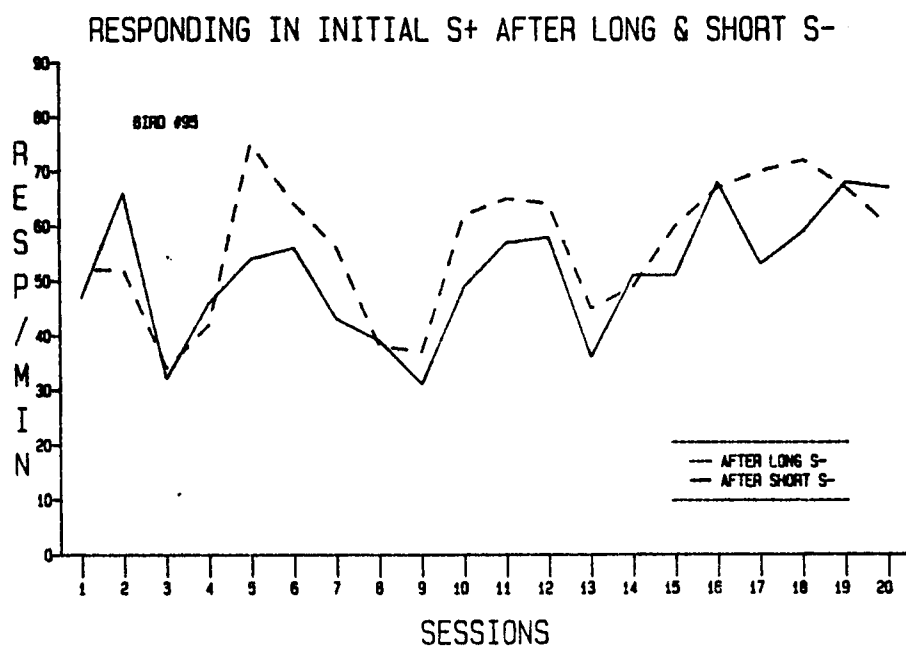


Figure 28. Average response/min for each session in the first 10 seconds of the S- component, both when it occurs after a long (40-sec) and a short (20-sec) S- for Bird 95.

long S- for each of the birds. A one-tailed, paired-comparison t-test of response rate each session after a long S- versus responding each session after a short S- for each session confirmed that response rate was significantly higher, at a .05 level of significance, for Birds 60, 74 and 95 ($n=20$, $t=1.92$; $n=20$, $t=3.03$; $n=20$, $t=2.61$, respectively).

Sign-tracking

Sign-tracking is a tendency to approach a signal positively correlated with periods of reinforcement and to withdraw from a signal positively correlated with periods of non-reinforcement. To measure sign-tracking, during the 16th and 17th presentations of the S+ component and the 16th and 17th presentations of the S- component, the position of the bird's head within a distance category of 8 cm width was noted. The 16th S- was of 40-sec duration and the 17th S- was of 20-sec duration. For all birds, 78% of the noted S+ distance categories were within 0 to 8 cm from the wall containing the pecking key, while only 24% of the S- categories were within this range. Thus, during S- components, the birds tended to withdraw from the key.

The distance categories used were too broad to discern much variation in the subject's position during an S+. The

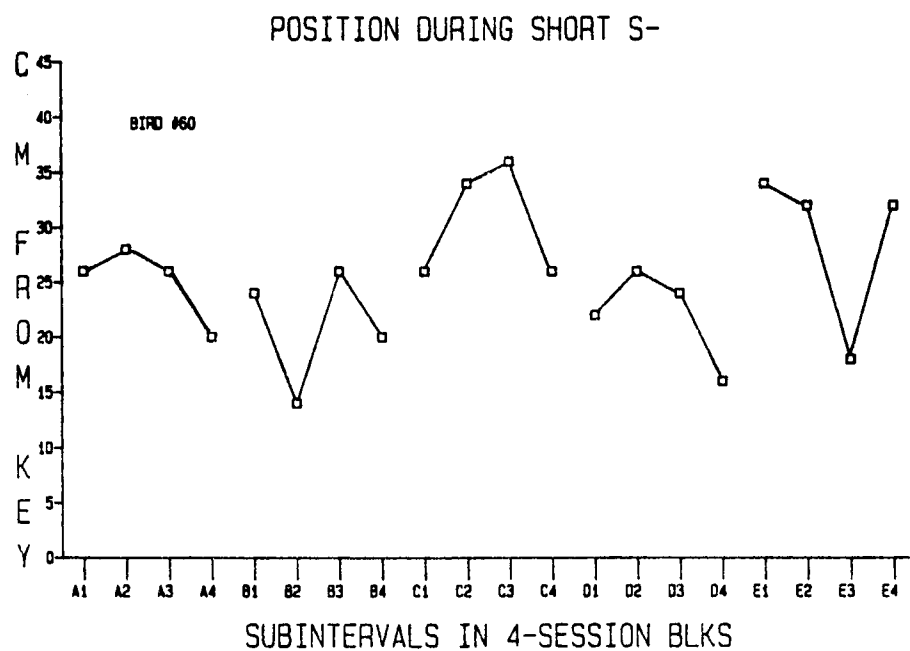


Figure 29. Average of the midpoints of the distance-from-key categories in consecutive 4-session blocks for each of the four 5-sec subintervals of the short S- for Bird 60.

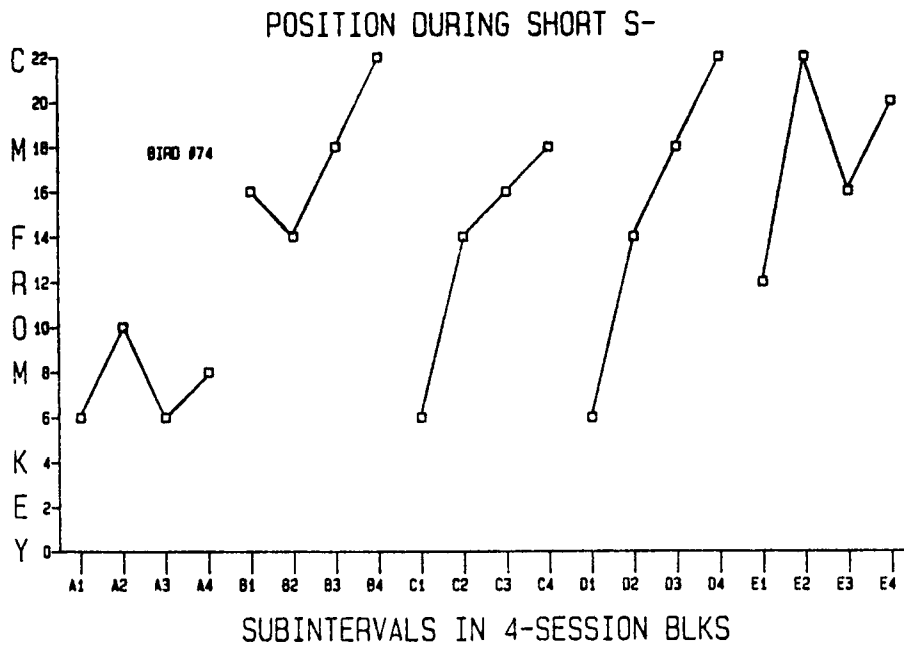


Figure 30. Average of the midpoints of the distance-from-key categories in consecutive 4-session blocks for each of the four 5-sec subintervals of the short S- for Bird 74.

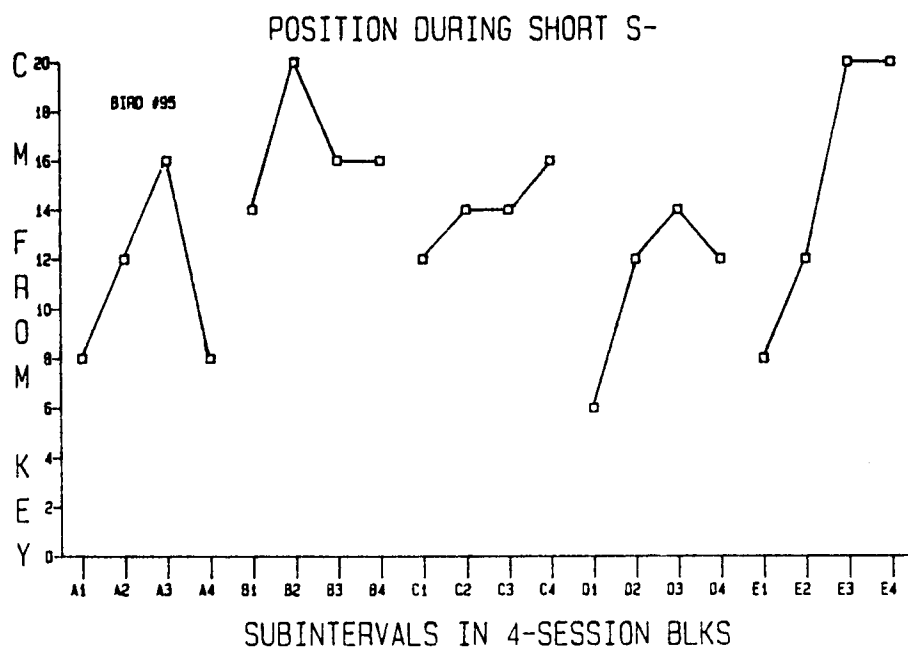


Figure 31. Average of the midpoints of the distance-from-key categories in consecutive 4-session blocks for each of the four 5-sec subintervals of the short S- for Bird 95.

study indicated that it would be necessary to measure a pigeon's position at least within the range of 0 to 8 cm from the signal key to discern a temporal pattern of approach during an S+.

The distance categories did discern a temporal pattern of withdrawal during the two durations of S-, however. To look more closely at the temporal course of withdrawal, Figures 29, 30 and 31 show the averages of the distance category midpoints for blocks of four sessions, in 5-sec segments of the short (20-sec) S- presentations.

For most of the short S- presentations recorded for Birds 74 and 95, there was an increase in their distance from the key over the course of the component's presentation. Bird 60 showed a tendency to increase and then decrease its distance from the key during the short S- component, except for the last block of sessions shown (Block E).

Figures 32, 33 and 34 show the pattern of withdrawal during the long (40-sec) S-. The averages of the distance category midpoints for blocks of four sessions, in 5-sec segments of the recorded long S- presentation, is given for Birds 60, 74 and 95, respectively.

The pattern of withdrawal during the long S- was fundamentally different from the pattern during the short S-. After a period of increasing withdrawal, the subjects decreased their distance from the key during the final

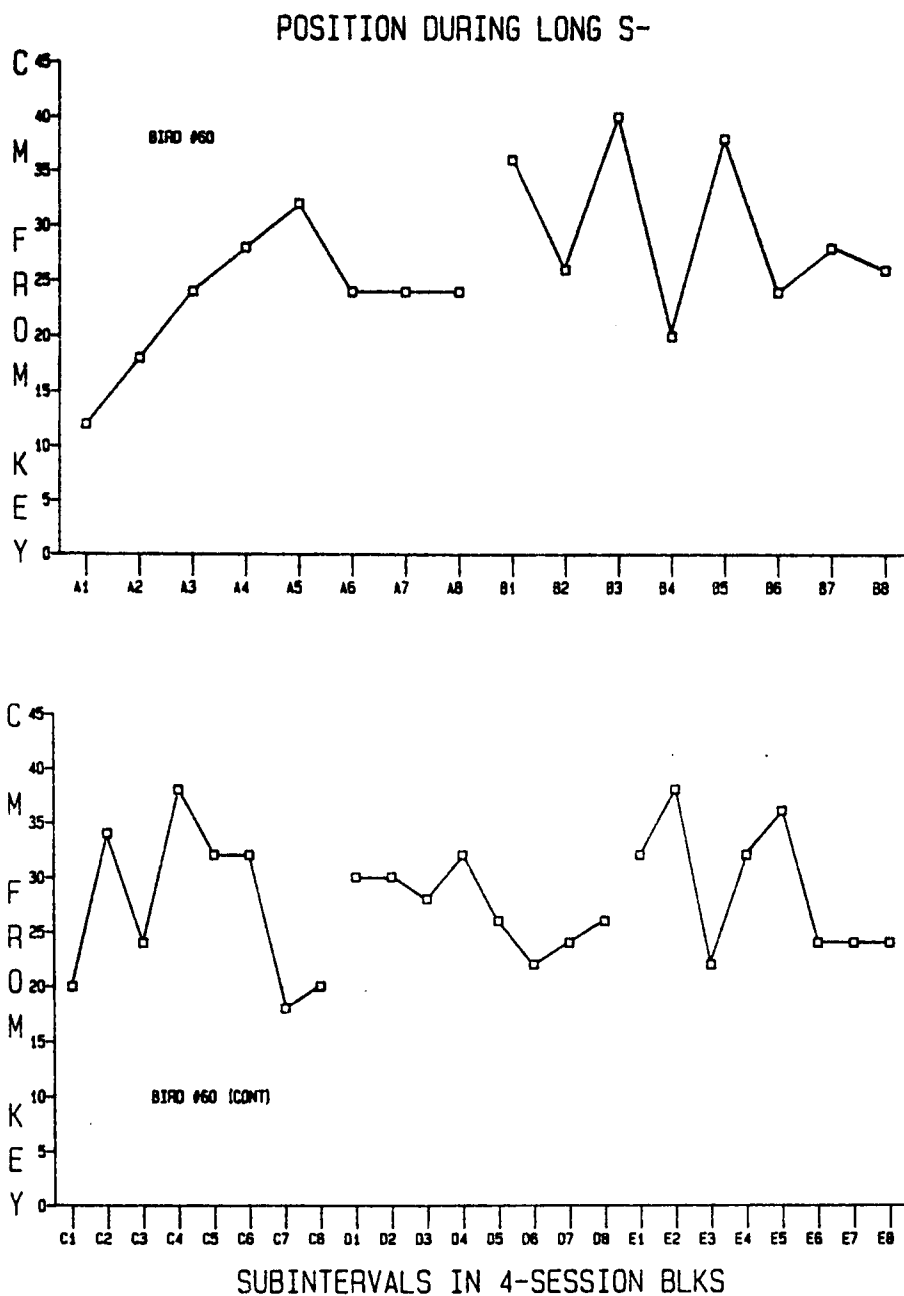


Figure 32. Average of the midpoints of the distance-from key categories in consecutive 4-session blocks for each of the eight 5-sec subintervals of the long S- for Bird 60.

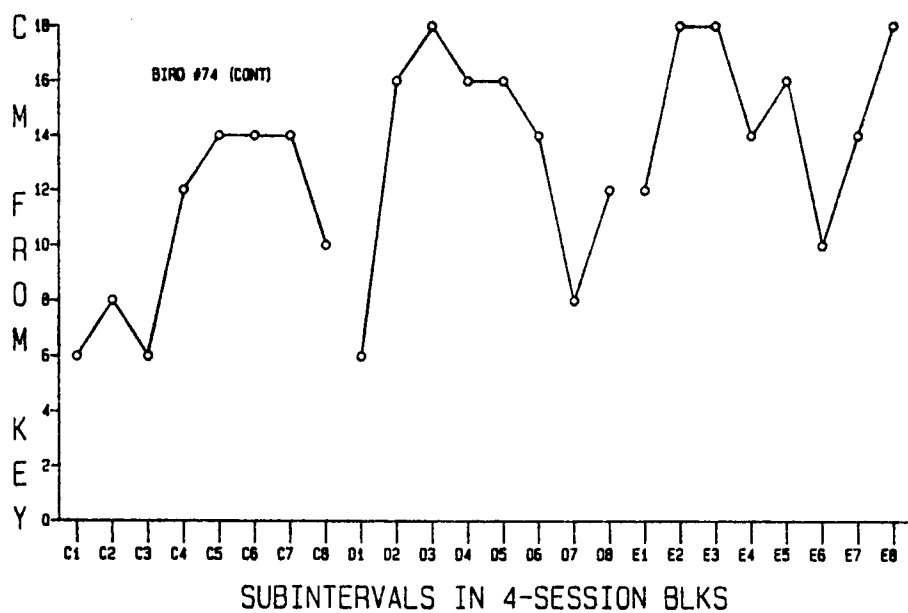
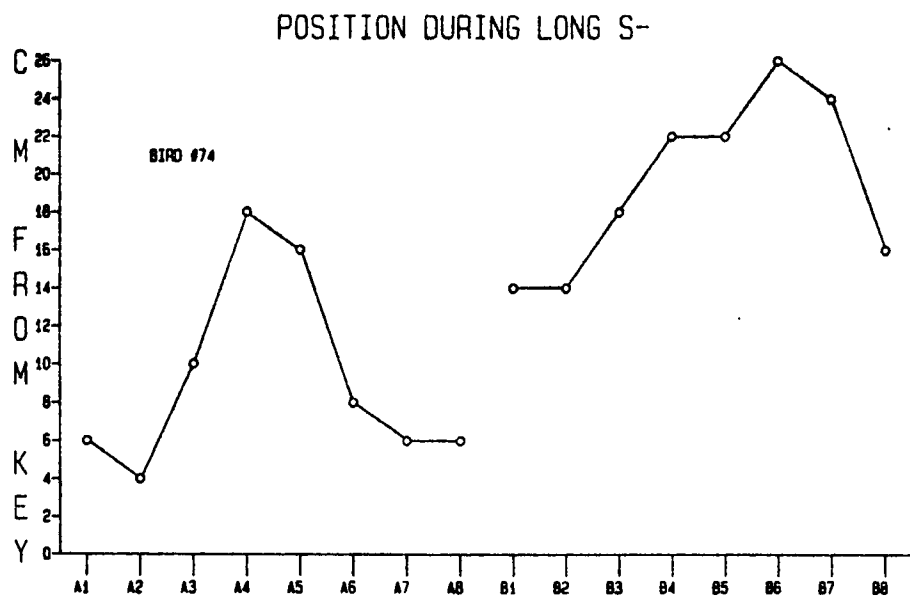


Figure 33. Average of the midpoints of the distance-from-key categories in consecutive 4-session blocks for each of the eight 5-sec subintervals of the long S- for Bird 74.

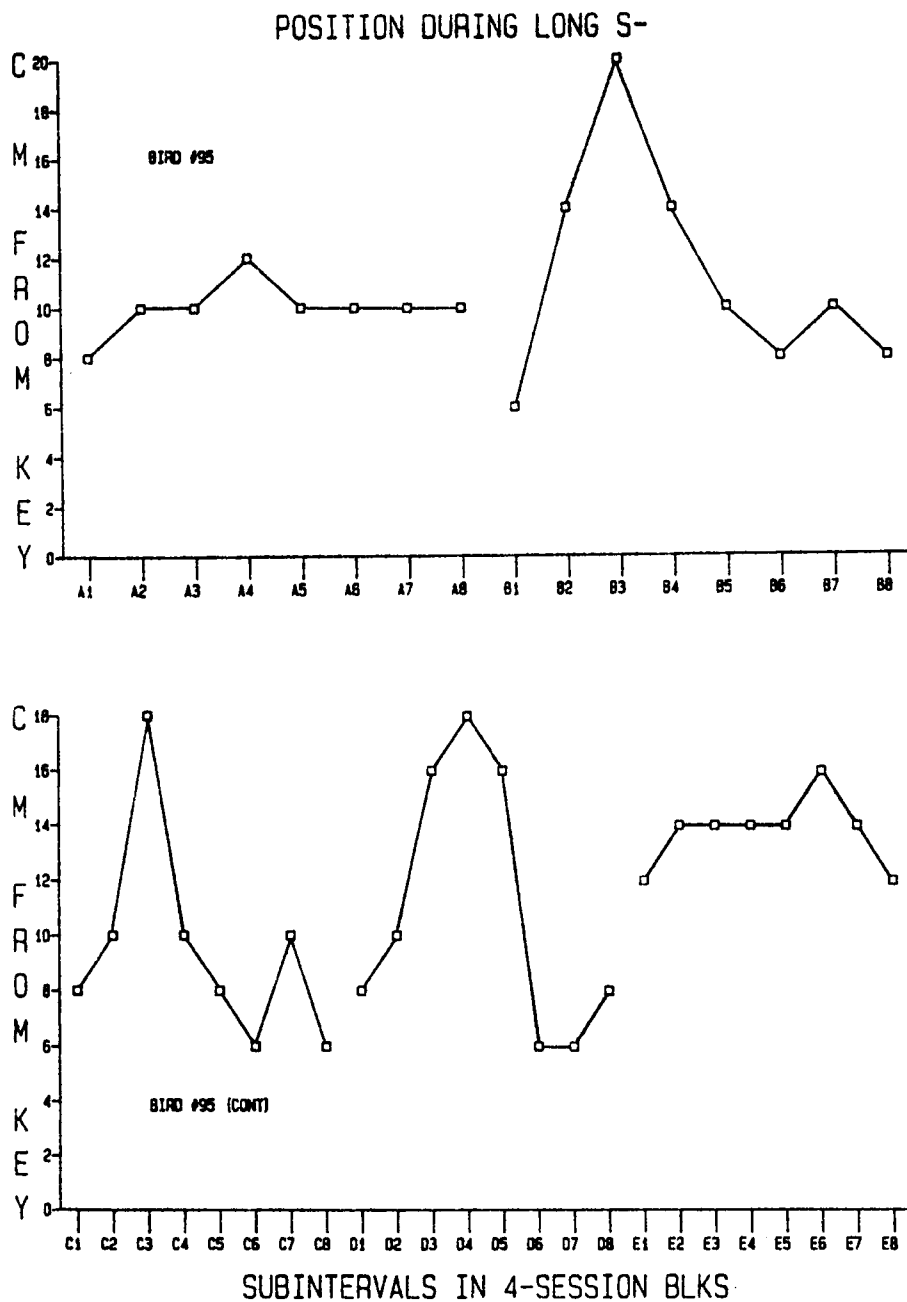


Figure 34. Average of the midpoints of the distance-from-key categories in consecutive 4-session blocks for each of the eight 5-sec subintervals of the long S- for Bird 95.

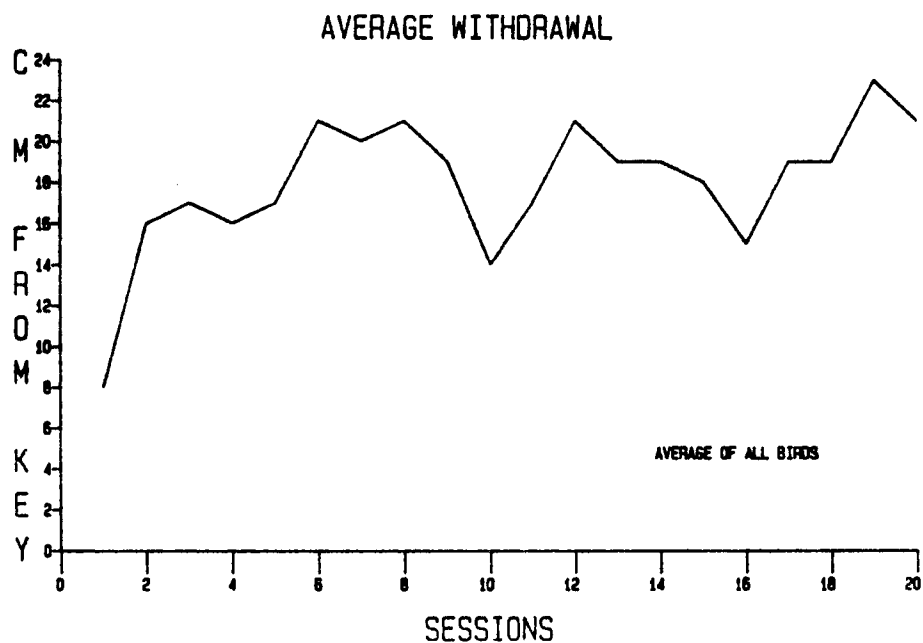


Figure 35. Average of the midpoints of the distance-from-key categories for the first four 5-sec subintervals of both the long and short S- for all birds over the course of the experiment.

segments of the long S-'s presentation. This was true for 13 of the 15 blocks shown.

One question of interest concerning the impermanence of local contrast patterns is whether the strength of withdrawal increased with discrimination training. An average of the distance-from-key categories for the first four subintervals of the long S- and the four subintervals of the short S-, for all birds, over the course of discrimination training is shown in Figure 35. The plot has a gradual upward slope, indicating that the strength of withdrawal did increase as training progressed.

DISCUSSION

Hinson and Staddon (1981) showed that the longer a preceding S-, the higher the response rate in a following S+. It is also known that subjects will tend to approach and direct their behavior toward a signal that is predictive of a reinforcing event and that they will tend to withdraw from a signal that is predictive of the non-occurrence of a reinforcing event. The phenomenon is known as sign-tracking. What has yet to be demonstrated is that a pattern of sign-tracking behavior could be the basis for the duration effect.

The present study shows how sign-tracking behavior in a preceding S- might determine response rate in a

following S+. As Rachlin (1973) suggested, withdrawal behavior begins at the transition from a differential predictor of food to a differential predictor of non-food and diminishes with time since the transition. The patterns revealed by this study show that withdrawal grew immediately after a transition, then diminished. In some instances, (e.g., Bird 60), withdrawal began to diminish by the end of the short S-, but in many cases the end of the short S- contained the strongest withdrawal value. In only one block of four sessions for one of the subjects did the end of a long S- contain the peak withdrawal value. In most cases, withdrawal diminished during the second half of a long S-'s presentation.

These patterns show how sign-tracking in a preceding S- might cause a duration effect in a following S+. Short S-'s end at a time when the tendency to withdraw is growing or has just begun to diminish. When an S+ follows, response rate during its presentation will tend to be depressed. Conversely, long S-'s end at a time when withdrawal has had time to diminish. When an S+ follows, withdrawal does not overshadow the tendency to approach a S+ at the point of transition from a S-.

The assumption of a Pavlovian process/additivity theory concerning the patterns of withdrawal behavior produced by variable durations of the S- was supported by this study. The results do not speak to the assumption

about patterns of approach because the distance categories used were too broad to discern much variation in the subject's position during a S+. Chapter IV revealed that there is an effect of the duration of a preceding S+ on a following S- and PP/AT assumes that the effect is based upon the patterns of approach during the presentation of the S+. The present study indicates that it would be necessary to measure a pigeon's position within a range shorter than 0 to 8 cm from the signal key in order to determine approach patterns.

One of the features of local contrast that has been of interest to its investigators is its impermanence. As discussed in the introduction, PP/AT explains the transience of local contrast patterns by assuming that the sign- tracking tendencies of approach and withdrawal become stronger as discrimination training progresses and take longer to diminish. Withdrawal, averaged over the first half of the short S- and the first half of the long S- for all birds, showed that the strength of withdrawal did increase (although weakly) over the course of discrimination training, as would be expected if the theory's assumption is correct.

The study indicated that withdrawal patterns are likely mechanisms for positive local contrast effects, although the results were not as clear as one would desire.

The short S- patterns of Bird 60 often did not show peak

withdrawal at the end of the component presentation, but Bird 60 did show the duration effect. Also, the patterns of approach were not assessed so they could not be supportive of PP/AT assumptions. A more detailed examination of position during variable durations of an S-, which would include every S- presentation and which would use very narrow position categories, probably would present a clearer picture. The present study indicated that such an effort would be worthwhile.

CHAPTER VI

GENERAL DISCUSSION

A multiple schedule of reinforcement represents one type of situation that can produce a discrimination, at least when different levels of reinforcement are present in the schedule components. A discrimination becomes apparent in a multiple schedule when response rates in the components begin to diverge.

One of the interesting aspects of multiple schedules, other than the fact that they can produce discriminations, is the insight that they can provide into the discrimination process. The insight comes from the sequential interaction between the components that is known as local contrast.

In the positive form of local contrast, there are increases in a component's response rate, especially at the beginning of its presentation, when it is preceded by a component signaled by a stimulus controlling a lower average response rate. In the negative form of local contrast, there are decreases in a component, when it is preceded by a component with a higher average response rate.

As can be seen, response rate elevation in S+ coupled to response rate depression in S- is in the direction of a greater divergence of response rates between the two components, which is the defining characteristic of a discrimination in a multiple schedule. Thus, local contrast amplifies discrimination performance during the process of discrimination formation.

Since local contrast is a prominent aspect of discrimination formation, this dissertation researched three areas which would clarify the characteristics of local contrast. The first area was the development of forward- and backward-acting contrast. In a multiple schedule, a component is presented in a sequence where the preceding component can have a profound interacting influence (forward-acting local contrast). It has been suggested by Buck, Rothstein and Williams (1975) that an anticipated, following component can also have an interacting influence (backward-acting contrast) and, in fact, the influence of the following component is the most important in determining the final discrimination performance of a subject.

Chapter II looked at forward- and backward-acting contrast effects on the within-component response rates of components in different multiple schedule sequences. In general, forward-acting local contrast tended to appear early in discrimination training, while backward-acting,

anticipatory contrast tended to appear, although weakly, in the later stages of discrimination. That anticipatory contrast is important in a final state of discrimination performance cannot be challenged, but it can be argued that the discrimination process, including the early formation processes where local contrast is found, is as important to understand as the final steady-state product. Therefore, neither forward-acting nor backward-acting contrast should be ignored.

The second question concerning local contrast that was addressed was the relationship of local contrast to behavioral contrast. One account of the relationship may be called a precursor theory, as developed by Mackintosh (1974) and Marcucella and MacDonall (1977). The theory is that local contrast develops and produces an elevation, in the case of positive contrast, or a depression, in the case of negative contrast, in responding. These changes in overall response rates are known as behavioral contrast. Once a change in response rate is obtained, micro-contingencies between rate of response and reinforcement take over to maintain the change, even though local contrast effects may decrease or go away entirely. The theory doesn't specify why local contrast develops or why it can be transitory, it only is concerned with the relationship that local contrast may have to the development of behavioral contrast. The results of chapter

III revealed that local contrast may accompany behavioral contrast and fade, while behavioral contrast continues.

Chapter III measured behavioral contrast in an S+ in terms of a second S+, the major difference between them being that one directly followed an S- and one did not, and correlated the measure with local contrast produced by the preceding S-. The positive correlation between local and behavioral contrast decreased over the course of discrimination training, while there was a slight increase in behavioral contrast and a slight decrease in local contrast. These results were in agreement with what a precursor theory would assume and support the view of Mackintosh and Marcucella and MacDonall.

As noted above, the precursor theory was concerned with the relationship of local to behavioral contrast and did not explain the nature of local contrast. But there have been two plausible theories advanced that account for local contrast. One is known as response competition theory and the other is known as a Pavlovian process/additivity theory (PP/AT). The third area covered by this dissertation is a resolution of these two theories.

Response competition theory divides behavior into two classes which compete with each other for the available time. One class is directly controlled by the given reinforcement (terminal responses) and the other class is not so directly controlled (interim responses). Since they

do compete, periods of time, signaled by a stimulus indicating that reinforcement is not forthcoming, allow interim responses to be expressed. Thus, the following intervals are relatively free of competition from these responses. Terminal responding in the presence of an S+ during such an interval would show a positive local contrast effect. A similar description of negative local contrast may be made by the response competition mechanism.

A Pavlovian process/additivity theory also focuses on a type of behavior that is auxiliary to terminal responding to explain local contrast, but the auxiliary behavior is much more definite than the interim responses of response competition theory and there is a larger body of research describing it. This type of behavior is known as sign-tracking. Sign-tracking is movement toward a signal that is predictive of a reinforcing event or it is movement away from a signal that is predictive of the non-occurrence of a reinforcing event.

One way to support a theory is to use it to make an accurate prediction of an experimental result. In Chapter IV, an effect of a duration of a preceding S+ upon response rate in a following S- was found. Longer S+ duration produced less responding in a following S-. Response competition theory would accurately predict that there would be a decrease in terminal responding if there were

longer preceding S+ periods. PP/AT would also make the same prediction.

But one way to weaken a theory is to show that it inaccurately predicts an experimental outcome. Response competition theory would say that an S- component of any length would lead to an initial elevation of responding in a following S+. However, in Malone and Cleary (1986), a short S- was found to consistently produce an initial depression in responding in a following S+.

Another means by which a theory is weakened is for it to have no explanation for an experimental result, while other theories do have an explanation. Experimental evidence indicates that sign-tracking movements increase as discrimination training continues (Hearst & Franklin, 1977). PP/AT predicts that since the effect of a duration of a preceding component on a following component depends on sign-tracking movements, it would be expected that the duration effect would increase as well over discrimination training. Figures 22, 24, and 25 show how this was the case for three of the four birds in the experiment reported in Chapter IV. Response competition theory is silent on why this would be.

PP/AT assumes that approach movements are strongest at a transition from an S- to an S+ and withdrawal movements are strongest at a transition from an S+ to an S-. If the theory's explanation concerning the effect of variable

durations of a preceding S+ component is to be supported, these characteristics of sign-tracking movements should be found when a variable duration effect is produced. In Chapter V it was found that withdrawal movements during an S- component's presentation did show a peak soon after a transition from an S+. Withdrawal movements were also found to decrease as time in an extended duration S- progressed. Withdrawal tendencies increased slightly over the discrimination training. These temporal properties of withdrawal sign-tracking movements coincided with an effect of the duration of a preceding S+ on response rate in a following S- and they serve as a plausible explanation for the duration effect.

The main conclusion that may be reached from the third area of research of this dissertation is that of the two plausible theories of local contrast, LAT is the most plausible because of the following points:

1. Response competition predicts that any preceding S- period should enhance initial responding in a following S+. Malone and Cleary (1986) found that short preceding S- periods depressed initial responding in a following S+.
2. PP/AT assumes that longer preceding S+ periods will result in lower responding in a following S- and that this duration effect will increase

in magnitude as discrimination training progresses. This was found in Chapter IV. Although response competition theory explains the duration effect, it is silent with regard to an increase in this effect over discrimination training.

3. PP/AT assumes that withdrawal tendencies peak soon after a transition from an S+ to an S- and with longer S- durations, withdrawal tendencies have time to subside. These temporal characteristics of withdrawal were substantiated in Chapter V.

4. PP/AT assumes that the temporal characteristics of withdrawal should coincide with an effect of a duration of a preceding S- on a following S+. This was found in Chapter V.

Response competition theory and a Pavlovian process/additivity theory are similar in that both explain local contrast effects with reference to an auxiliary response. From the points made above, it would be sensible to focus on sign-tracking movements as the most likely auxiliary response to be producing these effects, rather than an amorphous class of interim response, whose exact characteristics have yet to be defined or discovered.

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