

Changes in Response Topography During Behavioral Contrast

by

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A thesis
presented to the University of Manitoba
in partial fulfillment of the
requirements for the degree of
Master of Arts
in
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CHANGES IN RESPONSE TOPOGRAPHY DURING BEHAVIORAL CONTRAST

BY

D. ANDREW JONES

A thesis submitted to the Faculty of Graduate Studies of
the University of Manitoba in partial fulfillment of the requirements
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MASTER OF ARTS

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ABSTRACT

The topographical response patterns exhibited by three pigeons on multiple variable-interval (VI) 5 min VI 5 min of food reinforcement and multiple VI 5 min extinction for key-pecking were recorded using an apparatus that continuously tracked the position of the bird in the experimental chamber. Multiple VI 5 min VI 5 min produced complex and regular patterns between responses. During Multiple VI 5 min EXT the complex patterns dropped out and a simple close-to-key pattern was adopted during the VI component. With a reversal back to Multiple VI 5 min VI 5 min the complex patterns re-emerged but none were identical to the original patterns. The data suggest that additivity theory is not the best explanation of behavioral contrast and that alternate theories should be considered.

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CHANGES IN RESPONSE TOPOGRAPHY DURING BEHAVIORAL CONTRAST

Behavioral contrast in multiple schedules has been a frequently studied phenomenon in the past twenty years. The classic demonstration of behavioral contrast was conducted by Reynolds (1961). In this experiment pigeons were exposed to a series of multiple schedules with two alternating components. Each component was associated with a specific color (red or green) which illuminated the key light in the operant chamber. At the end of a 3-minute interval the color of the key changed and the second component was in effect. Both components in the first phase of the experiment were variable-interval 3-minute (VI 3-min) schedules of reinforcement. In the second phase, the second component was changed from a VI 3-min to extinction. As a result of the introduction of the extinction component an increase in responding occurred in the unchanged component, while responding decreased in the extinction component. Reintroduction of the VI 3-min schedule in the second component reversed this effect and restored the original response rate. This change in responding in one component when the other component changed, is termed behavioral contrast.

When two separate responses are maintained by separate schedules of reinforcement, two kinds of contrast may occur. Positive behavioral contrast refers to an increase in the rate of responding during the unchanged schedule produced by a decrease in the reinforcement density associated with the changed schedule. Conversely, negative contrast occurs when the rate of the response of the first schedule is decreased due to an increase in the reinforcement density of the second schedule. These interactions between schedules of reinforcement can occur when the two schedules are simultaneously available (concurrent schedules: Herrnstein, 1970) or when they are successively alternated (multiple schedules: Reynolds, 1961a).

The reinforcement schedule in the unchanged component is typically VI, although other schedules, such as fixed interval (Reynolds & Catania, 1961; Staddon, 1969) and Differential Reinforcement of Low Rates of responding (Reynolds, 1961b), have been used. The change in the second component is usually to extinction, but other schedules, such as a high VI schedule (VI 5-min), have been used (Brethower & Reynolds, 1962; Terrace, 1968). Varying types of responses have also been required to the two different schedules, such as key pecking and bar pressing (Scull & Westbrook, 1973) or key pecking and treadle pressing (McSweeney, 1982).

Several different explanations have been presented to account for the behavioral contrast phenomenon.

Perhaps the most well known explanation is based on experiments that assessed response rate in one schedule component when the reinforcement rate was changed in an adjacent component (Reynolds, 1961a, 1961b, 1961c; Bloomfield, 1967). The reinforcement model suggests that the response rate in one component depends upon the relative reinforcement rate (Herrnstein, 1970; Catania, 1973). The reinforcement model, however, does not easily account for response changes occurring in one component when the response rate, but not the reinforcement rate, changes in the adjacent component (Brownstein and Hughes, 1970; Lander, 1971; Wilkie, 1973). Conversely, positive contrast may not occur after a decrease in reinforcement in an adjacent component, with errorless discrimination procedures (Terrace, 1963). Therefore, a change in relative reinforcement rate may be neither necessary nor sufficient for positive contrast.

Another theory holds that positive contrast is a result of emotional responses generated by the aversiveness of not receiving reinforcement for previously reinforced responses under an adjacent component (Terrace, 1966). However, as mentioned above reinforcement rate changes are neither necessary nor sufficient for positive contrast; thus contrast may be produced in situations that do not involve emission of nonreinforced responses.

Changes in preference among schedule components have also been presented as an explanation of positive contrast. Specifically positive contrast has been suggested to result when the adjacent component is relatively less preferred (Bloomfield, 1969; Premack, 1969). However, relative preference for one component, as assessed with concurrent schedules, may not be a reliable predictor of positive contrast with the same schedule components arranged as a multiple schedule. Wilkie (1973) reported that positive contrast was obtained with signalled reinforcement in an adjacent component, whether or not preference for signalled reinforcement had been obtained in the same subjects when the schedules were arranged concurrently. Therefore, relative preference for schedule components also appears to be neither necessary nor sufficient for positive contrast.

Another major theory of contrast arose as a result of the procedural similarities for obtaining behavioral contrast and autoshaping developed by Brown and Jenkins (1968). In the autoshaping procedure a keylight was illuminated for 8 seconds and at its offset the food magazine was operated for 4 seconds. As a result the pigeons began to peck at the lighted key within 6 to 119 pairings of the keylight and feeder. Brown and Jenkins labeled this procedure autoshaping, since the pigeons appeared to "shape" themselves. Evidence from several studies (Gamzu & Williams; 1971, 1973) indicate that autoshaping reflects the

control of key pecking by Pavlovian stimulus-reinforcer contingencies. Pavlovian conditioning depends upon the existence of a differential relation between the CS and the US. The same is true in the autoshaping case, unless the response key is a differential predictor of food, autoshaping does not occur and already established key pecking will extinguish (Rescorla, 1967).

In the typical contrast experiment one begins with a multiple VI VI. This produces response-reinforcer dependencies in each component. However, there is no differential stimulus-reinforcer relation present. Food is equally likely in both components of the multiple schedule. When the procedure is changed to a mult VI-EXT schedule the response-reinforcer dependency continues in the VI component but a stimulus-reinforcer relation also appears. Just as in the autoshaping procedure, the VI component in the multiple schedule becomes a predictor of food which alternates with a stimulus associated with a zero rate of reinforcement (Gamzu & Schwartz, 1973). Therefore, some researchers theorize that positive behavioral contrast occurs because the procedure produces autoshaped "elicited" pecks (the stimulus-reinforcer relation) which add to the responses maintained by reinforcement (the response-reinforcer relation) to the unchanged component and thus increase the rate of responding in the component. This theory is called the additivity theory of behavioral contrast and was first

stated by Gamzu and Schwartz (1973). It resulted from findings by Gamzu and Williams (1971, 1973).

The major component of the additivity theory is that, whenever a differential stimulus-reinforcer relation exists, that stimulus will exert control over some class of behavior. There are two views as to what this class of behavior is. One view is that the class of behavior controlled by stimulus-reinforcer relations is that class appropriate to the reinforcer, (i.e., a class of consummatory responses). These responses, as Pavlovian conditioning would predict, are directed toward the signalling stimulus. In the pigeon pecking is a consummatory response (Jenkins & Moore, 1973; Staddon & Simmelhag, 1971) and the form of the response is appropriate to the reinforcer. Water reinforcement produces "water" pecks and food reinforcement produces "food" pecks (Jenkins & Moore, 1973). The second view, which is called sign tracking (Hearst & Jenkins, 1974) states that organisms will direct any activity toward a stimulus which signals reinforcement. The form of the response need not resemble the unconditioned response to food. It is not clear which of these views is correct at the present time.

Positive contrast may, therefore, be a result of a complex interaction between Pavlovian and operant discriminative processes. It is possible that the increase in response rate in the first component results from the

summation of operant responding and autoshaped pecking to the now more predictive stimulus. There are several lines of support for this argument: (a) When the first component stimulus is no longer part of a respondent response system (i.e. when a rat must press a lever for food reinforcement) behavioral contrast can only be obtained with great difficulty (Beninger, 1972; Pear & Wilkie, 1971). (b) When pigeons are required to make a treadle hopping response rather than key pecking (i.e. the response is no longer consummatory in nature) positive contrast has failed to occur (Hemmes, 1973; Westbrook, 1973). McSweeney (1983) has, however, recently obtained behavioral contrast with pigeons using a treadle hopping response.

As well, other experiments have shown that positive contrast may easily be obtained when the component stimuli are not located on the manipulandum for the operant response (Beecroft, 1969; Boakes, 1972; Farthing, 1975; Bradshaw, 1985). Conversely, contrast is not invariably obtained when the component stimuli are in fact located on the operant manipulandum (Terrace, 1963).

Several other studies have been done which provide strong support for the additivity theory of contrast. These studies have tried to discriminate the two kinds of keypecks, operant and autoshaped, which add together to produce behavioral contrast. Keller (1974) found that in addition to an operant class of keypecks there is a class of

pecks elicited by, and ordinarily directed to, a stimulus associated with a high rate of reinforcement, when that stimulus alternated with an extinction stimulus. Keller used a two-key procedure which displaced the stimulus for elicited pecks to a second key while retaining the response-reinforcer contingency on the first key. This procedure is reasonably successful in dissociating the two classes. The two key procedure is an application of "topographical tagging" introduced by Catania (1971, 1973). According to this procedure two response classes that occur to the same key, but which are controlled by different variables can be separated without loss to the total output by separating the controlling variables.

Marcucella (1981) also studied two different response classes using a single key procedure. The two kinds of pecking were easily discriminable on the basis of rate differences within a condition and on the basis of differential rates across conditions. There was a clear dissociation both in rate of development and magnitude of effects, of operant and autoshaped keypecking.

Autoshaping and operant pecks have also been differentiated on the basis of response duration. Schwartz and Williams (1972) have indicated that the duration of autoshaped pecks is generally short, while keypecks maintained by conventional reinforcement schedules are both long and short duration but primarily long. They found that initial keypecks maintained by all appetitive procedures are

short duration pecks and that short duration pecks are insensitive to differential reinforcement while long duration pecks are sensitive. They proposed that short duration pecks arise from the pigeon's normal feeding pattern and are directly enhanced by food presentation, while long duration pecks are controlled by the contingent effects of food presentation. Other investigations (Moore, 1973) have failed to find duration differences across different procedures and have offered alternative interpretations for the data observed by Schwartz and Williams.

McSweeney, Ettinger and Norman (1981) provide an excellent summary of the different versions of the additivity theories. They argue that the basic description of the additivity theory can be interpreted in at least three ways, only one of which is testable.

The 3 theories presented by Gamzu and Schwartz (1973), Rachlin (1973), and Hearst and Jenkins (1974) differ slightly in detail but all agree that an interaction between the operant and autoshaped (additive) responses are necessary for contrast to occur. If either of the relations (response-reinforcer or stimulus reinforcer) is absent or both are present but don't interact, contrast will not occur.

The problem with this theory is that it can be interpreted in at least 3 different ways depending on how the operant and autoshaped responses are distinguished.

The strongest version of the additivity theory is based on the premise that autoshaped (additive) and operant responses can be distinguished on the basis of physical form. Positive contrast occurs when the additive responses take a form that do not facilitate operant responses. Negative contrast would occur when one form interferes with the other form. No contrast would be present when additive responses are absent or take a form that do not facilitate operant responses. Negative contrast would occur when one form interferes with the other form. No contrast would be present when additive responses are absent or take a form which can not add to the operant ones.

An intermediate version of the additivity theory relies on the distinction between additive and operant responses and the theoretical processes that control them. Instrumental responses occur as a result of operant conditioning while additive responses may be attributed to classical conditioning. As in the first version, positive contrast occurs when the classically conditioned responses add to or facilitate the operant responses, no contrast would occur when only one process occurs or both are present and don't interact. This version proposes that operant and classically conditioned responses may be distinguished on a physical basis.

The weak version which McSweeney et al. (1981) feel is the testable version distinguishes between responses on the basis of environmental relations that control them. Instrumental responses are controlled by response-reinforcer relations and additive responses by stimulus-reinforcer relations. Both these relations must be present and summate for contrast to occur. The weak theory differs from the strong one in that it does not require physically different responses to occur. It differs from the intermediate theory because the weak one is not concerned with how the environmental relations control behavior.

In terms of testing the three versions only the weak version as said, is testable.

The strong version would be easy to test if one was in fact able to distinguish physical differences between the additive operant responses. Unfortunately, measurement devices have not been able to distinguish such differences to this point. Schwartz and Williams (1972) have tried to distinguish the two types of responses on the basis of response deviation as discussed earlier but other researchers have dismissed their findings with contradictory results (Zirax & Silberberg, 1978). This does not suggest, however, that distinctions based on physical forms are not possible. Pear and Eldridge (1984) suggest that recent advances in the study of response topography may yet yield a technology which will allow a distinction to be made between

behavior controlled by stimulus-reinforcer and response-reinforcer relationships.

The intermediate version of the additivity theory is not testable either since the question of whether operant and classically conditioning actually do control different responses is largely unanswered (Hearst & Jenkins, 1974). The fact that the distinction is presently untestable can be useful, however, as Pear and Eldridge (1984) point out by providing direction for future research "towards modifying the two concepts to account for disparate data" (p. 464).

The weak version, McSweeney et al. suggest, is testable by establishing the response-reinforcer and stimulus-reinforcer relations independently and examining how in fact they do or do not interact. McSweeney et al. indicate that in order to test the weak theory a summation test is needed in which operant responses could first be developed in a simple schedule of reinforcement then change to an autoshaping procedure to present the stimulus reinforcer relation. If the weak theory is correct, responding should be greater during the simple schedule when the stimulus from the autoshaping procedure is also present than when it is not.

McSweeney et al. indicate that only one study has really tested the weak theory (Bradshaw, Szabadi and Bevan, 1978) and they failed to establish responding during a

response-independent procedure with rats. Their experiment however, did not include the summation test which would have provided evidence against the additivity theory, but the results still do contradict the theory.

Finally, McSweeney et al. present several important points which help in the understanding of the various additivity theories of contrast.

First, it is apparent from McSweeney et al.'s review that neither one nor all of the theories are correct. Several problems are evident with many of the theories.

Second, testing the additivity theory is not easy because of the unclear definitions of stimulus-reinforcer and response-reinforcer relations. For example, additive responses are said to occur when there is a transition between stimuli that differ in value (Rachlin, 1973), whenever stimuli differentially predict reinforcers (Hearst & Jenkins, 1974), or when a stimulus-reinforcer dependency is present (Gamzu & Schwartz, 1973).

Third, it is possible that behavioral contrast may not be explained by a single theory. In fact, evidence is suggesting that there is more than one type of contrast (local and overall) and that each type may be controlled by different variables.

Finally, the weak theory which is presented is not a comprehensive enough theory to encompass all the possible results obtained by various researchers. What it does do however, is add to the base of knowledge and literature currently used to assess the validity of the additivity theory.

Hinson and Staddon (1978) have approached the question of behavioral contrast with a slightly different view than that held by the proponents of the additivity theory.

Hinson and Staddon have presented a response competition model of contrast which arose from the study of simple and concurrent schedules (Staddon, 1979). The basic notion is that contrast in multiple schedules occurs because of competition between interim and terminal behaviors both of which are produced when interval schedules of reinforcement are used (Staddon & Simmelhag, 1971). Thus, during both components of a multiple VI VI schedule both interim and terminal behaviors occur so that both mutually compete for time available in the experiment. When the schedule is changed to Mult VI-EXT, the terminal behaviors are eliminated in the EXT component. The interim behavior that did occur in the unchanged VI can then move into the EXT component leaving more time for terminal responding in the unchanged VI so that an increase in response rate (i.e. contrast) occurs. Thus, contrast in multiple schedules as in concurrent schedules is primarily due to a change in time

allocation with a greater percentage of time devoted to terminal behavior than interim behavior during VI-EXT.

Hinson and Staddon's hypothesis is supported, by a study in which the availability of interim behavior was explicitly manipulated (Hinson & Staddon, 1978). They compared 2 groups of rats who were trained to lever press initially on a multiple VI VI schedule and were then changed to a multiple VI EXT schedule. The only difference between the groups was that one group had a running wheel present in the chamber while the other group did not. The group with the wheel showed a large contrast effect while the group without showed no such effect. The important feature of this experiment was that the contrast effect was paralleled with a shift in running behavior. During the mult VI VI equal amounts of running occurred in both components. When the mult VI EXT condition was introduced almost all of the running shifted to the EXT component allowing more time for the terminal (lever-press) to occur.

Staddon's analysis is interesting because it offers a description of effects in multiple and concurrent schedules in a single theoretical model. Similarly, it offers an explanation for the apparent species differences reported for multiple schedules on the assumption that rats have fewer interim behaviors available in the usual operant experiment.

Additional support for the competition hypothesis arose from a study by White (1978) who studied contrast using different response levers located on different sides of the chamber for the two components. This allowed for the recording of time allocated to either side of the chamber in addition to the rate of lever presses. Results indicate that contrast occurred on both measures but were more reliable with time allocation but that there were changes in local response rates present. Thus, White concluded that an increase in time allocation was responsible for contrast rather than a change in response rate.

Williams (1983) however, indicates that the actual magnitude of the contrast effect was larger with the measure of response rate and that this difference in magnitude must be due to differences in local response rate.

Williams also points out that although evidence for the behavior competition theory is strong the theory faces a fundamental problem. That is, if contrast occurs as a result of competition for available time, the outcome of the competition should depend upon the frequency of responding in the changed component not the frequency of reinforcement. As Williams points out, however, the schedule during the changed component is not important, what is important is the relative rate of reinforcement. Williams supports his argument by examining the results of an experiment using a mult VI-VT (variable time) changing to a mult VI-EXT. In

this case, no operant is required during VT to gain reinforcement, therefore no competition occurs between terminal and interim behaviors during baseline. Thus, interim behaviors during the VI component of baseline could move into the VT component even during baseline, so that responding during mult VI VT should be greater than during mult VI VI. Also, when the change from mult VI VT to mult VI EXT occurs there should be little change in the amount of competition in the changed component and thus little change in the response rate of the unchanged VI component. Overall, there should be a smaller contrast effect with mult VI VT than with mult VI VI. Williams notes however, that the effect with both these schedules is basically the same (Williams, 1983).

Staddon recognizes this problem but argues that the frequency of operant responding is correlated with the frequency of reinforcement regardless of the schedule used.

Williams has shown that responding during the variable component, whether it be EXT VI-1 minute or signalled VI (Williams, 1980) do not predict the interactions between the components, thus the frequency of reinforcement is not correlated with reinforcement (Williams, 1983).

Besides, arguing against the response competition model presented by Hinson and Staddon, William's (1983) review paper presents an extensive assessment of the behavioral

contrast literature. William's clear message is that the additivity theory is "fundamentally incorrect" (p. 346) as an explanation of behavioral contrast. Williams believes "that a single dominant variable underlies contrast, at least in steady-state procedures, and defining that variable is of fundamental importance for specifying the independent variables that control all operant behavior" (p. 346).

Williams suggests that contrast "is primarily a function of changes in relative reinforcement frequency" (p. 348). He draws from several studies (Williams, 1976a, 1980) to substantiate his claim and effectively criticize many alternative explanations of contrast.

Williams also addresses the three lines of evidence which Schwartz & Gamzu (1977) suggest provide the strongest support for additivity theory. These are that 1) contrast should not occur with rats as subjects; 2) when pigeons are subjects, contrast should not occur if the reinforced response is something other than key-pecking; and 3) contrast should not occur with pigeons if the discriminative stimulus is located off the response key. Contrary to what Schwartz and Gamzu (1977) claim, Williams (1983) feels that not only do the results of the empirical tests of these three predictions not support additivity theory, they do in fact provide the basis for the argument against this theory as an explanation of contrast.

In addressing the first issue, effects of different species, Williams points to the many studies (Beninger & Kendall, 1975; Blough, 1980; McSweeney, 1983) which have obtained contrast with rats as subjects. Although contrast effects are not as great as when pigeons are used a contrast effect can be seen.

With regard to the effects of stimulus location, William's again appeals to studies using rats as subjects where contrast was obtained but the discriminative stimulus is located off the response lever. There have also been several studies using pigeons as subjects which have obtained contrast with off-key discrimination procedures (Farthing, 1975; Hemmes, 1973). The inconsistent results however, have led Williams to suggest that "there are two sources of contrast, one dependent on stimulus location because of the involvement of the stimulus-reinforcer contingency and one independent of stimulus location because relative rate of reinforcement has general effects on behavior that are not mediated by the contingencies" (p. 356). This explanation is supported by a study by Hearst and Gormely (1976) based on a discussion presented in Hearst and Jenkins (1974) paper.

In addressing the final issue, the effect of response type, Williams suggests that the claim that contrast does not occur when pigeons press treadles "also fails to hold up" (p. 357). Williams cites Davidson and Ferguson (1978)

and McSweeney (1983) to substantiate this claim. As well, Bushnell and Weiss (1980) demonstrate contrast when pigeons treadle press although the effects were small and not consistent across subjects.

In summary, Williams suggests that additivity theory should no longer be considered "as a viable explanation of contrast in multiple schedules (p. 369). Although McSweeney, Ettinger and Norman (1981) as discussed earlier, argue that a weak version of the theory has yet to be contradicted by the current literature. Williams argues that although no one theory can provide definitive evidence against the theory the wide range of findings which contradict the theory leave it in serious doubt as a viable explanation of contrast.

The main generalization that can be extracted from the previous discussion is that none of the previous theories of contrast can account for all of the various results from the numerous studies conducted. Two factors, however, seem to be consistent in many studies and should be included in any further theory. These are, as Williams presents them, "1) an effect of Pavlovian contingencies particularly as expressed as an excitatory rebound effect of removing an inhibitory stimulus which ... is usually transitory and stimulus independent. 2) A general effect of relative rate of reinforcement which ... occurs in steady-state situations and is stimulus-independent" (p. 379).

Furthermore, all of the theories discussed have dealt with quantitative changes during contrast while virtually none have examined the qualitative changes that occur. Although Williams does state that "all in all ... contrast is a multiple-determined phenomenon where several different variables may operate simultaneously in any particular situation and where one of these variables may be ... changes in response topography" (p. 379).

This experiment was designed to examine the changes in response topography that occur during contrast and whether the study of these changes may help to explain behavioral contrast. In order to examine these patterns thoroughly, it was necessary to develop complex stereotyped sequences of behavior using a high VI schedule. Hearst, Karesco, and Poppen (1964) observed pigeons to engage in stereotyped patterns of behavior during VI schedules, specifically high VI schedules. Pear, Rector and Legris (1982) also observed very regular spatiotemporal patterns using a VI schedule. It seems to follow that with a higher VI schedule, there are lower interreinforcement intervals which allow the simple pattern involved in a single response to undergo some extinction, thus allowing more complex patterns to appear and be adventiously reinforced as Skinner (1948) found.

Complex response patterns were desirable for at least 2 reasons. First, and most obviously, by developing more complex behavior patterns, it is easier to see qualitative

changes between phases of the experiments. Second, by developing the complex spatiotemporal patterns, a test of the additivity theory may evolve. This theory would predict that during the VI VI phase of the experiment one type of response patterns should exist. With introduction of the VI EXT phase this operant response pattern should remain and be joined by an autoshaped response pattern during the unchanged component. This autoshaped pattern should then be expected to drop out with a return to baseline conditions. This prediction is based on previous research by Evans (1982) and Pear (1985).

In the present experiment, key pecking was developed on a mult VI 5 min VI 5 min schedule. Next, the birds were shifted to a mult VI 5 min EXT schedule to determine the effect on the response patterns produced in the first phase. A reversal back to baseline conditions was then performed to determine the recoverability of the original pattern.

Method

Subjects

Subjects were 3 adult, male, White Carneaux pigeons. Two of the subjects were experimentally naive (10675 and 5549), the other subject (805) had experience with multiple schedules. They were maintained at approximately 80% of their free-feeding weights throughout the study; water, however, was available at all times in their home cages.

The free-feeding weight of Bird 5549 was 578 g, for Bird 805 it was 505 g and for Bird 10675 the free-feeding weight was 527 g. For the purpose of tracking the movement of the birds with the computer system described below, their heads and necks were darkened with black shoe polish prior to each session. When not in a session, the birds were housed in individual cages in a pigeon colony room that was regulated by a 12-hr-on/12-hr-off light-dark cycle. The pigeons' diet in their home cages consisted of Purina Racing Pigeon Checkers, which was the same food that was used for reinforcement during experimental sessions.

Apparatus

The experimental chamber and the programming and recording equipment were located in separate rooms. The room containing the experimental chamber was illuminated by four banks of florescent lights in open light fixtures on the ceiling. The lights were wired through a relay that was under the control of the programming equipment. Ventilation of the room was provided through a register in the ceiling.

An aluminum frame supported the top and sides of the chamber, the inside dimensions of which were 57 x 57 x 38 cm. The front wall of the chamber was made of an aluminum panel and two pieces of white opaque Plexiglas, while the other two walls were made of clear glass. The top of the chamber was made of clear Plexiglas and the floor consisted

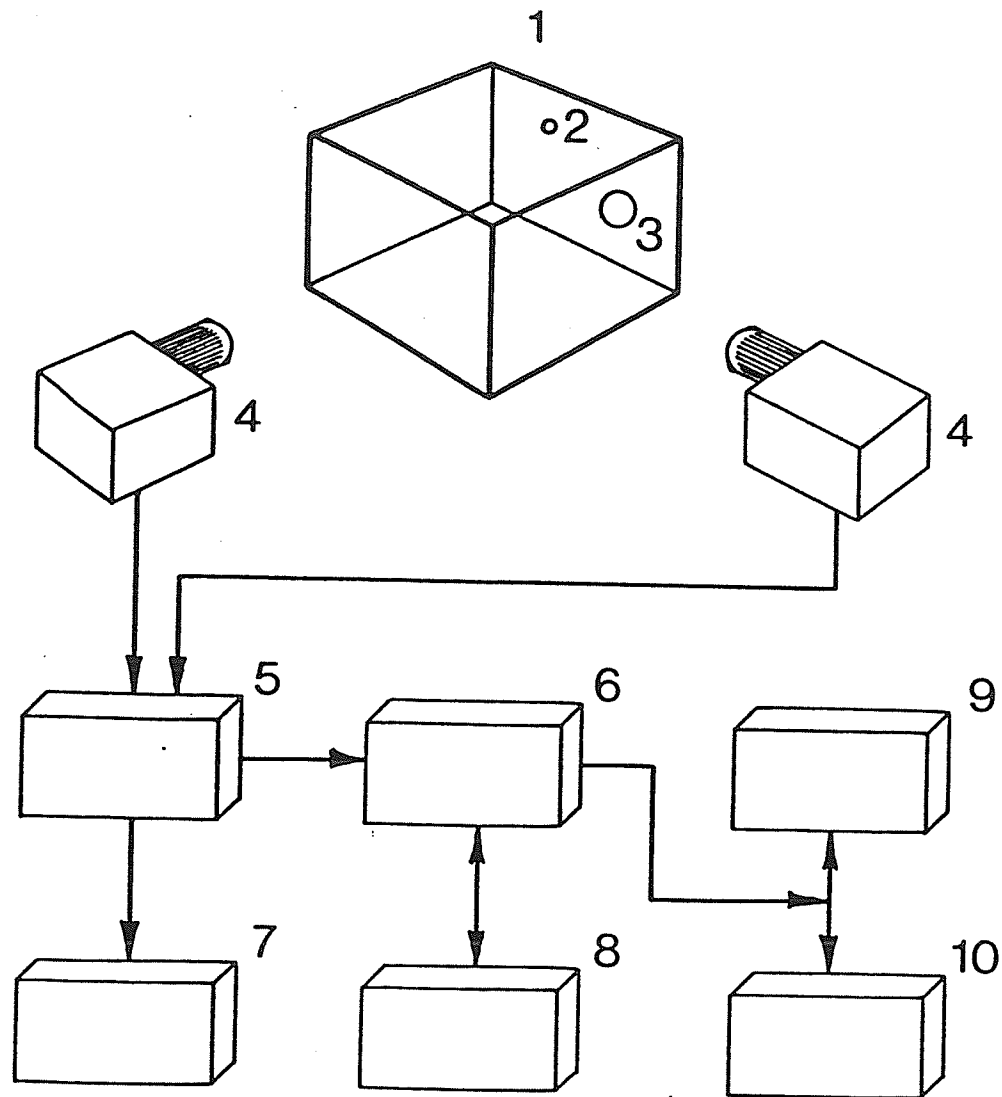
of aluminum mesh fitted into an aluminum drop pan. The interior of the chamber was illuminated through the top and the two transparent sides by the room lights, which were on during sessions and turned off automatically when each session was completed. Numerous air spaces in the top and bottom of the chamber provided ventilation of the chamber. A speaker in the room produced white noise continuously to mask sounds from outside the room.

Mounted on the aluminum panel of the front wall were: (1) a translucent plastic response key, which was 2.8 cm in diameter with its center located 20 cm from the mesh floor and 27.5 cm from the left adjacent wall; and (2) the feeder aperture, the bottom of which was located 12 cm from the floor. The key was illuminated by a red light during the first VI component and by a green light during the second VI component in phase A and the extinction schedule in phase B. During feeder operations the key was dark, and required a force of 0.18 N to record a key peck. An electrical relay behind the key produced an auditory stimulus each time the key was operated during the session, except during feeder operations. The feeder aperture was illuminated continuously by bulbs located behind the front panel. During reinforcement, which consisted of 3 sec access to the filled food hopper, the brightness of the feeder light increased.

The experimental room also contained two perpendicularly oriented TV cameras that were directed towards the two clear glass walls of the chamber. The cameras were connected to an electronic video-acquisition module which computed the position in space and time of the top center of the highest dark region viewed by each camera. The spatial xz coordinates were computed on one camera and the y coordinate was computed on the other camera. These computations were made 30 times per second, so that the target was tracked almost continuously. Since the pigeon's head was painted black, and the rest of the interior of the chamber was white and well-illuminated, the head was the target tracked by the system. To avoid interference of the tracing system by the metal joints connecting the glass walls, the chamber was turned at an angle of 15 degrees to the camera. This resulted in three narrow slices of the periphery of the chamber being excluded from the view of the cameras.

The video-acquisition module was connected to a Cromemco Z-2D microcomputer which collected the data, averaged the data points in groups of three, and stored the data on floppy disks for later analysis. This microcomputer was also used to program the experiment. An Epson Dot Matrix printer, controlled by the computer, was used to graph the data. A diagram of the apparatus is shown in Figure 1.

Figure 1. Diagram of the apparatus used in this experiment. (See text for explanation).



- | | |
|------------------|------------------|
| 1. Chamber | 6. Microcomputer |
| 2. Response Key | 7. TV Monitor |
| 3. Food Aperture | 8. Disc Storage |
| 4. TV Cameras | 9. CRT |
| 5. Logic System | 10. Printer |

Figure 1

Procedure

After being trained to eat from the feeder and to peck the response key for food reinforcement, the birds were placed on continuous reinforcement (i.e. every key peck reinforced for several sessions). They were then placed on the following sequence of schedules: Bird 5549, mult VI 5 min VI 5 min for 29 sessions, mult VI 5 min EXT for 23 sessions, mult VI 5 min VI 5 min for 17 sessions; Bird 805, mult VI 5 min VI 5 min for 39 sessions, mult VI 5 min EXT for 20 sessions, mult VI 5 min VI 5 min for 21 sessions; and Bird 10675, mult VI 5 min VI 5 min for 27 sessions, mult VI 5 min EXT for 25 sessions, mult VI 5 min VI 5 min for 15 sessions. Each session terminated after 54 minutes. Reinforcement time was subtracted from total time in calculating session time, and was excluded from all data analyses. Sessions were conducted daily, at approximately the same time each day, six or seven days per week. Dependent measures included: (a) graphs displaying the response rate per minute for all across all three phases of the study. (b) Graphs displaying spatiotemporal behavior wave patterns describing the absolute distance of the bird's head from the response key as a function of time, and (c) overhead plots of the path of the bird's head as it moved around the experimental chamber. Both these measures (b and c respectively) provided detailed, nearly continuous records of the precise sequence of spatiotemporal patterns occurring during each session.

It should also be noted that due to some programming problems, the range of the VI interval used was somewhat smaller than is typically used. Whereas the normal range varies from zero to 2 times the VI value used, this experiment used a range from .5 to 1.5 times the VI value.

Results

Bird 10675

The data from this study were analyzed by visual inspection. Figure 2 shows the response rate per minute during the red and green components across all three phases of the experiment for Bird 10675. Response rate in the first phase (mult VI 5 min VI 5 min) averaged 17.6 for the red component and 20.2 for the green component. The second phase, VI 5 min EXT, shows a contrast effect with response during the red component increasing to an average of 28.9 responses per minute and responses during the green component decreasing to an average of 8.2 responses per minute. During the third phase response rate in the red component increased to an average of 33.9 responses per minute, while responses during the green component increases to 25.2 responses per minute. Figure 3 shows data from the last session of mult VI 5 min VI 5 min prior to the introduction of VI 5 min EXT for bird 10675. The top graph in the figure shows the absolute distance of the bird's head from the key over the session. Each point is based on the

Figure 2. Response rate graph in responses per minute for all sessions across all three phases for Bird 10675.

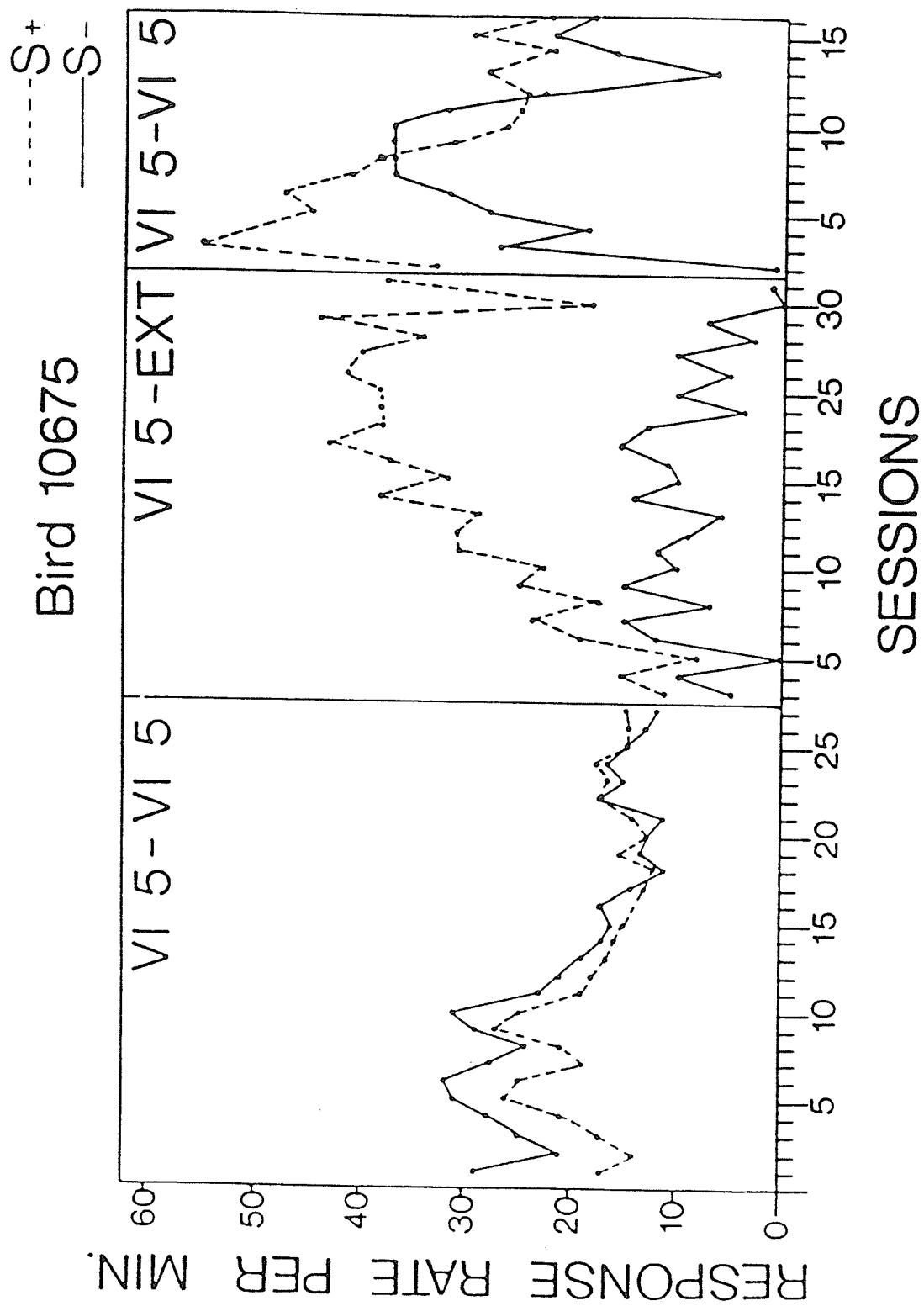


Figure 2

Figure 3. Last session of mult VI 5 min VI 5 min for Bird 10675. Distance of the bird's head from the key over the session is plotted in the top graph. Key pecks are indicated by vertical lines in the upper hand between the graph which, because of their density, form a solid black strip. The component is indicated by the horizontal lines between the lower pair of horizontal bands, black being the red component and white the green component. Errors in the tracking system are indicated by vertical marks in the upper part of the lower band. Expansions of the regions between a and b and between c and d are shown in the middle two graphs. Plots of these expanded data from an overhead view are shown in the bottom two graphs, each graph being an overhead view of the path described by the pigeon in producing the data in the graph immediately above it. "K" and "F" in the overhead plots indicate the positions of the key and feeder. The dotted lines indicate regions that were not visible to the camera.

Bird 10675
Mult VI 5 Min - VI 5 Min
Last Session

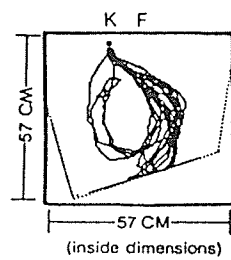
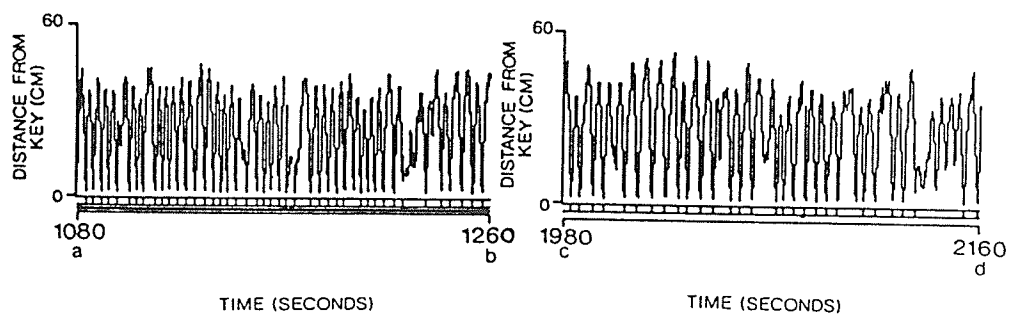
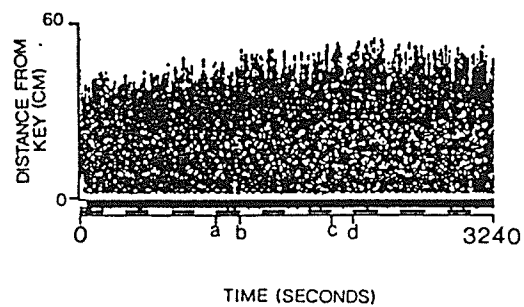
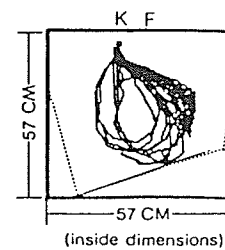


Figure 3



mean of three computations of each of the spatial coordinates in which the target was detected by the system at 1/30-sec intervals. Thus, successive points indicate the mean distance of the bird's head from the key at 1/10-sec intervals. The horizontal band just below the graph shows key pecks as vertical marks which, because of their density, form a solid black strip. The component is indicated by the horizontal lines between the lower pair of horizontal bands, black being the red component and white the green component.

Space is provided in the top portion of the lower band for displaying any errors that occurred in the tracking system. Errors were defined as instances in which (1) either camera failed to detect a dark region in the chamber or (2) the target being tracked moved at a speed greater than 10 cm/sec. (The latter was considered to be an error because it meant that a spurious dark target, such as a shadow, was being tracked momentarily. This could happen when the pigeon obscured its head and neck by, for example, flapping its wings or preening under its wings). As can be seen from the graph, several errors in the tracking system were recorded during this session.

Note from the distance plot that the bird pecked at a fairly constant rate and kept its head at a fairly uniform distance throughout the session, although there is a tendency for the distance to increase throughout the session.

The two middle graphs show expansions of the regions between a and b and between c and d in the above distance plot. These segments remain the same for all subsequent expansion graphs. It was decided that by examining the same sections for each bird this would ensure some objectivity in the presentation of the data.

In these plots, unlike the above distance plots, the data points are joined.

The graph on the left shows the 180 sec time segment for the 4th red component. The bird had a number of long excursions as well as some shorter ones from the key region.

The graph on the right shows the 180 sec time segment for the 6th green component. As seen in the figure, there were some short excursions from the key region but, all were generally of the same length.

The two bottom graphs show plots of the patterns described by the bird's movement on the xy plane (i.e. overhead plots) during the times shown in the distance plots immediately above. (The dotted lines in the overhead plots indicate the regions that were not visible to the cameras due to the technical reason mentioned in the apparatus section). Note that the majority of the excursions in the distance plot between a and b are pacing movements down the right hand wall of the chamber. On several occasions, however, the bird would continue this clockwise pacing until

a circle of the chamber had been completed when the bird would contact the key and then start the pattern again.

The pattern illustrated between c and d is essentially the same as the other distance plot, however, the bird does pace farther down the right hand wall and then turns to complete a figure-8 type pattern. These patterns changed frequently between and even within sessions, but generally all 3 birds had a basic pattern they engaged in.

Figure 4 shows the data from the last session of mult VI 5 min EXT prior to reintroduction of the mult VI 5 min VI 5 min.

The top graph clearly illustrates the contrast effect that occurred for Bird 10675. During the red component, the bird was quite close to the key, especially when compared to the top graph in Figure 3. There were very few excursions away from the key even during the S- showing the powerful stimulus control of the keylight even after 15 extinction sessions.

The middle graphs again indicate the time segments between a and b and c and d on the whole session distance plot.

When compared to the graphs in Figure 3 there are some obvious differences. Comparing the middle left hand graphs, the bird is much closer to the key and the number of

Figure 4. Last session of mult VI 5 min EXT for Bird 10675. of the bird's head from the key over the session is plotted Distance in the top graph key pecks are indicated by vertical lines in the upper hand between the graph which because of their density, form a solid black strip. The component is indicated by the horizontal lines between the lower pair of horizontal bands, black being the red component and white the green component. Errors in the tracking system are indicated by vertical marks in the upper part of the lower band. Expansions of the regions between a and b and between c and d are shown in the middle two graphs. Plots of these expanded data from an overhead view are shown in the bottom two graphs, each graph being an overhead view of the path described by the pigeon in producing the data in the graph immediately above it. "K" and "F" in the overhead plots indicate the positions of the key and feeder. The dotted lines indicate regions that were not visible to the camera.

Bird 10675
Mult VI 5 Min - EXT
Last Session

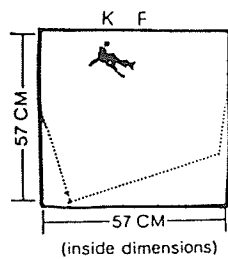
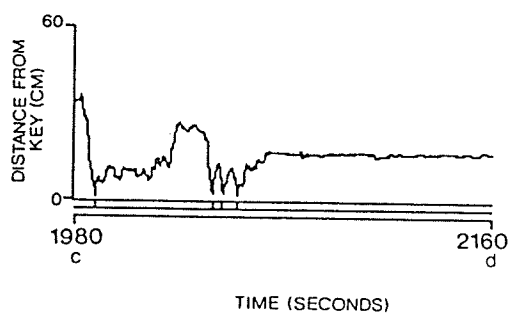
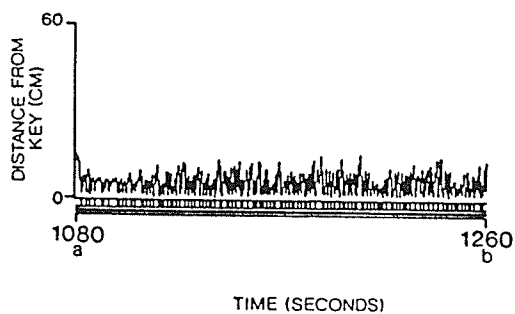
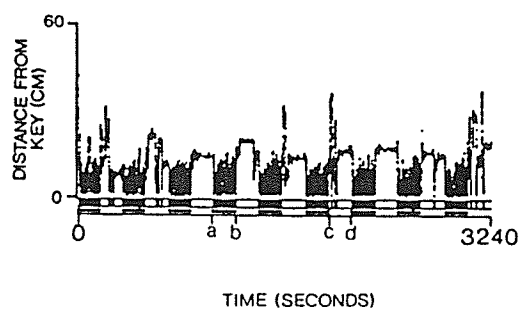
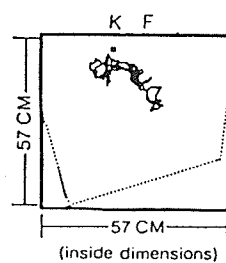


Figure 4



responses is much higher as indicated by the first horizontal band under the graphs. Comparing the right hand graphs the bird only pecks 4 times during the extinction segment and maintains a fairly constant distance from the key with no long excursions as in Figure 3.

The bottom graphs can also be compared to the corresponding graphs in Figure 3. During the S+ component, the bird is close to the key and paces from left to right in front of it. The wall pacing-circle pattern evident in Figure 3 has virtually disappeared. During the S- component also, the figure-8 pattern has disappeared; the bird simply sits by the key or paces from the left to right in front of the key. The bird was also seen to sit and preen himself on a number of occasions.

Figure 5 shows the maximum day of contrast for Bird 10675 which was session 49. Note the longer excursions and increased number of pecks during the S- component when compared to Figure 4. The middle graphs are similar to those of Figure 4, the bird is in close to the key and pecking rapidly during the S+ and sitting by the key during the S-.

The overhead plots are essentially the same as those in Figure 4; note, however, the circle during the S- component which corresponds to the excursion to the right hand side of the middle distance versus time plot.

Figure 5. Sesion of maximum contrast for Bird 10675. Distance of the bird's head from the key over the session is plotted in the top graph. Key pecks are indicated by vertical lines in the upper hand between the graph which, because of their density, form a solid black strip. The component is indicated by the horizontal lines between the lower pair of horizontal bands, black being the red component and white the green component. Errors in the tracking system are indicated by vertical marks in the upper part of the lower band. Expansions of the regions between a and b and between c and d are shown in the middle two graphs. Plots of these expanded data from an overhead view are shown in the bottom two graphs, each graph being an overhead view of the path described by the pigeon in producing the data in the graph immediately above it. "K" and "F" in the overhead plots indicate the positions of of the key and feeder. The dotted lines indicate regions that were not visible to the camera.

Bird 10675
Maximum Contrast

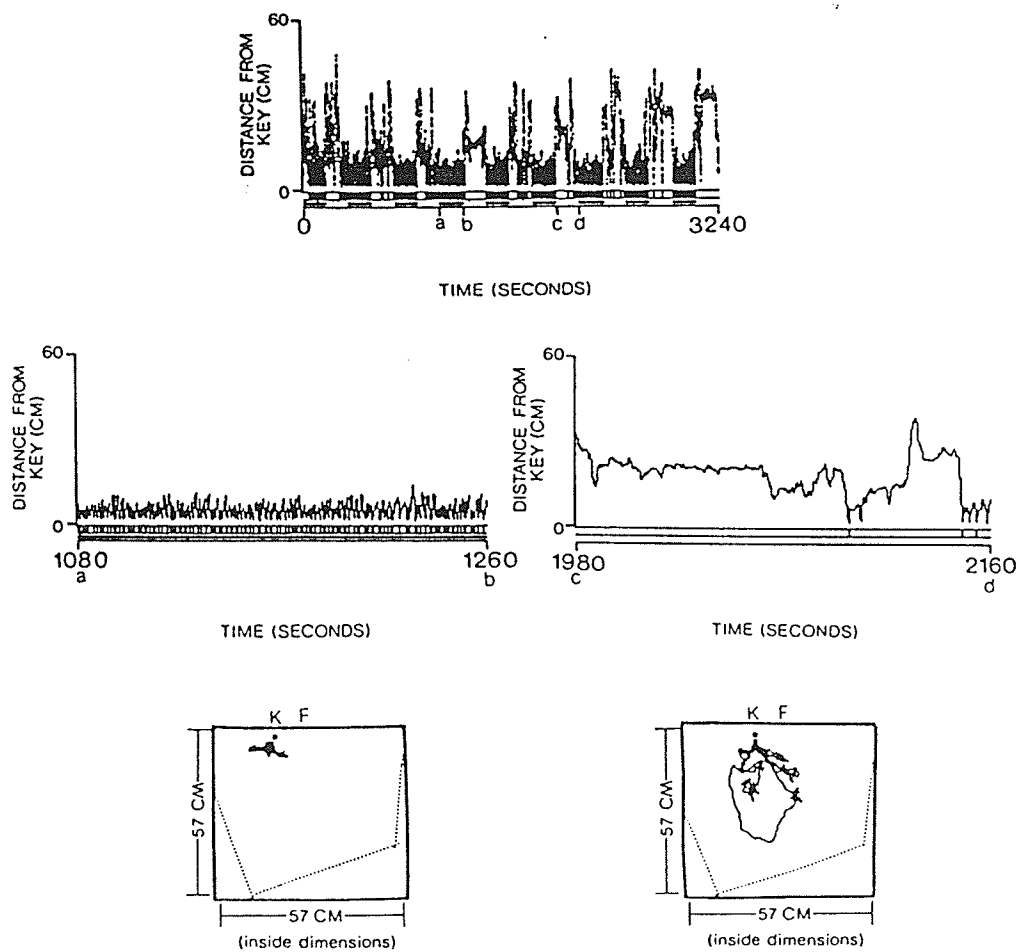


Figure 5

Figure 6 shows the return to baseline conditions of mult VI 5 min VI 5 min after the mult VI 5 min EXT phase for Bird 10675. The top graph indicates that the bird has begun to move back from the key but not to the extent that was present during baseline (see figure 3).

The middle graphs indicate very regular excursions from the key not present during baseline. For the time segment between a and b the long excursions appear as counterclockwise circles on the bottom graph. While on the graph of the distance plot between c and d there are two different excursions present. The somewhat longer circles are made counterclockwise while the shorter ones are made clockwise, each circle ends with a key peck or a number of key pecks.

Figure 6. Last session of the return to mult VI 5 min VI 5 min for Bird 10675. Distance of the bird's head from the key over the session is plotted in the top graph. Key pecks are indicated by vertical lines in the upper band between the graph which, because of their density, form a solid black strip. The component is indicated by the horizontal lines between the lower pair of horizontal bands, black being the red component and white the green component. Errors in the tracking system are indicated by vertical marks in the upper part of the lower band. Expansions of the regions between a and b and between c and d are shown in the middle two graphs. Plots of these expanded data from an overhead view are shown in the bottom two graphs, each graph being an overhead view of the path described by the pigeon in producing the data in the graph immediately above it. "K" and "F" in the overhead plots indicate the positions of the key and feeder. The dotted lines indicate regions that were not visible to the camera.

Bird 10675
 Mult VI 5 Min - VI 5 Min
 (Reversal)
 Last Session

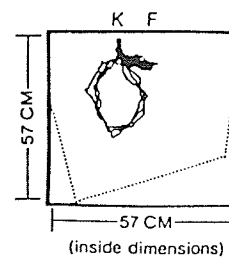
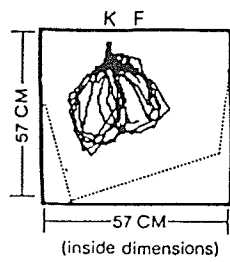
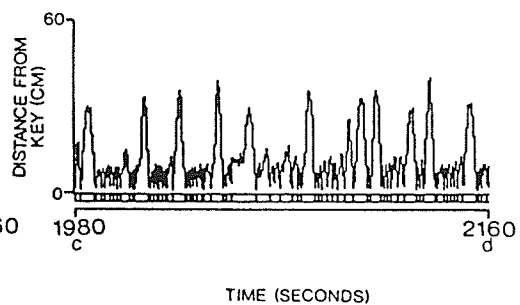
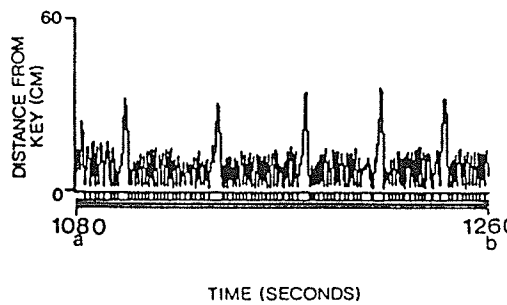
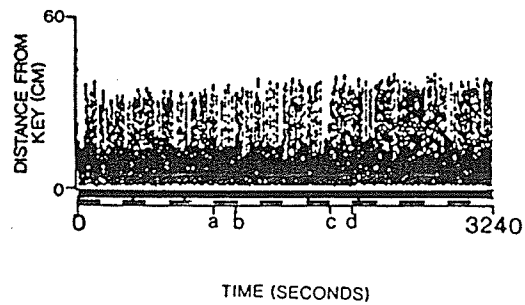


Figure 6

Bird 5549

Figure 7 shows the response rate per min during both components of the 3 phases of the experiment for Bird 5549. Response rate in the first phase average 8.9 responses per minute for the red component and 8.6 responses per minute for the green component.

During VI 5 min EXT response rate increased to 16.2 responses per min for the red and decreased to 3.04 responses per min for the green component, over session 30 to 51.

In the third phase response rate during the red component decreased to an average of 11.3 responses per min and increased to 7.8 responses per min during the green component. Note that although there is not a great contrast effect present as far as changes in response rate is concerned, there is definitely an effect present as the following figures will demonstrate.

Figure 8 shows data from the last session of baseline for Bird 5549. The top graph indicates a very stable response pattern with the bird covering most of the chamber with its particular pattern.

The middle graphs tell a similar story; the bird covers the entire chamber with its pattern after each key peck. Note that on the bottom graphs the longer excursions in the

Figure 7. Response rate graph in responses per minute for all sessions across all phases for Bird 5549.

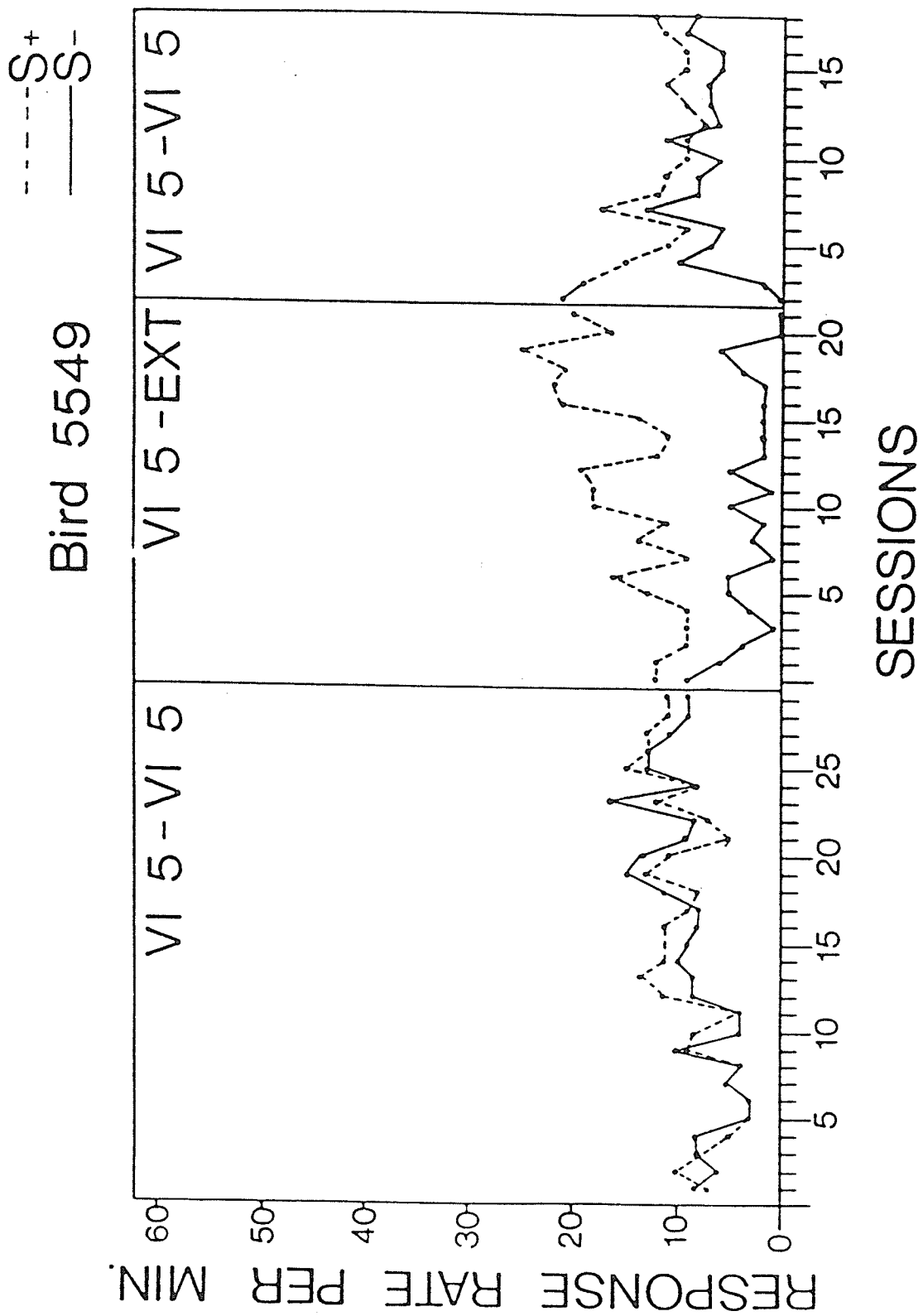


Figure 7

Figure 8. Last session of mult VI5 min VI 5 min for Bird 5549. Distance of the bird's head from the key over the session is plotted in the top graph. Key pecks are indicated by vertical lines in the upper hand between the graph which, because of their density, form a solid black strip. The component is indicated by the horizontal lines between the lower pair of horizontal bands, black being the red component and white the green component. Errors in the tracking system are indicated by vertical marks in the upper part of the lower band. Expansions of the regions between a and b and between c and d are shown in the middle two graphs. The pattern illustrated consists of two circles, one made to the right of the key (clockwise) and labelled "r" and one made to the left (counter-clockwise and labelled "l" as indicated. Plots of these expanded data from an overhead view are shown in the bottom two graphs, each graph being an overhead view of the path described by the pigeon in producing the data in the graph immediately above it. "K" and "F" in the overhead plots indicate the positions of the key and feeder. The dotted lines indicate regions that were not visible to the feeder.

Bird 5549
Mult VI 5 Min – VI 5 Min
Last Session

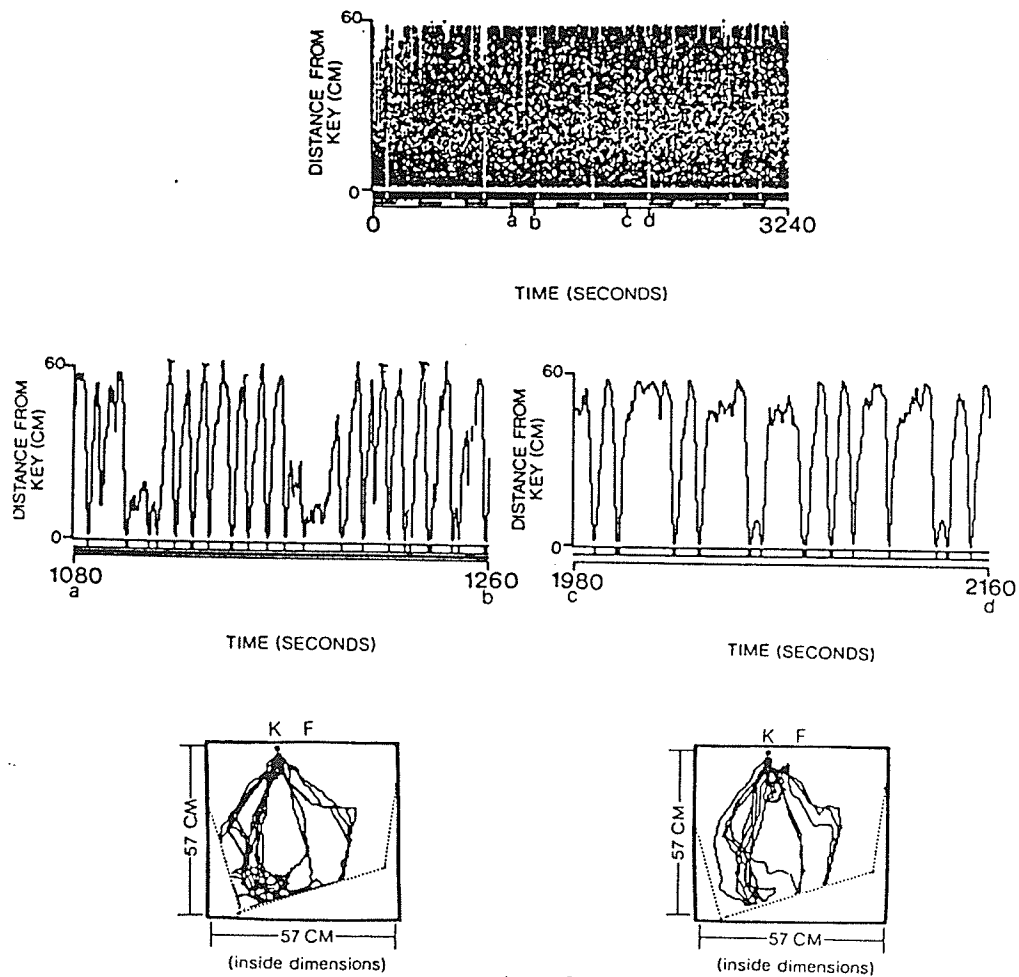


Figure 8

distance plot between a and b are large circles while the short excursions are movements to the right of the key. The pattern illustrated consists of two circles, one made to the right of the key (clockwise) and labelled "r" and one made to the left (clockwise) and labelled "l" as indicated. These circles tended to alternate but not in every case. A similar circling pattern occurred between c and d, however, the bird tended to spend more time in the back right hand corner of the chamber pacing to the left than back to the right.

Figure 9 shows data from the last sessions of mult VI 5 min EXT prior to the reintroduction of baseline conditions. This session is also the session of maximum contrast for Bird 5549.

The top graph illustrates the clear contrast effect from session 51. During the S+ the bird maintained fairly close key orientation but did make some longer excursions to the back of the chamber. During the S- the bird stayed quite far from the key and only four times did the bird peck the key during the S- component; this occurred during the 4th presentation.

The middle graphs also provide an excellent presentation of the contrast effect present. During the S+ there is the close-key behavior and during the S- the bird is away from the key and wandering around the chamber. The bottom graphs

Figure 9. Last session of mult VI 5 min EXT and maximum contrast session for Bird 5549. Distance of the bird's head from the key over the session is plotted in the top graph. Key pecks are indicated by vertical lines in the upper hand between the graph which, because of their density, form a solid black strip. The component is indicated by the horizontal lines between the lower pair of horizontal bands, black being the red component and white the green component. Errors in the tracking system are indicated by vertical marks in the upper part of the lower band. Expansions of the regions between a and b and between c and d are shown in the middle two graphs. The pattern illustrated consists of two circles, one made to the right of the key (clockwise) and labelled "r" and one made to the left (counter-clockwise) and labelled "l" as indicated. Plots of these expanded data from an overhead view are shown in the bottom two graphs, each graph being an overhead view of the path described by the pigeon in producing the data in the graph immediately above it. "K" and "F" in the overhead plots indicate the positions of the key and feeder. The dotted lines indicate regions that were not visible to the camera.

Bird 5549

Mult VI 5 Min - EXT

Maximum Contrast

Last Session

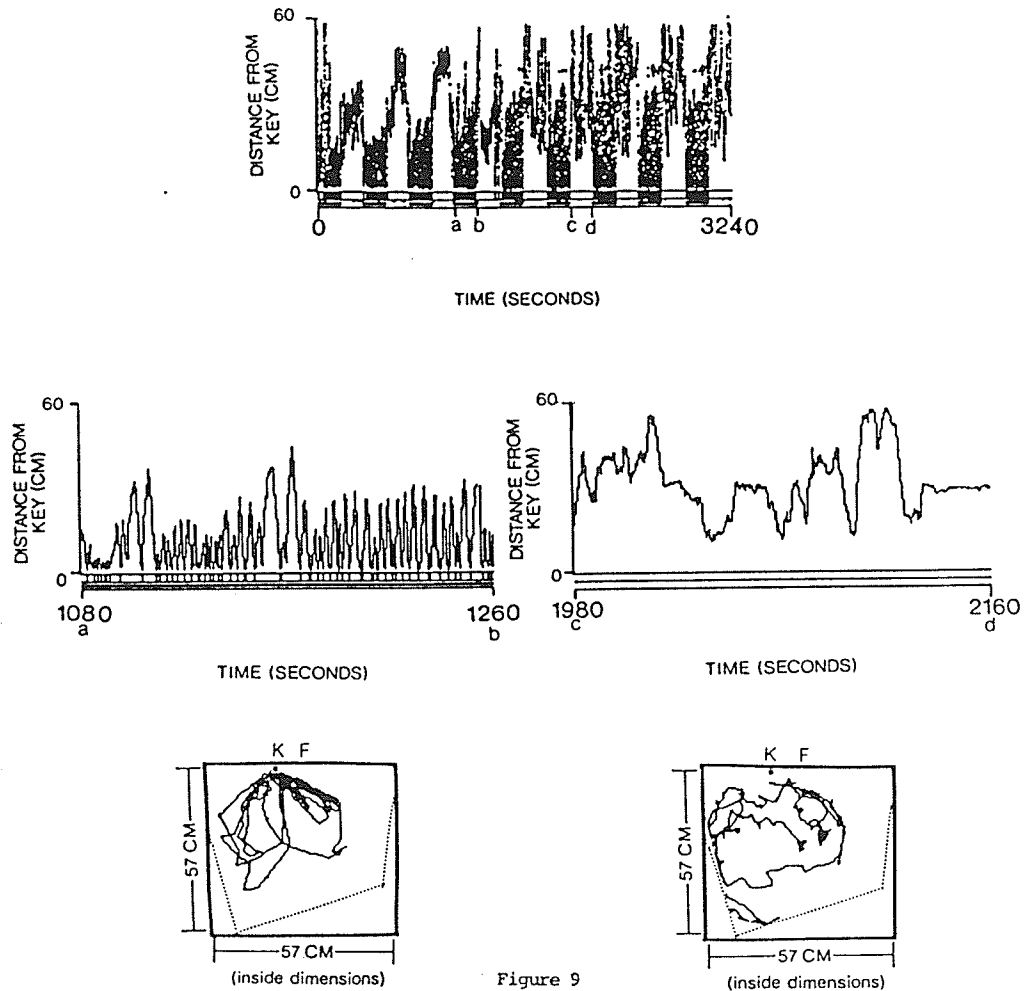


Figure 9

illustrate further the patterns present during this phase. The left hand graph (a and b) shows the pacing pattern to the right of the key that the bird most frequently engaged in. The circles to the left of the key were executed in a counterclockwise pattern while the one to the right was completed in a clockwise fashion. The graph on the right clearly indicates the unpatterned wandering the bird engaged in during the S-.

Figure 10 shows data from the return to baseline conditions for Bird 5549. The top graph shows the return of the key-pecking during the green component; note, however, that the bird's pattern no longer covers the entire chamber as it did during baseline.

The middle graphs show the close-key orientation that the bird is maintaining; again this is quite different from the long excursions seen in the baseline pattern. Similarly, the overhead plots indicate that the circles present in the baseline pattern have virtually been eliminated leaving a pacing pattern to the right of the key and partially down the right hand wall.

Figure 10. Last session of the return to mult VI 5 min VI 5 min for Bird 5549. Distance of the bird's head from the key over the session is plotted in the top graph. Key pecks are indicated by vertical lines in the upper hand between the graph which, because of their density, form a solid black strip. The component is indicated by the horizontal lines between the lower pair of horizontal bands, black being the red component and white the green component. Errors in the tracking system are indicated by vertical marks in the upper part of the lower band. Expansions of the regions between a and b and between c and d are shown in the middle two graphs. The pattern illustrated consists of two circles, one made to the right of the key (clockwise) and labelled "r" and one made to the left (counter-clockwise) and labelled "l" as indicated. Plots of these expanded data from an overhead view are shown in the bottom two graphs, each graph being an overhead view of the path described by the pigeon in producing the data in the graph immediately above it. "K" and "F" in the overhead plots indicate the positions of the key and feeder. The dotted lines indicate regions that were not visible to the camera.

Bird 5549
Mult VI 5 Min-VI 5 Min
(Reversal)
Last Session

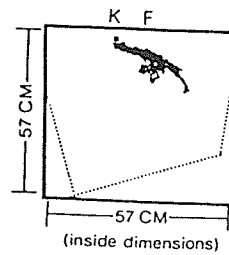
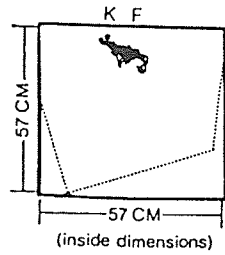
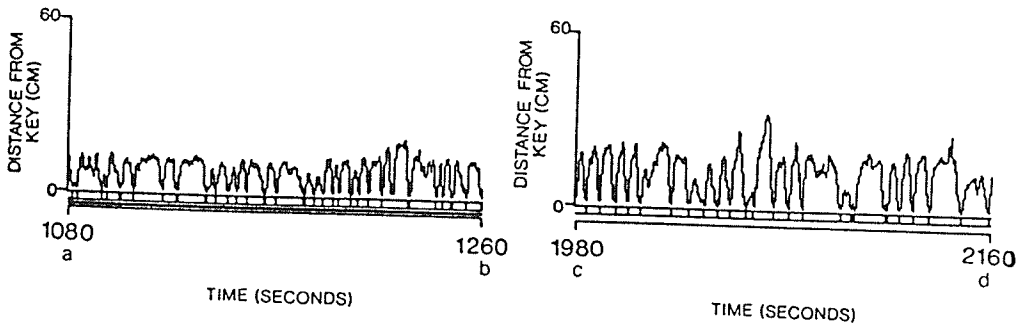
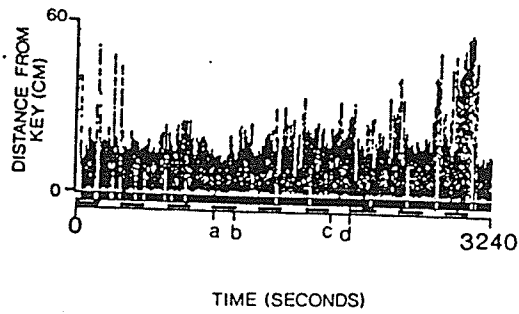


Figure 10

Bird 805

Figure 11 shows the response rate per min during the 2 components across all three phases for Bird 805. Response rate for the red component averaged 27.6 responses per min in the first phase, 20.1 in the second phase and 24.1 in the third phase. During the green component, the response rate averaged 26.5 in the first component, 3.2 in the second phase and 10.6 in the third phase. As can be seen from the graph, at no time did the bird's behavior every really stabilize. As a result, at session 39 of baseline, it was decided that the second phase should be initiated to complete the study in a reasonable amount of time.

The arrow at session 28 indicates a time at which the bird had been overfed and thus may account for the poor performance on this day and the next.

During the contrast phase although the behavior appears to be erratic a constant effect is present as is indicated in the following figures.

The top graph of Figure 12 indicates the close-key behavior maintained by the bird during the last session of baseline. This is further indicated in the middle graphs and can be seen to be a downward pacing pattern to the right of the key in the overhead plots.

Figure 11. Response rate graph in responses per minute for all sessions across all three phases for Bird 8051.

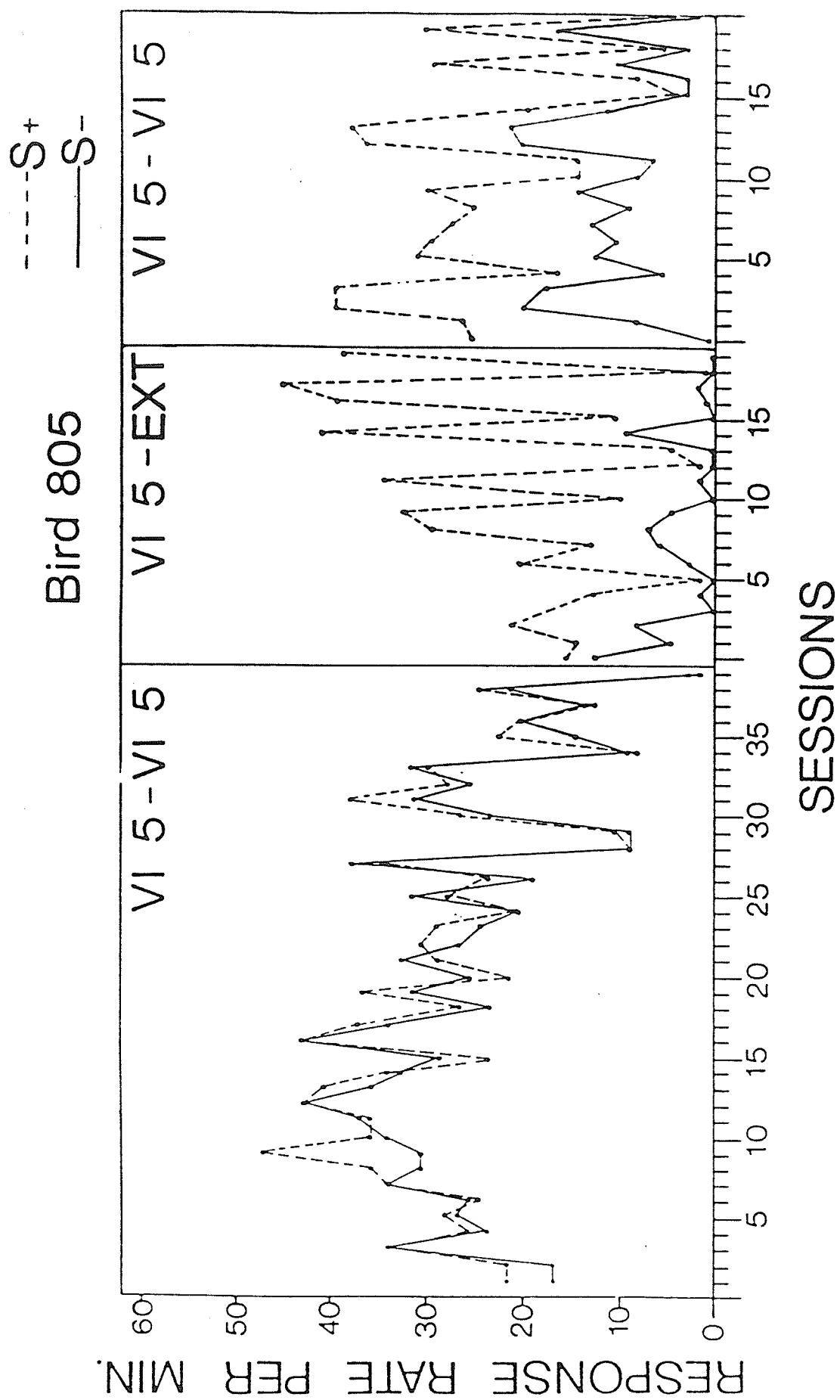


Figure 11

Figure 12. Last session of mult VI 5 min VI 5 min for Bird 805. Distance of the bird's head from the key over the session is plotted in the top graph. Key pecks are indicated by vertical lines in the upper band between the graph which, because of their density, form a solid black strip. The component is indicated by the horizontal lines between the lower pair of horizontal bands, black being the red component and white the green component. Errors in the tracking system are indicated by vertical marks in the upper part of the lower band. Expansions of the regions between a and b and between c and d are shown in the middle two graphs. The pattern illustrated consists of two circles, one made to the right of the key clockwise and labelled "r" and one made to the left (counter-clockwise and labelled "l" as indicated. Plots of these expanded data from an overhead view are shown in the bottom two graphs, each graph being an overhead view of the path described by the pigeon in producing the data in the graph immediately above it. "K" and "F" in the overhead plots indicate the positions of the key and feeder. The dotted lines indicate regions that were not visible to the camera.

Bird 805
Mult VI 5 Min-VI 5 Min
Last Session

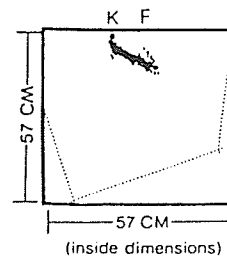
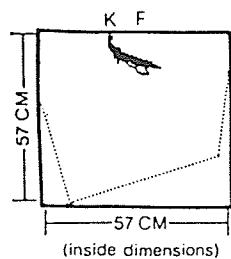
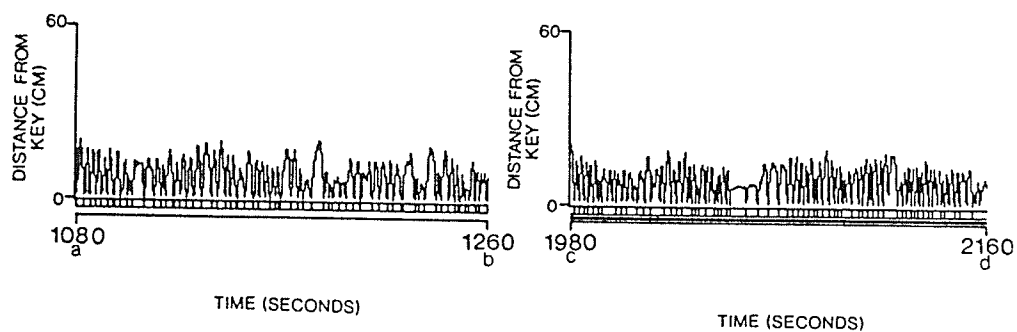
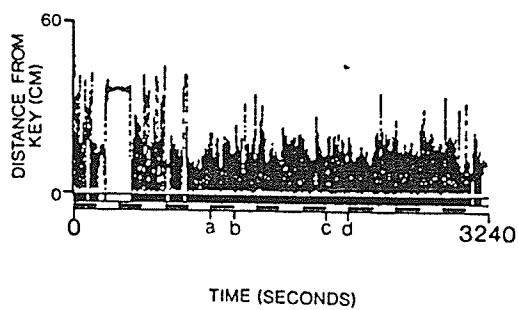


Figure 12

In Figure 13, a clear contrast effect is seen with Bird 805 when compared to the baseline of Figure 12. There is some pecking during the S- but the majority of the time is spent in the back right hand corner of the chamber.

During the S+ the bird is quite close to key; in fact it sits just to the right of the key and pecks (see bottom left-hand graph) while during the S- the bird moved to the far right-hand corner of the chamber and sat with its back to the key.

Figure 14 shows data from the session of maximum contrast (session 57). The bird sat to the right of the key and pecked during the S+ (see overhead plot) and again moved to the right-hand corner during presentation of the S-. Upon presentation of the S+ the bird would move back up to the left side of key and resume pecking.

The top graph of Figure 15 gives a good example of how the bird's pattern changed with reintroduction of the baseline conditions. Although it maintained essentially the same pattern as was present during the previous phase, the bird has moved out from the key and now has a pattern similar to the baseline pattern at least for the red component (see distance versus time and overhead plot). During the green component the bird has regained its close-key pattern, but now has rather rough counterclockwise circles interspersed within the pacing pattern. These

Figure 13. Last session of mult VI 5 min EXT for Bird 805. Distance of the bird's head from the key over the session is plotted in the top graph. Key pecks are indicated by vertical lines in the upper hand between the graph which, because of their density, form a solid black strip. The component is indicated by the horizontal lines between the lower pair of horizontal bands, black being the red component and white the green component. Errors in the tracking system are indicated by vertical marks in the upper part of the lower band. Expansions of the regions between a and b and between c and d are shown in the middle two graphs. Plots of these expanded data from an overhead view are shown in the bottom two graphs, each graph being an overhead view of the path described by the pigeon in producing the data in the graph immediately above it. "K" and "F" in the overhead plots indicate the positions of the key and feeder. The dotted lines indicate regions that were not visible to the camera.

Bird 805
Mult VI 5 Min -EXT
Last Session

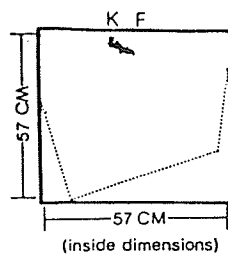
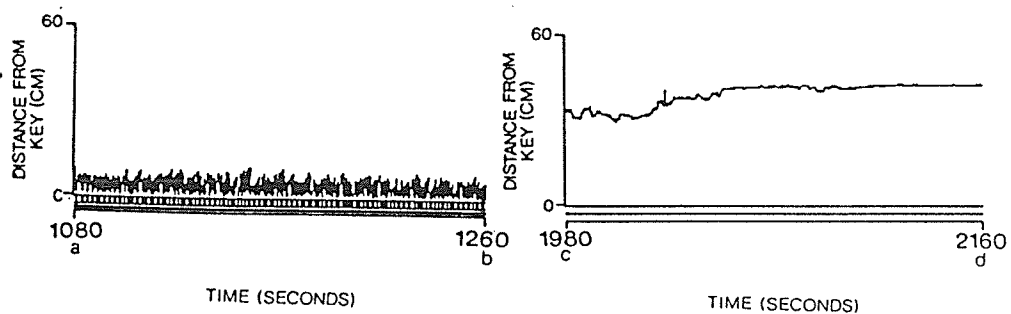
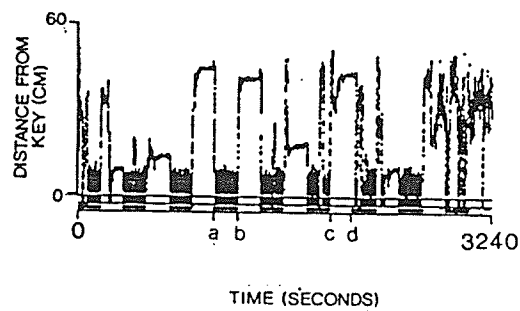


Figure.13

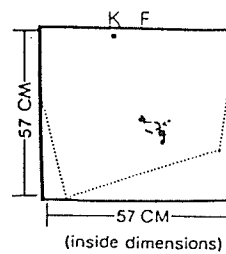


Figure 14. Session of maximum contrast for Bird 805. Distance of the bird's head from the key over the session is plotted in the top graph. Key pecks are indicated by vertical lines in the upper hand between the graph which, because of their density, form a solid black strip. The component is indicated by the horizontal lines between the lower pair of horizontal bands, black being the red component and white the green component. Errors in the tracking system are indicated by vertical marks in the upper part of the lower band. Expansions of the regions between a and b and between c and d are shown in the middle two graphs. The pattern illustrated consists of two circles, to the right of the key (clockwise) and labelled "r" and one made to the left (counter-clockwise) and labelled "l" as indicated. Plots of these expanded data from an overhead view are shown in the bottom two graphs, each graph being an overhead view of the path described by the pigeon in producing the data in the graph immediately above it. "K" and "F" in the overhead plots indicate the positions of the key and feeder. The dotted lines indicate regions that were not visible to the camera.

Bird 805

Maximum Contrast

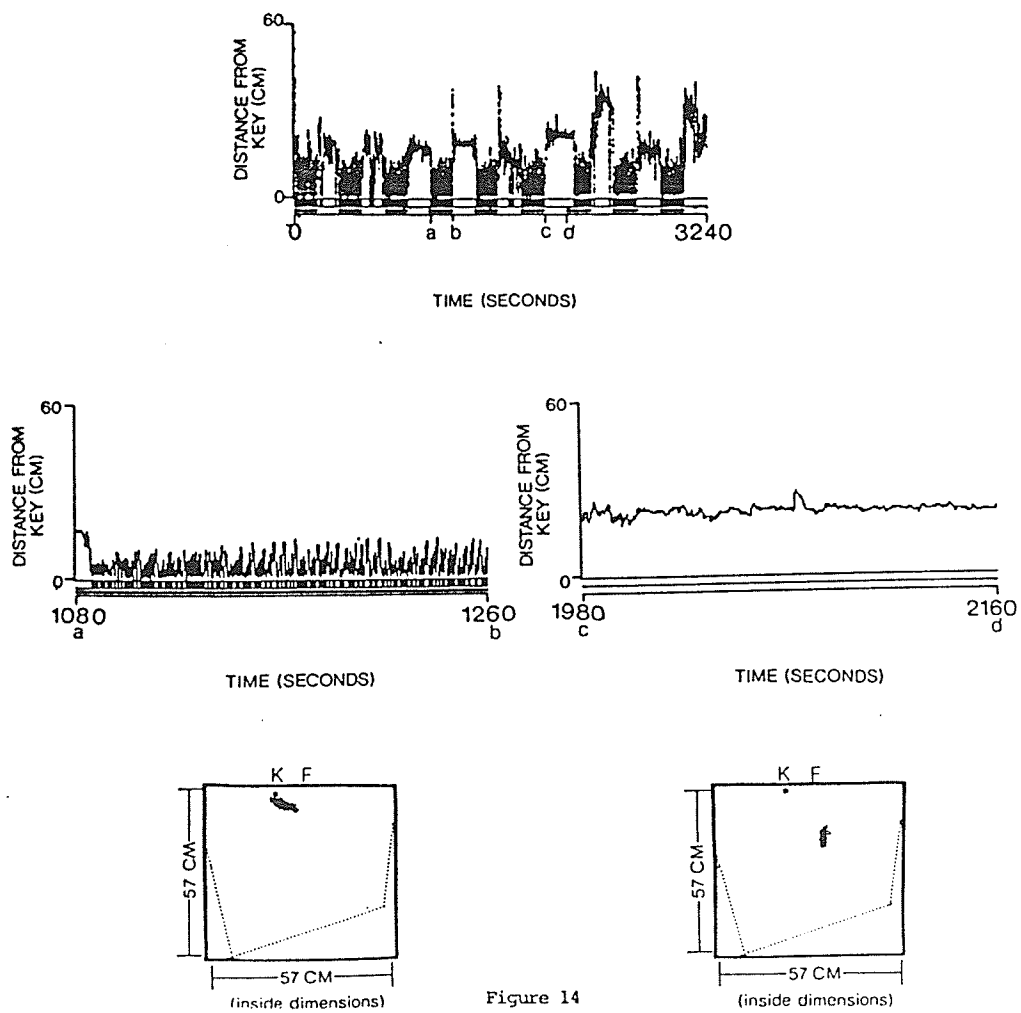


Figure 15. Last session of the return to mult VI 5 min VI 5 min for Bid 805. Distance of the bird's head from the key over the session is plotted in the top graph. Key pecks are indicated by vertical lines in the upper hand between the graph which, because of their density, form a solid black strip. The component is indicated by the horizontal lines between the lower pair of horizontal bands, black being the red component and white the green component. Errors in the tracking system are indicated by vertical marks in the upper part of the lower band. Expansions of the regions between a and b and between c and d are shown in the middle two graphs. The pattern illustrated consists of two circles, one made to the right of the key (clockwise) and labelled "r" and one made to the left (counter-clockwise) and labelled "l" as indicated. Plots of these expanded data from an overhead view are shown in the bottom two graphs, each graph being an overhead view of the path described by the pigeon in producing the data in the graph immediately above it. "K" and "F" in the overhead plots indicate the positions of the key and feeder. The dotted lines indicate regions that were not visible to the camera.

Bird 805
Mult VI 5 Min-VI 5 Min
(Reversal)
Last Session

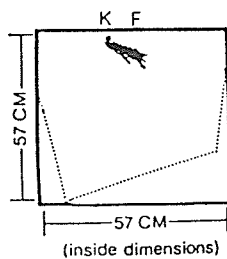
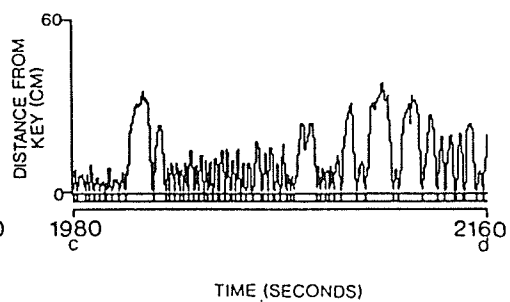
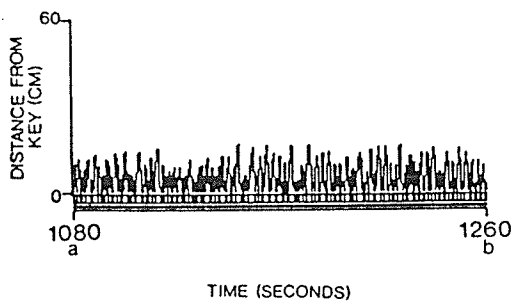
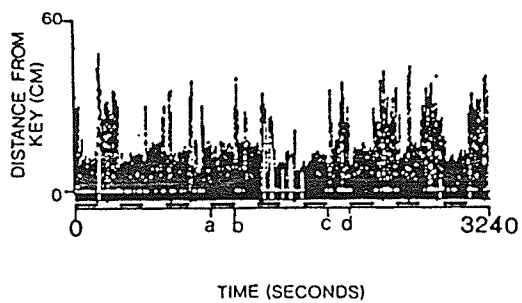
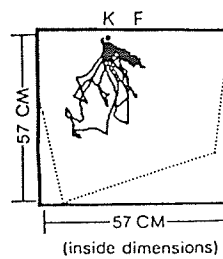


Figure 15



circles are seen as the longer excursions on the distance plots between c and d. Again, there is a contrast effect occurring with Bird 805. The response rate graph, however, would not really lend itself to such an interpretation.

Discussion

There were clear changes in the spatiotemporal patterns of behavior exhibited by all 3 birds in this experiment during behavioral contrast. Although only 2 birds (10675 and 5549) displayed what could be called complex spatiotemporal patterns all 3 birds' patterns, deteriorated when extinction was administered. When the subjects were returned to baseline conditions, similar patterns of responding reemerged but none were the exact same patterns present during baseline. The likely reason for these behavior pattern changes across baselines is that different parts of the pattern were being adventitiously reinforced; therefore the patterns were constantly changing. Williams (1983) also notes that "the degree of reversability will vary with several factors including the nature of the discriminative stimuli, the nature of the response key and the conditioning environment that surrounds it" (p. 366). He also suggests from an experiment conducted in 1981 (Williams & Heyneman) "that adventitious response-reinforcer pairings play a major role in maintaining elicited behavior" (p. 366). Indeed, irreversibility of response rates is not

a unique phenomenon in behavioral contrast studies (Beninger & Kendall, 1975; Lyons & Thomas, 1967; Bushnell & Weiss, 1980). It was also apparent from this study that response patterns could change between and within sessions as certain components of these patterns are reinforced and others extinguished. Pear (1985) clearly demonstrates how these patterns can change between sessions when subjects are on VI-5 min. schedules (p. 225).

As well, the change within sessions is indicated by Figures 10 and 15, for example. The response pattern was not uniform throughout the sessions for either component as the distance of the subject from the response key varied throughout the session. A more detailed analysis of the data using much smaller segments of the behavior pattern as Pear (1985) demonstrated would likely show the exact changes of the pattern within the session. (Due to the time restraints, however, this detailed analysis was not conducted for this study.) These pattern changes are further discussed by Pear (1985). "There are at least two possible explanations for this type of phenomenon: 1) each pattern is under the control of a particular stimulus as a result of having been advantageously reinforced in the presence of that stimulus, 2) the distinct patterns are actually parts of a single superordinate pattern. Verification of the first explanation would require identifying the controlling stimuli, which might be time

correlated. Verification of the second explanation would require showing regularity in the alterations between the superordinate patterns independent of any controlling stimuli" (p. 230).

The results of this study also lend themselves to the ongoing debate as to the validity of the additivity theory. Williams' (1983) review of additivity theory led him to suggest that this theory is a "fundamentally incorrect" (p. 346) explanation of behavioral contrast. Although this study cannot single-handedly refute the additivity theory the results do suggest that an alternate theory would be more acceptable. As discussed earlier, Hinson and Staddon (1978) proposed that contrast occurs because of competition or response substitution between interim and terminal behaviors. Both these types of behaviors are produced by any interval schedule of reinforcement (Staddon & Simmelhag, 1971). Therefore, during both components of a multiple VI VI schedule, as was used in this study, both interim and terminal behaviors occur. When the schedule is changed to multiple VI EXT, terminal behaviors are eliminated in the EXT component and the interim behavior that occurs in the unchanged VI component can then move into the EXT component) leaving more time for terminal responding in the unchanged VI component and subsequently causing a contrast effect. In examining Hinson and Staddon's theory in light of this study, the results suggest that no behavioral competition

occurs. There are what Staddon would call terminal (keypecking) and interim (circling, pacing, etc.) behaviors present, but there is no transference of such behavior from one component to the other when extinction is introduced. From Staddon's theory, one would expect that the bird would maintain a close-to-key pattern during the S+ of the VI 5 min EXT schedule. Hinson and Staddon would then suggest that the interim behavior during the EXT component should increase, which in fact it did not. All 3 birds stayed near the back of the experimental chamber and showed a definite decrease in their amount of interim behavior when compared to the baseline conditions. Thus, Hinson and Staddon's argument that behavior contrast results from a competition between the interim and terminal behaviors, when compared with this study is incorrect.

The response competition or substitution idea, however, is still useful in addressing the data in terms of the additivity theory as proposed by Gamzu and Schwartz. As discussed earlier, these theorists suggest that contrast is a function of joint control of stimulus-reinforcement and response-reinforcer relationships. As such, there appear to be significant parallels between autoshaping and behavioral contrast. Based on this notion response topographies developed during baseline should be maintained while some other pattern of responding occurs during contrast to cause the increase in responding during the S+. One pattern being

developed by the stimulus-reinforcer relationship, the other by the response-reinforcer relationship. As discussed earlier, however, there was no addition of response patterns. Instead, the complex pattern dropped out and was replaced by a close-key pattern during the VI EXT phase. Following from Hinson and Staddon's competition theory, it may be possible that instead of there being an addition of responses there is a substitution of autoshaped responses for the operant responses in the unchanged component which results in an increase in responding. The operant responses might then have reemerged with the reintroduction of the VI 5 min. schedule in the changed component. The difficulty with such an interpretation is that in the contrast situation no method has been devised by which response-reinforcer and stimulus-reinforcer relationships can be independently manipulated to demonstrate control over a particular skeletal response. Therefore, one cannot be sure that one response pattern is a result of an operant situation and the other a result of an autoshaping situation and whether the two add together or not. Pear and Eldridge (1984) do point out, however, that there is a similarity between the closeness of the bird's head to the response key during the reinforcement component of a multiple VI-EXT schedule and during autoshaping. Furthermore, they indicate that this similarity does suggest "a possible connection between autoshaping and behavioral contrast" (p. 461), but that a more precise measurement system is needed to obtain

more conclusive evidence as to the extent of this similarity. Such a premise, however, does raise the question as to what role autoshaping plays in behavioral contrast. As already discussed, for contrast to occur two different keypecks must add together. The data suggest however that there is no real evidence of such an addition. There is however, an addition of an approach behavior to contrast situation which is not present during the baseline. As the data illustrate the bird moves in close during the unchanged component and increases pecking while it moves away from the key during the changed component. This is an example of what Hearst and Jenkins (1974) call "sign-tracking". This approach behavior therefore, is something that is added and subtracted during the contrast situation. Similar approach behaviors were found by Evans (1982) who concluded that autoshaped key pecks are under joint control of stimulus-reinforcer and response reinforcer contingencies in that autoshaped keypecks are sensitive to their consequences. Therefore, in the contrast situation there may be in fact an addition of two behaviors which result in contrast, namely the addition of the approach behavior and the operant pattern of responding. So, in fact, it may be incorrect to assume that one should see an autoshaped pattern adding to the operant response pattern, instead an approach pattern is what needs to be examined in the contrast situation. Whether this apparent addition of "sign tracking" behavior and autoshaped keypecks is a viable

explanation of contrast should be considered in further studies of this type.

With regards to McSweeney et al. (1981) it was suggested that the additivity theory could only be tested in terms of the specification of the environmental conditions necessary to control behavior but that the theoretical mechanisms underlying contrast were not testable. Based on the discussion presented by Pear and Eldridge (1984), however, it seems possible that with future research efforts the technology necessary to identify the mechanisms that control behavior in behavioral contrast may be found.

Therefore, it seems that the question of whether the additivity theory is indeed valid is not the fundamental question which needs to be addressed. It seems more important to add to the current data base which researchers use to modify the theoretical accounts of behavior. As Pear and Eldridge (1984) explain, "as our data base expands, a science often develops powerful though unforeseen techniques of inference where direct measurement is not possible" (p. 463). Therefore, even by testing the additivity theory as McSweeney et al. (1981) suggest, we may not be gaining any more information than we already know in terms of how behavioral contrast occurs. Furthermore, McSweeney et al. (1981) suggest that only the weak version of the additivity theory is testable. More research, however, along the lines of this study, may allow researchers to eventually make

distinctions between elicited and operant pecks on the basis of physical form. Thus what McSweeney et al. (1981) feel would be the strongest test of additivity, on the basis of physical difference, may in fact be possible.

This procedure also has one advantage over previous studies of the additivity theory which show that the sum of instrumental and signal-key responses during a signal-key schedule are approximately equal to the size of contrast during a one-key procedure when food is the reinforcer (Keller, 1974). The advantage is that this procedure does not have to assume that response-reinforcer relations and stimulus-reinforcer relations can be spatially separated as on the signal-key procedure and that the change from nondifferential reinforcement to differential reinforcement causes the development of responding to the signal key. Rather than assuming that a specific procedure has produced spatial separation, the present approach attempts to determine whether identifiably separate topographies have developed. Williams and Heyneman (1981) suggest that this assumption is an oversimplification and that failing to find operant-key contrast is likely due to the confounding effects of changes in the response unit when nondifferential reinforcement is changed to differential reinforcement (Williams, 1983).

Williams and Heyneman (1981) used a procedure in which signal-key pecking was substantially reduced by a 2-second

change over delay where reinforcement for operant key pecking did not produce reinforcement within 2 seconds of the last signal key-peck. Based on the results, Williams and Heyneman (1981) point out that the response-reinforcer relation seems to play a major role in maintaining the signal-key pecking; thus the procedure cannot be taken as a valid method for dissociating elected and operant behavior. The qualitative analysis employed in this study does not have to depend on such assumptions and, therefore, in the future, may be able to distinguish the two types of keypecks.

A further test of the additivity theory would be to try and obtain contrast in a situation where the S+ is not located on the response key but is an arbitrary point in space as Pear (in press) has used in a recent shaping study. By successfully using such a procedure to obtain contrast, further evidence may result which could help explain the inconsistent results which have been found with both pigeons and rats and provide information as to the validity of the additivity theory. It may also, as Williams (1983) suggests, clarify if "there are two sources of contrast, one dependent on stimulus location because of the involvement of the stimulus-reinforcer contingency and one independent of stimulus location because relative rate of reinforcement has general effects on behavior that are not mediated by the Pavlovian contingencies" (p. 356).

In summary, the results of this study suggest that the additivity theory is perhaps not the best explanation of behavioral contrast. The results tend to contradict Hinson and Staddon's (1978) behavioral competition model of contrast as well.

Although the results cannot firmly support or reject additivity theory they do add to the current knowledge about behavioral contrast and provide the framework for further research in this area using a qualitative topographical analysis rather than the typical quantitative statistical analysis.

Furthermore, with current research efforts, a more precise measurement device may be developed which will provide the evidence needed to unequivocally reject or confirm the additivity theory by allowing the measurement of the physical forms of the elicited and operant response topographies. More importantly, however, such a device may allow researchers to examine the contrast effect and understand more about the fundamental laws of behavior.

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