

AN EXAMINATION OF THE EFFECTS OF PARTIAL REINFORCEMENT ON
SIGN- AND GOAL-TRACKING IN THE PIGEON

by

Kathleen M. Silva

A thesis presented to the University of Manitoba
in fulfillment of the thesis requirement for the degree of Master of Arts in the
Department of Psychology

Winnipeg, Manitoba
(c) Kathleen Silva April, 1991



National Library
of Canada

Bibliothèque nationale
du Canada

Canadian Theses Service Service des thèses canadiennes

Ottawa, Canada
K1A 0N4

The author has granted an irrevocable non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of his/her thesis by any means and in any form or format, making this thesis available to interested persons.

The author retains ownership of the copyright in his/her thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without his/her permission.

L'auteur a accordé une licence irrévocable et non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de sa thèse de quelque manière et sous quelque forme que ce soit pour mettre des exemplaires de cette thèse à la disposition des personnes intéressées.

L'auteur conserve la propriété du droit d'auteur qui protège sa thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

ISBN 0-315-76782-0

Canada

**AN EXAMINATION OF THE EFFECTS OF PARTIAL REINFORCEMENT
ON SIGN- AND GOAL-TRACKING IN THE PIGEON**

BY

KATHLEEN M. SILVA

A thesis submitted to the Faculty of Graduate Studies of
the University of Manitoba in partial fulfillment of the requirements
of the degree of

MASTER OF ARTS

© 1991

Permission has been granted to the LIBRARY OF THE UNIVER-
SITY OF MANITOBA to lend or sell copies of this thesis, to
the NATIONAL LIBRARY OF CANADA to microfilm this
thesis and to lend or sell copies of the film, and UNIVERSITY
MICROFILMS to publish an abstract of this thesis.

The author reserves other publication rights, and neither the
thesis nor extensive extracts from it may be printed or other-
wise reproduced without the author's written permission.

I hereby declare that I am the sole author of this thesis. I authorize the University of Manitoba to lend this thesis to other institutions or individuals for the purpose of scholarly research.

Kathleen M. Silva

I further authorize the University of Manitoba to reproduce this thesis by photocopying or by other means, in total or in part, at the request of other institutions or individuals for the purpose of scholarly research

Kathleen M. Silva

Abstract

The sign- and goal-tracking behavior of three pigeons exposed to a partially reinforced sign-tracking procedure was examined using a within-subject design. In Experiment 1, the pigeons were exposed to 100%, 50%, 25%, and 10% conditioned stimulus (CS) - unconditioned stimulus (US) pairings in a fixed-trial response-independent sign-tracking procedure. The decreasing order of percentages was followed by a reversal to 100% CS-US pairings. In Experiment 2, the position of the CS was switched between two locations during 50% CS-US pairings. The CS and the US were located 60 cm apart in both experiments. A computer-controlled tracking system provided a continuous record of the bird's position and movements by monitoring the location of the top of the bird's head in three-dimensional space across time. Depending on the dependent measure, the results of Experiment 1 suggested that partial reinforcement increases sign-tracking and decreases goal-tracking. Although inconclusive, the results of Experiment 2 suggested that the birds altered their approaches to the CS according to where it was located. The difficulties in measuring sign- and goal-tracking in the pigeon were discussed. It was suggested that topview movement plots of the birds' behavior best represents sign- and goal-tracking behavior because the plots contain information regarding length, angle, and proximity of approach to the CS and/or feeder. The effects that were present may be accounted for by several theoretical orientations including behavioral competition, Konorski's model, behavior systems, and the generalized matching equation.

Acknowledgements

This thesis was conducted while I was supported by a fellowship from the Natural Sciences and Engineering Research Council of Canada. I would like to thank the members of my committee, Dr. Robert Tait and Dr. Carl Schwarz, who each made unique and valuable contributions that greatly strengthened the thesis. Thanks also to Dr. William Timberlake for his helpful suggestions and comments.

A special thanks to my advisor, Dr. Joseph Pear, for his unyielding assistance and patience, and for sharing his view of learning over the last four years.

Thanks to my family for their support and understanding, and my friends in the lab - Gloria, Randy, and Mike - who made the daily grind of research more bearable. Finally, thanks to Fran and Fozzy Bear for everything.

An Examination of the Effects of Partial Reinforcement on Sign- and Goal-tracking in the Pigeon

The approach and contact behaviors elicited by localized signals for biologically relevant stimuli were first reported by Brown and Jenkins (1968). They labeled this approach and contact behavior autoshaping because the pigeons appeared to shape themselves to perform a free-operant response. In autoshaping, hungry or thirsty pigeons will peck a response key that is illuminated for a brief time (e.g., 8 s) before the presentation of food or water. The stimulus paired with food or water (e.g., a response key illuminated red) is often termed the conditioned stimulus (CS) and the food or water is termed the unconditioned stimulus (US). The period of time between the offset of the US and the onset of the CS is termed the intertrial interval (ITI). An explicit stimulus that is presented during the ITI (e.g., a response key illuminated blue) is termed the intertrial stimulus (ITS). In 1974 Hearst and Jenkins coined the term sign-tracking to refer to behavior that is directed toward or away from a stimulus as a result of the relation between that stimulus and an appetitive, aversive, or non-occurrence of another stimulus. Sign-tracking has often been considered the general rubric under which more specific phenomena such as autoshaping are a part (Tomie, Brooks, & Zito, 1989).

A phenomenon related to sign-tracking is termed goal-tracking. Goal-tracking occurs when the experimenter arranges a sign-tracking procedure and the animal approaches the site of the US (e.g., food hopper) during the CS (Boakes, 1977). Goal-tracking has most often been reported in studies that used rats as the experimental subjects. Goal-tracking is rarely observed in pigeons (Boakes, 1977, 1979).

Pigeons and Sign-Tracking

Several studies have examined the effects of modality, localizability, and other physical properties of the CS on the sign-tracking response. For example, it has been shown that approaching and contacting the CS rarely occurs when the CS is a widespread visual or diffuse auditory stimulus (Bilbrey & Winokur, 1973; Hearst, 1975; Hearst & Jenkins, 1974). Wasserman (1973) found that pigeons do not autoshape to a CS that was paired with a US in a dark chamber, although they did direct behavior toward the site of the US. In contrast to the aforementioned studies, pigeons will approach and peck at a single, stationary, visual CS even if the CS moves from one location to another on successive trials (Wasserman, Franklin, & Hearst, 1974) or within a trial (Skinner, 1971).

Other studies have examined the effect of the type of US and the duration of the US on autoshaped responding. For example, Jenkins and Moore (1973) reported that pigeons learned to peck the CS at nearly the same rate, irrespective of whether a food or a water US was used. Gibbon and Balsam (1981) and Perkins, Beavers, Hancock, Hemmendinger, Hemmendinger, and Ricci (1975) reported that US-duration (e.g., 3-s vs. 9-s access to food) does not affect maintained responding. A comprehensive discussion of the variables that affect autoshaping and sign-tracking can be found in Locurto, Terrace, and Gibbon (1981); however, because it is especially relevant to the experiments presented here, the effect of partial reinforcement on sign-tracking will be described in more detail below.

Rats and the Sign-/Goal-Tracking Relation

When rats are used as the experimental subjects, pairing a localizable stimulus (e.g., a retractable lever or the illumination of a light [CS]) with an appetitive reinforcer (e.g., food or water [US]) generates two apparently conflicting behaviors: approach to the CS (sign-tracking), and/or approach to the site of the US (goal-tracking). Typically, rats will approach the CS when it is presented and, later in the CS interval, approach the feeder (Boakes, 1977; Davey & Cleland, 1982). Thus, it is necessary to discuss sign- and goal-tracking in reference to one another when rats are the subjects.

Several studies have exposed rats to various experimental preparations and examined the effect of these preparations on sign- and goal-tracking. Boakes (1977) exposed rats to light-food presentations in which the light was mounted within a lever. Depression of the lever activated a microswitch that recorded a lever press. Pressing the lever was the measure of sign-tracking and entry into the food hopper was the measure of goal-tracking. Boakes found that the frequency of both behaviors increased when the offset of the CS was immediately followed by the US, but the frequency of both behaviors decreased when the CS was presented without the US and when the CS and the US were presented independently of one another.

A well established procedure used in sign-tracking research requires the animal to discriminate between two CSs — one that is followed by the US (the CS+) and another that is not followed by the US (the CS-). Using such a discrimination procedure, rats have been observed to sign- and goal-track at higher rates during the CS+ than during the CS- (Farwell & Ayres, 1979; van Haaren, van Hest, & van de Poll, 1987).

The length of the ITI also has an effect on the sign- and goal-tracking behavior of rats. Studies that have manipulated the length of ITI have found that short ITIs produce

higher rates of goal-tracking than sign-tracking, and that long ITIs produce higher rates of sign-tracking than goal-tracking (van Haaren et al., 1987).

Some recent interpretations have alluded to the importance of the physical characteristics of the CS (e.g., the illumination of a light vs. the presentation of another animal) in determining the form of the sign-tracking response (Cleland & Davey, 1983; Timberlake, 1983; Timberlake & Grant, 1975; Timberlake & Lucas, 1989). A behavior systems model claims that the CS used in autoshaping and sign-tracking studies may serve two general purposes: (a) as a signal for the US, and (b) as a releaser of phylogenetically preorganized behaviors (Timberlake, 1983). Briefly, a CS that is a signal for food releases phylogenetic foraging behaviors that consist of, or include, approaching the CS. For hungry rats in an experimental chamber, a retractable lever serving as a CS will release investigative foraging behaviors that result in touching, pressing, licking, or gnawing the lever with the forepaw or the mouth (Antip, 1977; Davey & Cleland, 1982; Davey, Oakley & Cleland, 1981; Davey, Phillips & Cleland, 1981). Rats will also engage in predatory behaviors such as pouncing and biting directed toward a rolling ball-bearing that is paired with food, and approach and engage in social behaviors such as anogenital sniffing when a live restrained rat is paired with food. However, a rat will not approach a block of wood that serves as a CS (Timberlake, 1983; Timberlake & Grant, 1975; Timberlake, Wahl, & King, 1982).

Timberlake (1983) hypothesized that the basis for CS-elicited behavior evolved because it increased an animal's efficiency in interacting with biologically significant stimuli (see Hollis, 1982 for a similar argument). Conditioning occurs when the appropriate behavior system is activated (e.g., feeding) and the stimuli predicting the biologically relevant stimuli resemble those stimuli that ordinarily predict and elicit that behavior system in the natural environment. The resemblance between the CS in the lab environment and the CS in the natural environment is based on both physical and temporal characteristics. Thus, presenting a rat with a moving object that predicts the imminent delivery of food increases predatory behavior, whereas presenting a moving object temporally separate from food is less effective (Timberlake & Lucas, 1989).

Pigeons and the Sign-/Goal-Tracking Relation

Despite the abundant evidence regarding goal-tracking in rats, very little is known about goal-tracking in pigeons. In fact, only a few published studies have investigated goal-tracking in pigeons, perhaps because pigeons do not appear to goal-track in the typical autoshaping/sign-tracking situation in which the CS and the US are spatially and temporally

contiguous (Boakes, 1979). Unlike rats, pigeons sign-track throughout the CS presentation during autoshaping. This result may be partly due to the fact that in the standard experimental chamber, the differentiation between sign-tracking and goal-tracking may be difficult to assess because of the close physical proximity between the CS and the feeder. When the CS and the US are located close to each other, sign- and goal-tracking are similar forms of behavior so that differentiation between the two is difficult (Hearst, 1979; Van Hest, van Haaren, Kopp, & van der Schoot, 1986). Thus, in order to investigate sign- and goal-tracking in pigeons, researchers altered the typical autoshaping experimental preparation (e.g., Boakes, 1977, 1979; Hearst & Jenkins, 1974).

One way to alter the typical autoshaping preparation is to spatially separate the CS from the US. One method of spatial separation is to use a long experimental chamber (commonly referred to as "long-box" experiments). The first of the long-box experiments was conducted by Jenkins (reported in Hearst & Jenkins, 1974). The long-box consisted of a relatively long and narrow experimental chamber where a 5-s CS (illuminated response key) was presented 91 cm from a 4-s US (food). Jenkins demonstrated that pigeons will approach a distant CS provided that the CS is a reliable predictor of food. Approaches to the CS were impressive because they persisted even though such behavior sometimes prevented the pigeons from obtaining any food due to the distance they had to travel (Hearst & Jenkins, 1974).

Boakes (1977) conducted a similar experiment but reported slightly different results. Although some of Boakes' pigeons behaved like those in Jenkins' research, others "would wait, apparently paralyzed by indecision, halfway between the signal and the food aperture." (p. 85) Some pigeons did eventually approach the CS, but only after considerable training, and under non-standard houselight conditions (no further details were given). Boakes reported that there appear to be critical procedural variables such as the intensity of the house light, saliency of the cues associated with the food hopper, type of CS, distance of the CS from the US, and the saliency of the US that influence whether sign- or goal-tracking occurs. Grastyan and Vereczkei (1974) observed similar oscillations between the CS and the US in cats exposed to a sign-tracking procedure where the CS was spatially separated from the feeder.

Using a CS that was located 60 cm from the US, Van Hest et al. (1986) examined sign- vs. goal-tracking in pigeons. Their research showed that pigeons sign-tracked more when the CS paired with food was illuminated for 6 s relative to the amount of sign-tracking observed when the CS was illuminated for 20 s or 40 s. Goal-tracking was unaffected by altering the duration of the CS.

Silva, Silva, and Pear (in press) attempted to further define the experimental conditions under which pigeons would sign- and/or goal-track. Their study exposed three pigeons to various distances between a light CS and the location of a food US. Their results showed that whether a pigeon sign- or goal-tracked depended on the distance between the CS and the US. Using an experimental preparation with a 60-s variable length ITI, an 8-s CS, and a 3-s US, Silva et al.'s pigeons (a) sign-tracked for the duration of the CS when it was located close to the US (CS-US distance = 22 cm), (b) approached the CS at the beginning of the CS presentation and then moved toward the feeder during the latter part of the CS presentation when it was located at intermediate distances from the US (CS-US distance = 26 cm, 29 cm, and 42 cm), and (c) goal-tracked for the duration of the CS when it was located far from the US (CS-US distance = 60 cm).

The Silva et al. (in press) study obtained goal-tracking at a relatively large CS-US distance whereas van Hest et al. (1986) obtained sign-tracking at a comparable CS-US distance. One important difference between Silva et al.'s procedure and van Hest et al.'s procedure was that the pigeons in van Hest et al.'s study had 15 s to intersect a photobeam close to the feeder that would then result in 4-s access to food; thus, approaching the CS when it was far from the feeder resulted in no loss of food. No such procedure to prevent food loss due to travel time was used by Silva et al.. Although Boakes' (1977) description of his study is brief, it appears that he did not use any procedure to prevent food loss, which could account for the similarity between his finding of goal-tracking at a large CS-US distance and that of Silva et al.'s (in press). This explanation, however, does not seem to account for why Jenkins (described in Hearst and Jenkins, 1974) obtained sign-tracking at an even larger CS-US distance than the one that produced goal-tracking in Boakes' (1977) and Silva et al.'s (in press) studies. Jenkins' study, like Boakes' and Silva et al.'s, did not contain any procedure to prevent food loss due to travel time. As stated above, Jenkins reported that his pigeons continued to sign-track even though they consequently sometimes failed to obtain some or all of the food when it was available. There are a number of other non-specified procedural differences that could account for the differences between the findings of Jenkins and van Hest et al. on the one hand and those of Boakes and Silva et al. on the other, including intensity of the background illumination, saliency of the cues associated with the feeder, duration of the food interval, characteristics of the CS, and shape of the experimental chamber. Unfortunately, little is known at present about the effects of these variables on sign- vs. goal-tracking.

Effects of Partial Reinforcement on Sign- and Goal-Tracking

One variable whose effect on sign- and goal-tracking is better understood is partial reinforcement (PRF). During PRF, not every presentation of the CS is followed by the US. An often cited study was conducted by Gonzalez (1974) who exposed three pigeons to 100%, 50%, 25%, and 12.5% CS-US pairings. Gonzalez's results showed that the keypeck rate increased at 50%, and then decreased slightly as the percentage of CS-US pairings decreased. At least one keypeck occurred in the presence of all CSs during 100% and during 50% CS-US pairings; however, this dependent measure slightly decreased during 25% pairings, and then sharply decreased during 12.5% pairings. Latency to keypeck following CS onset was twice as long for two of the three birds when the percentage of pairings changed from the 100% to 50% CS-US pairings. These latencies further increased for all birds during the 25% and the 12.5% conditions (see Gamzu & Williams, 1971; Perkins et al., 1975; Schwartz & Williams, 1972 for similar results).

Gibbon, Farrell, Locurto, Duncan, and Terrace (1980) exposed five groups of pigeons to 100%, 75%, 50%, 33%, and 10% CS-US pairings. These researchers found that when the rate of acquisition was assessed in terms of the number of USs delivered before reaching asymptotic responding, little or no significant effect across percentages of CS-US pairings was evident. Furthermore, over the course of maintained training, the lower percentages were correlated with higher rates of pecking the CS.

Rather than using the autoshaped keypeck as the dependent measure, Boakes (1979) conducted an experiment to determine the effects of PRF on approach to a light-CS (i.e., sign-tracking) and approach to the feeder (i.e., goal-tracking) in pigeons. One group of pigeons was exposed to 100% CS-US pairings and another group was exposed to 50% CS-US pairings. The CS and the feeder were separated by 60 cm. Sign- and goal-tracking were measured as the proportion of time on a platform in front of the CS and in front of the feeder relative to the time on these platforms during the ITI. Boakes' data showed that the pigeons goal-tracked more during 100% pairings than during 50% pairings, but showed little difference in the amount of sign-tracking between the two conditions.

The effects of PRF on sign- and goal-tracking in rats has also been investigated (e.g., Holland, 1979; Davey & Cleland, 1982). Davey and Cleland (1982) exposed one group of rats to 100% CS-US pairings and another group to 50% CS-US pairings and discovered that PRF produced higher rates of sign-tracking than did 100% CS-US pairings. Conversely, 100% CS-US pairings produced higher rates of goal-tracking than did 50% CS-US pairings.

Another PRF procedure whose effects on sign-tracking are fairly well understood is an omission procedure. During an omission procedure, responding to the CS (e.g., pecking or approaching an illuminated response key) results in the US being withheld at the end of the CS presentation. An examination of omission contingencies is relevant to any examination of PRF because omission of a US following the CS is, by definition, an instance of PRF.

Holland (1979) exposed rats to an omission contingency for sign-tracking where food was cancelled if the rat reared toward the CS (i.e., sign-tracked). These rats continued to sign-track despite the omission contingency that resulted in the cancellation of approximately half of the USs; although, these rats did sign-track less than a control group that was equated in every respect to the omission group except that the rats in the control group were not responsible for the sequencing of events in their experimental chambers. Observations of experimental sessions indicated that sign-tracking occurred during the early portion of the CS presentation and goal-tracking occurred during the later portion of the CS presentation for both the omission and the control groups (see Davey, Oakley, & Cleland, 1981 for a similar result).

Peden, Browne, and Hearst (1977) conducted an experiment to determine the effect of PRF and an omission procedure on sign-tracking in pigeons when the CS and the US were separated by 60 cm. One group of pigeons was exposed to the omission contingency where movement between 18 and 34 cm from the CS resulted in cancellation of the food. Another group of pigeons, equated in every respect to the omission group except that they were not responsible for the sequencing of events in their experimental chambers, served as a control group. Peden et al.'s data showed that the omission group approached the CS on 58% of the trials, whereas the control group approached the CS on 93% of the trials.

Some studies have attempted to characterize some of the behavioral changes that occur during omission contingencies when rats are experimental subjects. Davey et al. (1981), in addition to measuring the frequency of pressing the lever-CS, also examined the effect of an omission contingency on the topography (i.e., physical characteristics) of the pressing response and on approaches to the feeder. Davey et al. showed that the omission contingency reduced lever presses that resulted in loss of food, but produced subtle changes that permitted touching the CS to occur without loss of food. The frequency of lever touches and the rate of approaches to the feeder was unaffected by the omission contingency. Similar changes in pigeons' response topographies have been observed during omission training. Barrera (1974) and Eldridge and Pear (1987) noted that pigeons continue to approach the CS during omission training, but redirect pecking to different

areas in the chamber near the CS. Although many keypecks were redirected, some still contacted the CS resulting in cancellation of the US.

Measuring Sign- and Goal-Tracking

Sign-tracking has typically been monitored using discrete measures or crude nearly continuous measures. One method is to project photobeams across various areas of the chamber and record an instance of sign-tracking when the subject intersects the beam closest to the CS (Cleland & Davey, 1983).

Another method involves visual observation. This procedure requires observers to monitor the subject during an experimental session and record instances and topography of sign-tracking according to an operational definition (Davey et al., 1981).

Automated measures such as dividing the chamber floor into sections of platforms that have pressure-activated microswitches that record the position of the subject in the chamber have also been used (Boakes, 1979; Holland, 1977; Matthews & Lerer, 1987; van Hest et al., 1986). A related method uses an experimental chamber that has a floor that tilts (like a see-saw) and closes a microswitch depending on what half of the chamber the subject is standing. Tilting the floor toward the CS is used as the index of sign-tracking (Hearst & Franklin, 1977; Wasserman et al., 1974).

Goal-tracking has been measured using a food hopper with a door whose activation upon entry by a subject closes a microswitch (Davey & Cleland, 1982; Davey & Cleland, 1984; Davey et al., 1981). It is also possible to measure goal-tracking using a photobeam. This method records an instance of goal-tracking when a head-poke into the feeder interrupts a photobeam (Farwell & Ayres, 1979), or an infrared light (van Haaren et al., 1987). van Hest et al. (1986) and Boakes (1979) measured goal-tracking by recording the amount of time pigeons spent on a thin metal platform in front of the CS, a similar platform in front of the feeder, and a platform in the center of the experimental chamber.

The most continuous measure of sign-tracking was used by Eldridge and Pear (1987) and later by Silva et al. (in press). These researchers used a computer-controlled tracking system that continuously recorded the four-dimensional (Cartesian coordinates and time) position of a pigeon's head as it moved about an experimental chamber during various autoshaping and sign-tracking preparations. Tracking was done by a video-acquisition module that analyzed the signals from two black-and-white video cameras observing the target. The system tracks the highest dark region in the experimental space, which is the top of a pigeon's darkened head.

The two experiments in the present study used the same apparatus used by Silva et al.

(in press) to investigate the changes in sign- and goal-tracking during an experimental preparation in which the CS and the US were separated by 60 cm. The tracking system offered an advantage over previous studies that measured sign- and goal-tracking because it provided a nearly continuous record of the subject's movement patterns during experimental sessions. Furthermore, the graphical display of these data provided information about the sign- and goal-tracking behaviors that was not evident from more discrete dependent measures (see Silva et al., in press).

Experiment 1 examined the effect of PRF on sign- and goal-tracking when pigeons served as subjects. Experiment 2 examined the effect of moving the CS to a new location during PRF on sign- and goal-tracking.

Experiment 1

Studies that used rats as subjects have shown that PRF (specifically 50% CS-US pairings) produces higher levels of sign-tracking than does continuous reinforcement (CRF; 100% CS-US pairings), whereas CRF produces higher rates of goal-tracking (Davey & Cleland, 1982). In general, studies that used pigeons as subjects have found that 50% CS-US pairings produces higher rates of autoshaped keypecking than the keypecking rates during 100% CS-US pairings (Gonzalez, 1974). Studies that evaluated the effect of PRF on sign- and goal-tracking have shown that 50% CS-US pairings produces lower levels of goal-tracking than 100% CS-US pairings, but has little effect on sign-tracking (Boakes, 1979).

As discussed above, sign- and goal-tracking in pigeons are difficult to assess in the typical autoshaping arrangement because of the close proximity of the CS to the site of the US (Boakes, 1979; van Hest et al., 1986). Given that an experimental situation can be created that will engender goal-tracking in the pigeon (e.g., Silva et al., in press), Experiment 1 examined the effects of PRF on sign- and goal-tracking when pigeons are used as the experimental subjects. A within-subject design was used to record and analyze movement patterns during signalled response-independent food presentations when the CS was located 60 cm from the feeder. Three pigeons were exposed to 100% CS-US pairings, followed by exposure to 50%, 25%, and to 10% pairings, and a reversal back to 100% CS-US pairings. Subjects were exposed to three sessions of random CS-US pairings to assess any effects of presenting a stimulus and food on the subjects' behavior prior to conditioning. The number of sessions each bird received in each phase is shown in Table 1.

As discussed above, Davey and Cleland (1982) and Davey et al. (1981) found that

Table 1

Number of Sessions in Each Phase

Phase	Bird 1	Bird 2	Bird 3
Random	3	3	3
100%	11	12	15
50%	11	11	14
25%	12	10	11
10%	14	11	10
100%	16	11	13

PRF increases sign-tracking and decreases goal-tracking in rats. Boakes (1979) found PRF has little effect on sign-tracking, but decreases goal-tracking in pigeons. These conclusions are based upon comparing 100% to 50% CS-US pairings. It has been demonstrated that pigeons show increments in autoshaped responding during 50% pairings, but decrements during lower percentages (e.g., Gonzalez, 1974; Perkins et al., 1975); therefore, Boakes' and Davey and Cleland's conclusions may be applicable to 50% pairings only and not to lower percentages of PRF. Furthermore, neither study collected any topographical data that may have provided some information about the behavior that led to the change in their discrete dependent variables. Thus, the present experiment examined the relative movement toward the CS and the feeder during 25% and 10% CS-US pairings as well as during 100% and 50% pairings. Furthermore, the present study also provided topographical data by examining plots of the pigeon's movement patterns during pre-selected CS presentations (see Silva et al., in press).

It was hypothesized that the pigeons would approach the feeder during the presentation of the CS during 100% CS-US pairings more than they would approach the CS. There would then be an increase in the amount of approach to the CS during 50% pairings, followed by decreases in approach during 25% and 10% pairings. Finally, the birds would approach the feeder even more during the reversal to the 100% condition than they had during the initial 100% condition.

Method

Subjects

Three adult, male, experimentally naive, White King pigeons (*Columbia livia*), approximately 1-yr old obtained from a local supplier served as subjects. When not in an experimental session, the birds were housed in individual cages in a colony room regulated by a 13-hr on/11-hr off light-dark cycle. The pigeons' diet consisted of commercially available poultry food. Water was available at all times in their home cages and grit was provided with the food.

Apparatus

The experimental chamber and the programming and recording equipment were located in separate rooms. The experimental room containing the chamber was illuminated by four banks of fluorescent lights in open light fixtures on the ceiling. The lights were wired through a relay that was controlled by the programming equipment, ensuring that the

room lights were on during an experimental session and off when the session concluded. A register in the ceiling ventilated the room. A speaker in the room provided 82 dB white noise as a masking stimulus.

A metal frame painted white supported the top and sides of the experimental chamber, the inside dimensions of which were 57 x 57 x 38 cm. An aluminum panel and two pieces of white opaque Plexiglas, each of which were attached to one side of the panel, formed the front wall of the chamber. The left adjacent wall consisted of white opaque Plexiglas, while the other two walls consisted of clear glass. The top of the chamber consisted of two pieces of clear Plexiglas, attached by hinges to facilitate opening the chamber. The bottom of the chamber consisted of an aluminum mesh floor fitted into a stainless steel drop pan. Air spaces in the top and bottom of the chamber provided ventilation to the chamber. The room lights illuminated the chamber through the top and two clear glass sides.

The feeder aperture was mounted on the aluminum panel of the front wall, 13.5 cm from the floor and equidistant from the side walls. Three plastic response keys, also mounted on the front wall were nonfunctional and covered with white paper so that they were not visible to the birds. The CS consisted of a 4-cm diameter red light that was projected from behind the white Plexiglas of the left side wall by a 100-w General Electric flood lamp. A 4-cm diameter blue light projected to the immediate right of the CS in the same manner served as the ITS.. The center of the ITS was located 4 cm to the right of the center of the CS. The CS and the ITS could not be presented at the same location because each was projected from a different lamp. The center of the CS and the center of the ITS were located 25 cm above the mesh floor of the chamber, and 60 cm from the feeder aperture (CS and ITS on the left wall, 51 cm from the left front corner). The feeder aperture was illuminated continuously by two SL-313 bulbs in series with a 33-ohm resistor. During food presentations, which consisted of a 3-s access to the food hopper filled with the same food used in the home cages, the brightness of the feeder light was intensified by the isolation of the resistor from the circuit.

The experimental room also contained two perpendicularly oriented T.V. cameras directed towards the two clear glass walls of the chamber. The cameras were connected to an electronic video-acquisition module that computed the position of the highest dark region viewed by the cameras. The highest dark region was typically the pigeon's head. One horizontal coordinate (x) was computed on one camera, and the other horizontal and the vertical coordinates (yz) were computed on the other. These computations were made 30 times per s. The chamber was turned at an angle of 10° to the cameras to avoid interference of the tracking system by the metal joints connecting the glass walls. This

resulted in several 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 that collected data, averaged these values in groups of three (yielding 10 data points per s), stored the data on magnetic disks for later graphing and analysis, and controlled the experiment. A Panasonic Dot Matrix printer, controlled by the computer, was used to plot the data. A block diagram of the apparatus reproduced from Pear and Eldridge (1984) is shown in Figure 1.

Procedure

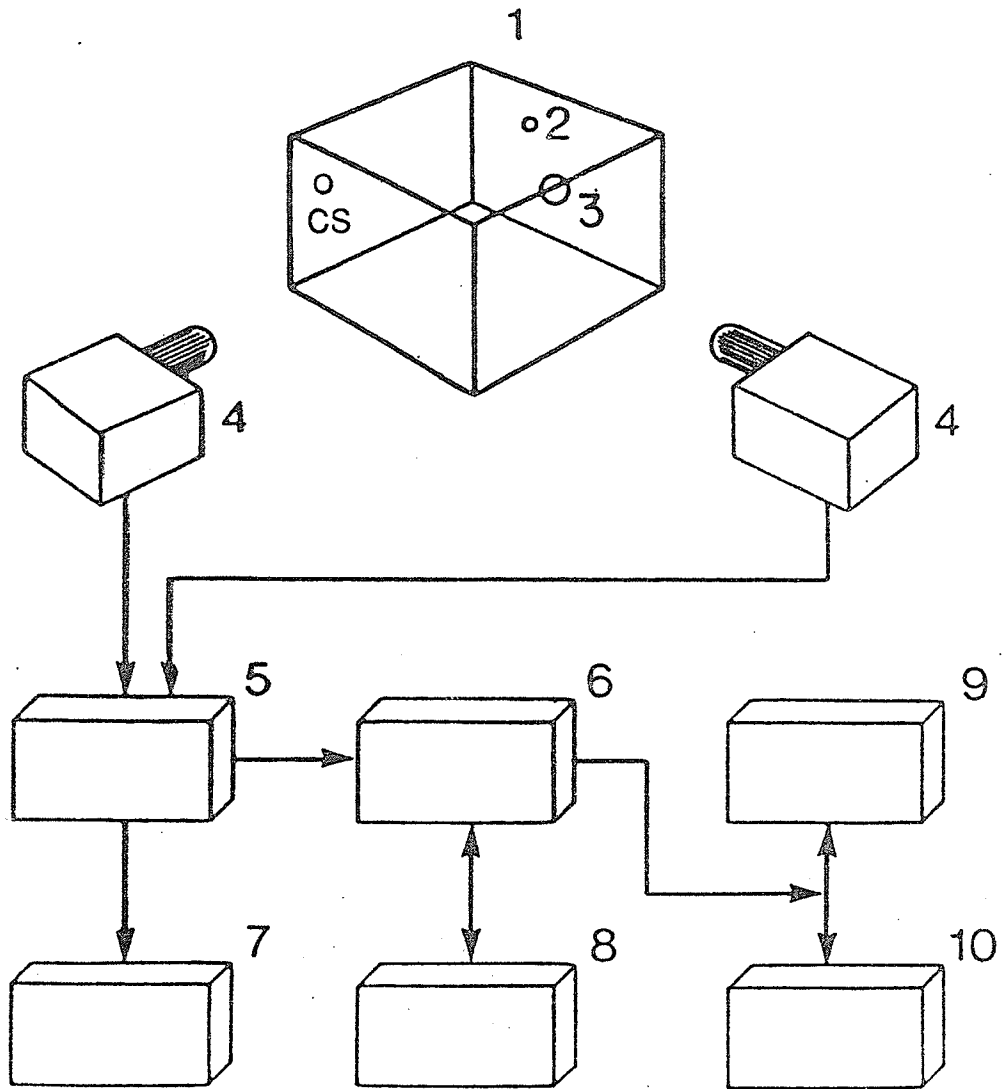
General experimental procedures. Experimental sessions were conducted at the same time daily, five days per week. Each session was terminated after 25 CS presentations or 1800 s, whichever occurred first. The birds were fed following each session an amount necessary to maintain their weights at approximately 80% of their free-feeding weights.

Experimental design. Each bird was exposed to the following sequence of conditions: (a) baseline condition, (b) random CS-US pairings, (c) 100% CS-US pairings, (d) 50% CS-US pairings, (e) 25% CS-US pairings, (f) 10% CS-US pairings, and (g) 100% CS-US pairings.

Preliminary training. The birds were trained to approach and eat from the food hopper prior to the baseline condition. During this training the birds were placed in the experimental chamber with the food hopper raised and the feeder aperture illuminated. Once the subject approached the raised hopper and consumed the food for approximately 15 s, the hopper was repeatedly raised at random intervals that got progressively longer until they were about 60 s in length. Food was presented independent of the bird's behavior. This continued until each bird approached and consumed the food within approximately 3 s for 20 consecutive trials. The feeder light was illuminated only when the hopper was raised.

Baseline. The birds were exposed to three sessions in which the blue ITS was continuously illuminated and there was no feeder presentations. Each session was terminated after 1800 s. The purpose of the baseline condition was to assess any tendency to approach or withdraw from an explicit stimulus.

Figure 1. A diagram of the Behavioral Tracking System. Two video cameras were connected to a video-acquisition module that computed the spatial coordinates (x, y, z) of a hypothetical dark point on a pigeon's head as the bird engaged in keypecking and other activities in an experimental chamber. The bird's head was painted black to ensure adequate tracking. The coordinates were obtained 30 times per second. The resulting data were averaged in groups of three and stored on diskettes for later use.



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

Random CS-US presentations. The birds were exposed to three sessions in which the CS, ITS, and the US were randomly presented independently of one another. Each session terminated after 1800 s. The CS and the ITS were projected through the left wall of the experimental chamber. The CS was presented for a fixed period of 8 s. The ITI averaged 60 s and ranged from 30 s to 90 s. Food was presented for 3 s. The lengths of the ITIs were determined by a pseudorandom probability generator. The purpose of this condition was to determine if the behavior during the CS in the subsequent 100% CS-US pairing condition was a result of the CS being paired with the US.

Fixed-trial signalled response-independent food presentations (100% CS-US pairings). All birds were exposed to fixed-trial signalled response-independent presentations of food in which the CS and the ITS were projected through the left wall of the experimental chamber. The CS was presented for a fixed period of 8 s, at the end of which it terminated and food was presented for 3 s. CSs were separated by ITIs averaging 60 s ranging from 30 s to 90 s (the length of the ITIs were determined in the same manner as during random CS-US presentations).

Partial reinforcement. Following exposure to the 100% condition of CS-US pairings, the reinforcement schedule was changed to 50%, then to 25%, and then to 10% CS-US pairings. The CS presentations and the ITI lengths during PRF were identical to those during the 100% condition except that the feeder presentations followed the CS 50%, 25%, and 10% of the time during the appropriate phases.

Dependent measures. The dependent measures were: (a) percentage of CSs with a movement ≤ 18 cm from the CS, (b) percentage of CSs with a movement ≤ 30 cm from the CS, (c) mean closest distance from the CS, (d) mean distance from the ITS at the end of the ITI, 0.1 s before the onset of the CS, (e) percentage of CSs with a movement ≤ 18 cm from the feeder, (f) percentage of CSs with a movement ≤ 30 cm from the feeder, (g) mean closest distance from the feeder during the CS presentation, (h) mean distance from the feeder at the end of the ITI, 0.1 s before the onset of the CS, (i) mean distance from the CS, (j) mean distance from the feeder during the CS presentation, (k) mean distance from the ITS, (l) mean distance from the feeder during the ITI, (m) percentage of CSs with a mean distance ≤ 18 cm from the CS, (n) percentage of CSs with a mean distance ≤ 18 cm from the feeder, (o) topview plots (i.e., in the xy or horizontal plane) of the movement patterns produced by the subject during the CS presentation, and (p) topview plots of the behavior patterns produced by the subject during the ITI. All distances were measured from the bird's head.

Operational definitions. One of the goals of the present research concerned the measurement of sign- and goal-tracking behavior; thus, sign- and goal-tracking were defined in several ways. Initially, an instance of sign-tracking occurred if the bird's mean distance from the CS was ≤ 18 cm, and an instance of goal-tracking occurred if the bird's mean distance from the feeder during the CS presentation was ≤ 18 cm. The criterion of 18 cm was based on that used by van Hest et al. (1986). This definition, however, did not detect the effect that the experimental manipulations had on the subjects' behavior. The definitions of sign- and goal-tracking were later redefined such that an instance of sign-tracking was any movement ≤ 18 cm from the CS, and an instance of goal-tracking was any movement ≤ 18 cm from the feeder during the CS presentation. Because only one subject showed an increase in sign-tracking according to this 18 cm criterion, the criterion was later relaxed such that an instance of sign-tracking was any movement ≤ 30 cm from the CS, and an instance of goal-tracking was any movement ≤ 30 cm from the feeder during the CS presentation. See the Discussion section for other reasons for changes in the criterion.

Data analysis. Measures (a) through (h) were calculated by taking the mean of these measures during the last three sessions of each phase. The last three sessions were used to obtain a stable measure of maintained responding. The standard error of these means was calculated. Measures (i) through (n) were graphed across sessions. Movement plots (measures [o] and [p] above) were computer-graphed from stored data. The movement plots are presented from time periods during the 5th, 12th, and 20th CS presentations as well as during the ITI before each of these CSs from the last session of each phase. This data presentation format was used in Silva et al.'s (in press) research.

The percentage of CS-US pairings was changed when the bird's average mean distance from the CS and from the feeder during CS presentations during the last three sessions of a phase was within 15% of the average mean distance from the CS and from the feeder during CS presentations during the previous five sessions of the phase. Furthermore, no general increasing or decreasing trend could be present over the last three sessions of a phase. Data analyses were done by visual inspection (Kazdin, 1982).

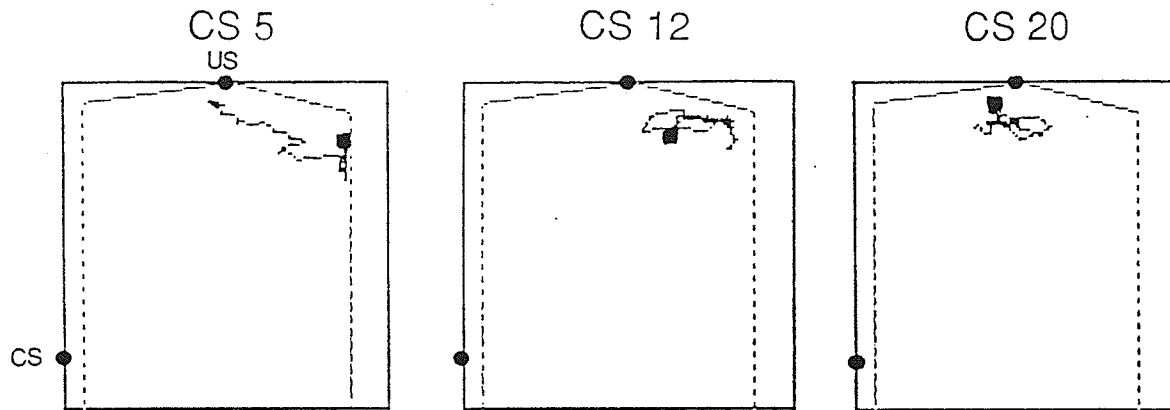
Results

Figures 2 and 3 present information regarding the specific movements of the birds during the CS and during the ITI during random CS-US pairings. Figure 2 shows the movements of each bird plotted as a path in the horizontal plane during the 5th, 12th, and 20th CS presentations of the last session of random CS-US pairings. A similar graphical presentation was used by Silva et al. (in press). The position of the bird at the

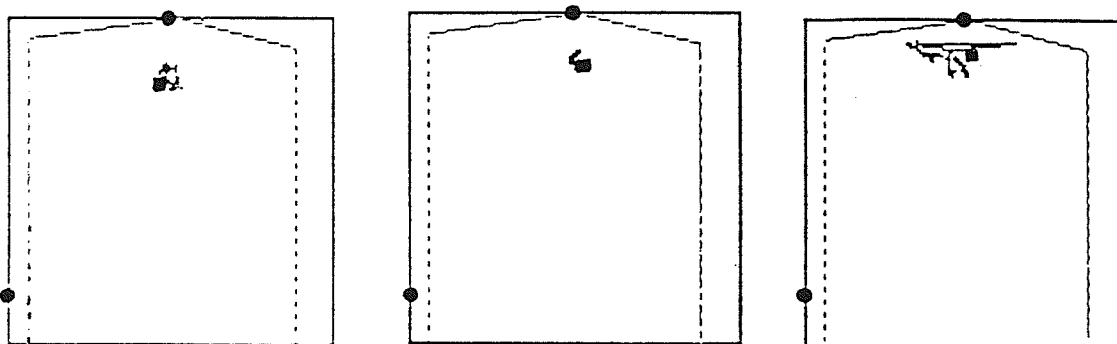
Figure 2. Paths followed by each bird during the 5th, 12th, and 20th CS presentations of the last session of random CS-US pairings in which the CS was located 60 cm from the feeder plotted from a top view perspective (i.e., the xy or horizontal plane). The position of the feeder is indicated by the dot at the top center of each plot. The position of the CS is indicated by the other dot on the lower left side of each plot. The dashed lines indicate regions of the chamber from which data could not be obtained for the technical reason explained in the Apparatus section. The black square in each plot indicates the position of the bird at the beginning of the CS presentation.

RANDOM CS-US PAIRINGS

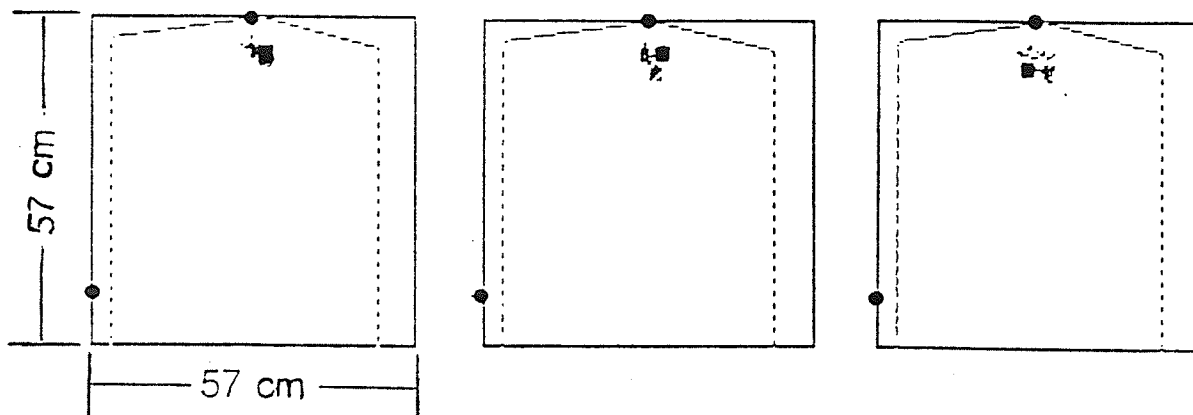
BIRD 1



BIRD 2



BIRD 3



beginning of each CS presentation is indicated by the black square in each plot. The dot at the top of each plot indicates the position of the feeder and the dot on the left side of the plot indicates the position of the CS. The dashed lines in the plot represent regions of the chamber that the bird could not be tracked by the video cameras due to the problem described above in the Apparatus section. The plots in Figure 2 show that Bird 1 generally moved between the right wall and the feeder and Birds 2 and 3 moved in front of the feeder.

Figure 3 shows the movements of each bird plotted as a path in the horizontal plane that occurred during the ITIs prior to the CSs shown in Figure 2. The general shape of the bird's movement patterns during the ITIs are similar to the shape of the movement patterns during the CSs in Figure 2. Note that the dots appear more dense during the ITIs than during the CSs because more data were collected during the ITI.

Figure 4 shows the movements of each bird plotted as a path in the horizontal plane during the 5th, 12th, and 20th CS presentations of the last session of 100% CS-US pairings and each PRF phase. In general, the movement patterns seen in the figure are representative of those that occurred during other CSs (except Bird 1, CS 5). The phases are presented in the order in which they occurred starting at the top of the figure, and the data are presented according to the format used in Figure 2.

During 100% CS-US pairings, all birds generally moved toward the feeder at the start of the CS presentation and remained near the feeder until food was delivered. During 50% and 25% CS-US pairings, all birds generally moved toward the CS at the onset of the CS presentation and then moved toward the feeder and remained there until food was delivered. During 10% CS-US pairings, the birds either remained relatively motionless (e.g., Bird 3) or made occasional movements toward the feeder (e.g., Bird 1, CS 12; Bird 2, CS 20). During 10% CS-US pairings, supplemental visual observation revealed that although the birds made little movement during the CS and during the ITI, they did approach and eat from the feeder when food was presented. During the reinstatement of the 100% condition, all birds resumed the movement patterns observed during the initial 100% condition (i.e., all birds primarily moved toward the feeder at the start of the CS presentation and remained near the feeder until food was delivered).

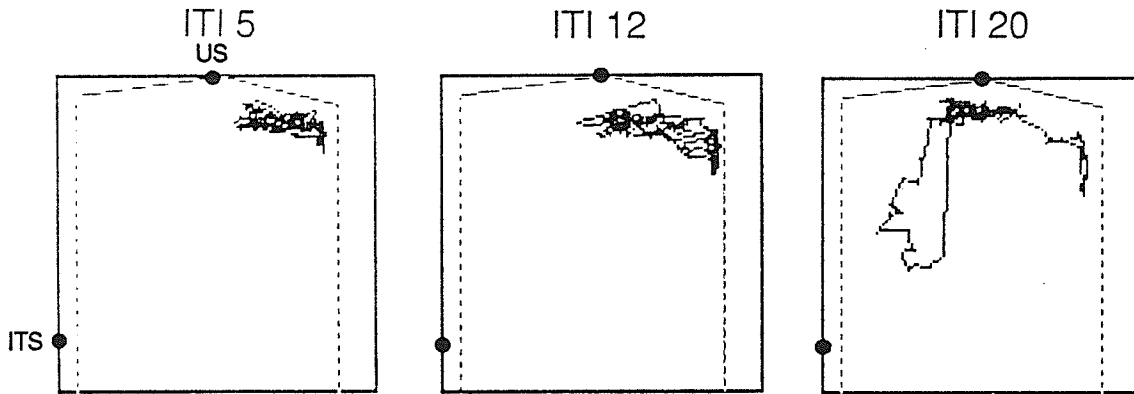
Independent judges supported this visual interpretation of the data (see Appendix A).

In order to preclude the possibility that the movements observed during the CS were simply extensions of the birds' patterns during the ITI, Figure 5 shows the movements of each bird plotted as a path in the horizontal plane that occurred during the ITIs prior to the

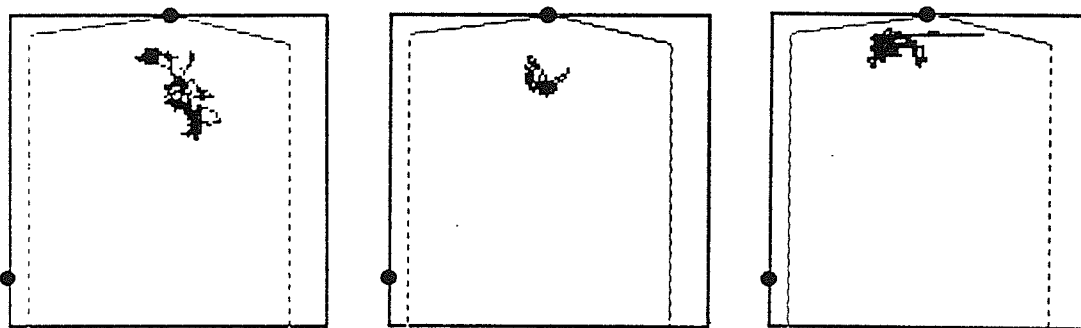
Figure 3. Paths followed by each bird during the ITIs prior to the CS presentations shown in Figure 2. The explanation of the plots is the same as for Figure 2, except that the dot on the lower left side of each plot indicates the position of the ITS.

RANDOM CS-US PAIRINGS

BIRD 1



BIRD 2



BIRD 3

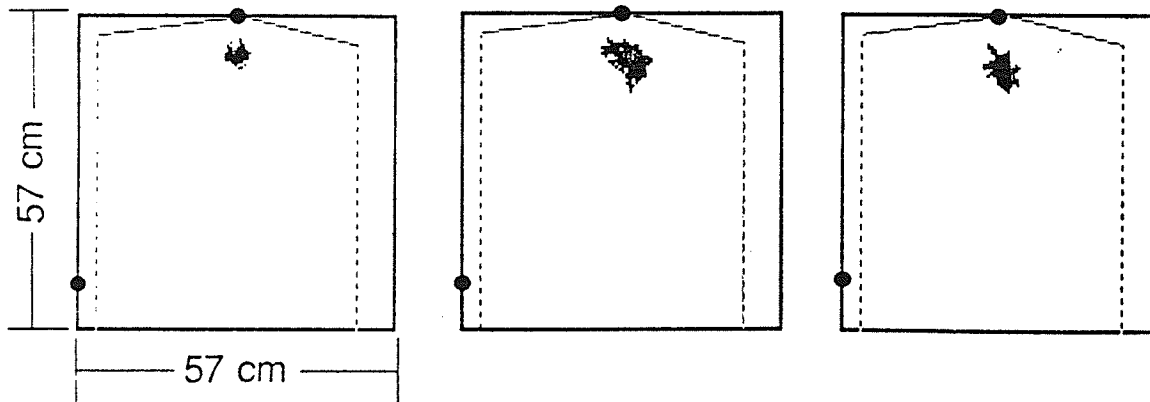


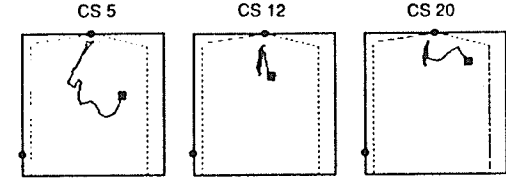
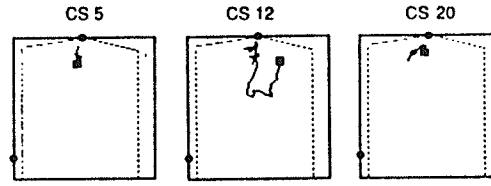
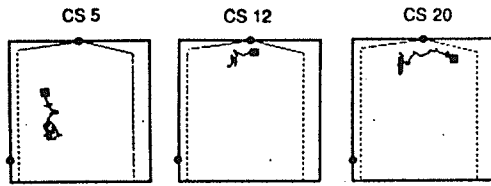
Figure 4. Paths followed by each bird during the 5th, 12th, and 20th CS presentations of the last session of 100%, 50%, 25%, 10%, and the reversal to 100% CS-US pairings in which the CS was located 60 cm from the feeder plotted from a top view perspective (i.e., the xy or horizontal plane). The phases are shown in the order in which they were presented starting at the top of the figure. The explanation of the plots is the same as for Figure 2.

BIRD 1

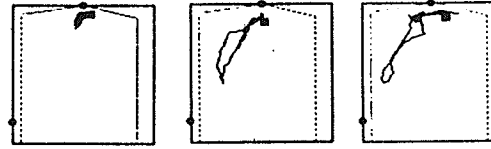
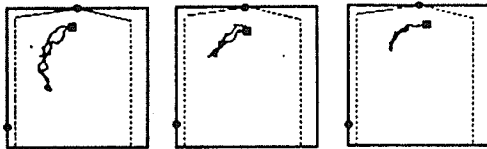
BIRD 2

BIRD 3

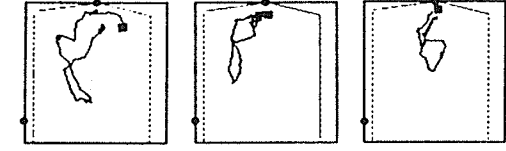
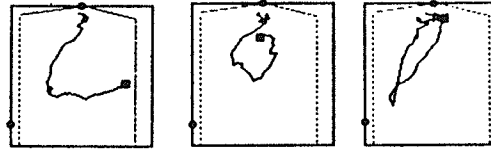
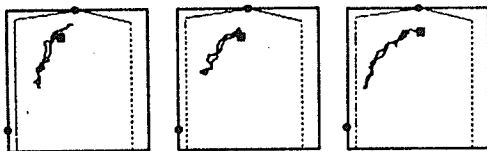
100% CS-US PAIRINGS



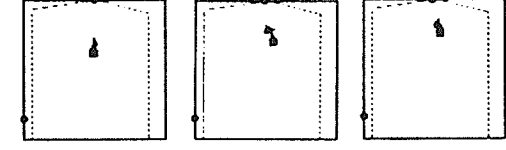
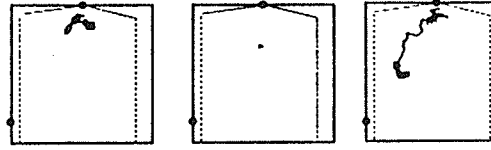
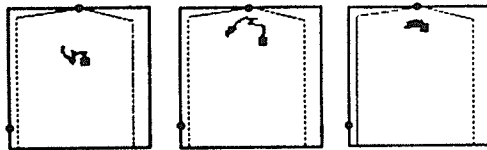
50% CS-US PAIRINGS



25% CS-US PAIRINGS



10% CS-US PAIRINGS



100% CS-US PAIRINGS (REVERSAL)

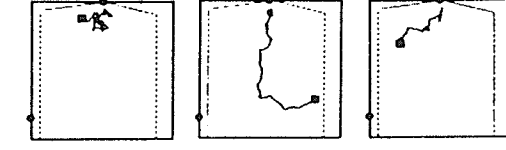
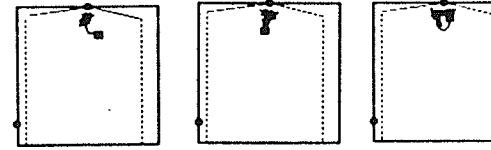
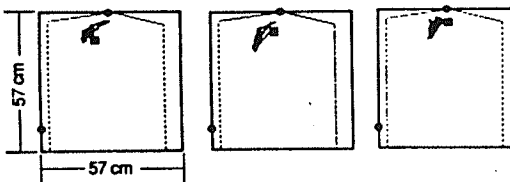


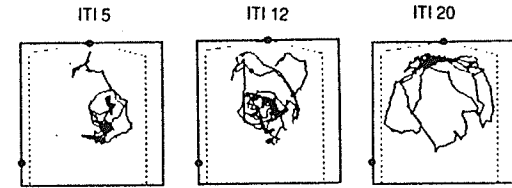
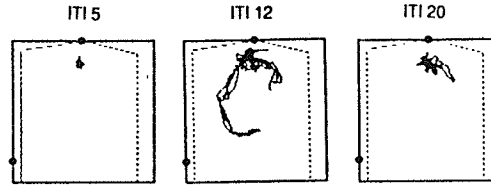
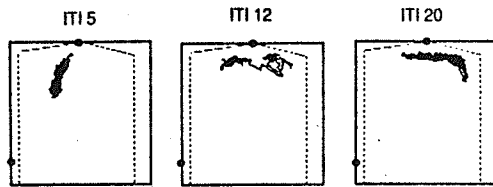
Figure 5. Paths followed by each bird during the ITIs prior to the CS presentations shown in Figure 4. The explanation of the plots is the same as for Figure 4, except that the dot on the lower left side of each plot indicates the position of the ITS.

BIRD 1

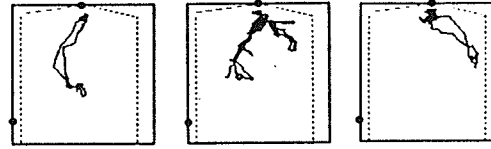
BIRD 2

BIRD 3

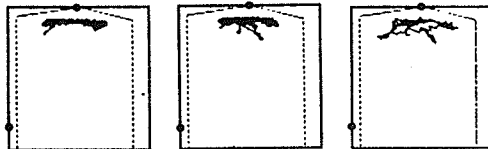
100% CS-US PAIRINGS



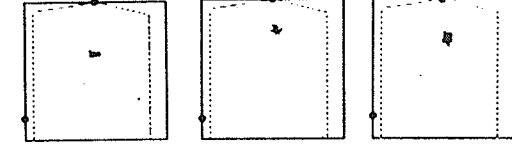
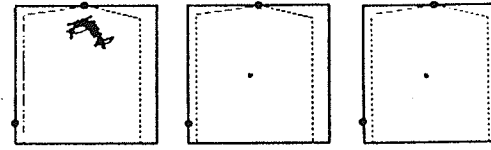
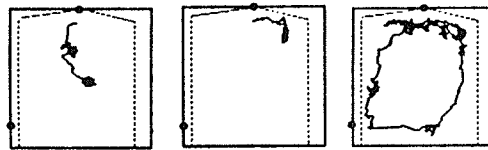
50% CS-US PAIRINGS



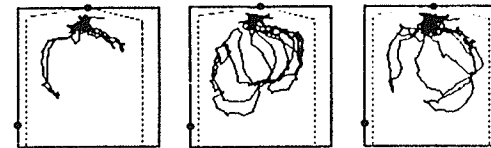
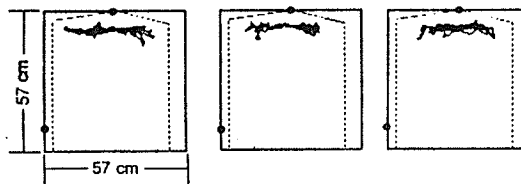
25% CS-US PAIRINGS



10% CS-US PAIRINGS



100% CS-US PAIRINGS (REVERSAL)

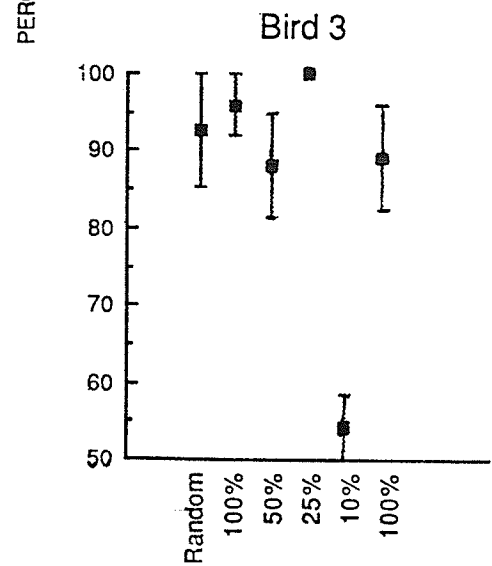
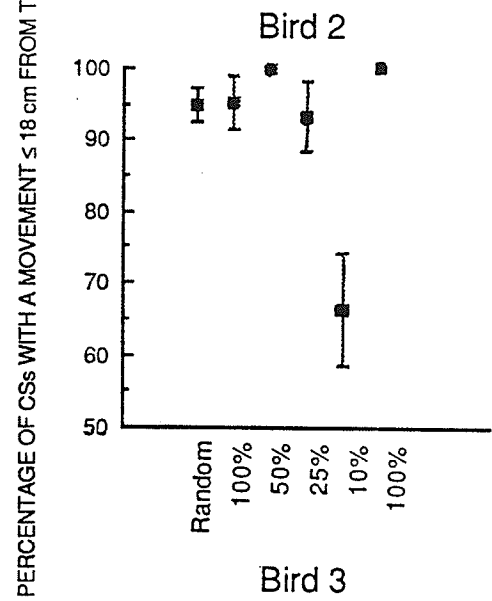
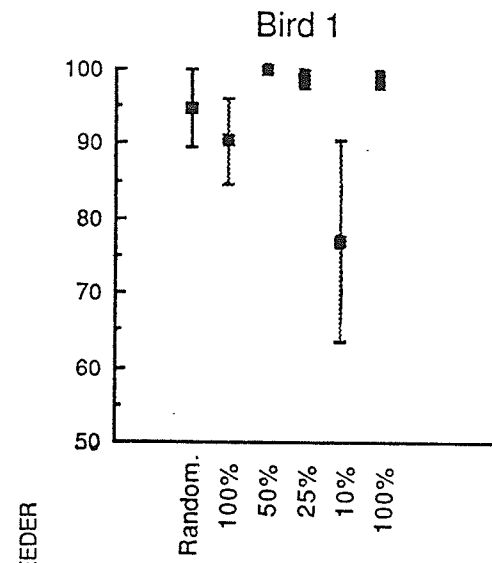
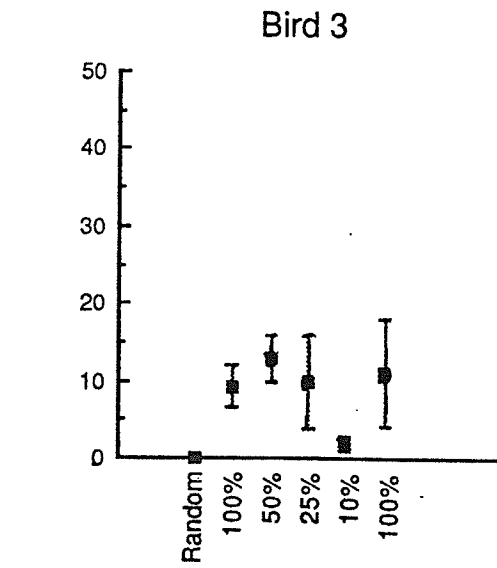
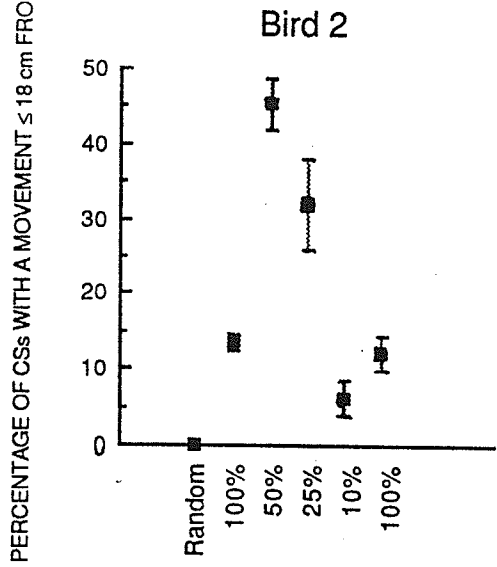
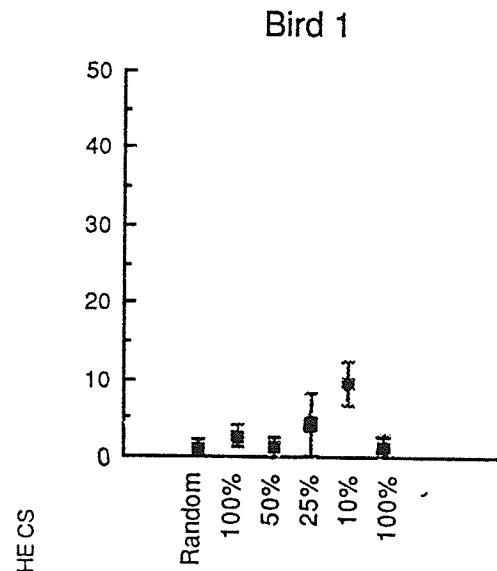


CSs shown in Figure 4. The movement patterns seen in Figure 5 are representative of those that occurred during other ITIs. Bird 1's patterns remained relatively unchanged during the experiment. This bird generally paced along the feeder wall. A notable exception is this bird's pattern during 10% CS-US pairings, in which it engaged in behavior farther from the feeder and was less active than in previous conditions. Bird 2's patterns changed across all percentages of CS-US pairings. During 100% CS-US pairings, this bird remained relatively close to the feeder. During 50% CS-US pairings, this bird engaged in behavior farther from the feeder, but also spent some time near the feeder. During 25% CS-US pairings, Bird 2 engaged in circular patterns that took it even farther from the feeder. During 10% CS-US pairings, Bird 2 remained relatively motionless. During the return to 100% CS-US pairings, this bird engaged in movement patterns that seemed to have components of the previous 100%, 50%, and 25% conditions. Bird 3's patterns also changed across all percentages of CS-US pairings. During 100% CS-US pairings, this bird engaged in behavior near the center of the chamber, but also spent some time in front of the feeder. During 50% CS-US pairings, this bird engaged in behavior in several areas of the chamber and continued to spend some time in front of the feeder. During 25% CS-US pairings, Bird 3 spent more time near the feeder. During 10% CS-US pairings, Bird 3 remained relatively motionless. During the return to 100% CS-US pairings, this bird engaged in movement patterns that seemed to have components of the previous 100%, 50%, and 25% conditions. Thus, it is difficult to ascertain from Figures 4 and 5 whether movements during the CS are extensions of the patterns during the ITI.

Figure 6 shows the percentage of CSs with a movement ≤ 18 cm from the CS (left graphs) and from the feeder (right graphs) averaged across the last three sessions of each experimental condition (i.e., this dependent measure measures the percentage of CSs with an instance of sign-tracking and goal-tracking, respectively). Examining the graphs on the left side of Figure 6, Bird 1 and 3's data show that there was generally no effect on the percentage of CSs with a movement ≤ 18 cm from the CS throughout the experiment, except for an increase at 10% CS-US pairings for Bird 1 relative to random, 100%, and 50% CS-US pairings, and an increase at 100% relative to random and a decrease at 10% CS-US pairings for Bird 3. Bird 2 showed increases at 100% and 50% CS-US pairings, followed by decreases at 25% and 10% pairings. Upon reinstatement of the 100% condition, all birds showed a return to levels comparable to those established during the initial 100% condition.

The graphs on the right side of Figure 6 show the percentage of CSs with a

Figure 6. Percentage of CSs with a movement ≤ 18 cm from the CS (left graphs) and from the feeder (right graphs) averaged across the last three sessions of each experimental condition. Each error bar represents the standard error of the mean of the last three sessions of each experimental condition.



movement ≤ 18 cm from the feeder averaged across the last three sessions of each experimental condition. In general, there were no consistent effects across birds throughout the experiment, except for a decrease at 10% CS-US pairings. For Bird 1, this decrease was different from the 50%, 25%, and the 100% reversal conditions, but not from the random or the initial 100% condition. Upon reinstatement of the 100% condition, Bird 1 showed a higher level than the one established during the initial 100% condition, and Birds 2 and 3 showed a return to the levels established during the initial 100% condition.

Figure 7 shows the percentage of CSs with a movement ≤ 30 cm from the CS (left graphs) and from the feeder (right graphs) averaged across the last three sessions of each experimental condition. This new criterion for sign- and goal-tracking was introduced to see if relaxing the distance criterion would result in consistent effects across birds. Examining the graphs on the left side of Figure 7, all birds showed an increase in the percentage of CSs with a movement ≤ 30 cm from the CS as the experimental conditions progressed from random to 100% to 50% CS-US pairings. Bird 1 showed a further increase at 25% followed by a decrease at 10% CS-US pairings. For Bird 2, there was a decrease at 25% and no additional changes at 10% CS-US pairings. For Bird 3, there was no additional changes at 25% and a decrease at 10% CS-US pairings. Upon reinstatement of the 100% condition, all birds showed a return to the levels established during the initial 100% condition. The graphs on the right side of Figure 7 show that there was no consistent effect across birds and across percentages of CS-US pairings when the percentage of CSs with a movement ≤ 30 cm from the feeder was measured.

Figure 8 shows the birds' mean closest distance from the CS (left graphs) and from the feeder during the CS presentation (right graphs) averaged across the last three sessions of each experimental condition. Examining the graphs on the left side of Figure 8, all birds showed decreases in their closest distance from the CS as the experimental conditions progressed from random to 100% to 50% CS-US pairings, no additional changes during 25% CS-US pairings, and an increase during 10% CS-US pairings. Upon reinstatement of the 100% condition, all birds showed a return to the levels established during the initial 100% condition.

The graphs on the right side of Figure 8 show the birds' closest distance from the feeder during the CS presentation calculated over the last three sessions of each experimental condition. In general, there were no consistent effects across birds throughout the experiment, except for an increase in the closest distance from the feeder

Figure 7. Percentage of CSs with a movement ≤ 30 cm from the CS (left graphs) and from the feeder (right graphs) averaged across the last three sessions of each experimental condition. Each error bar represents the standard error of the mean of the last three sessions of each experimental condition.

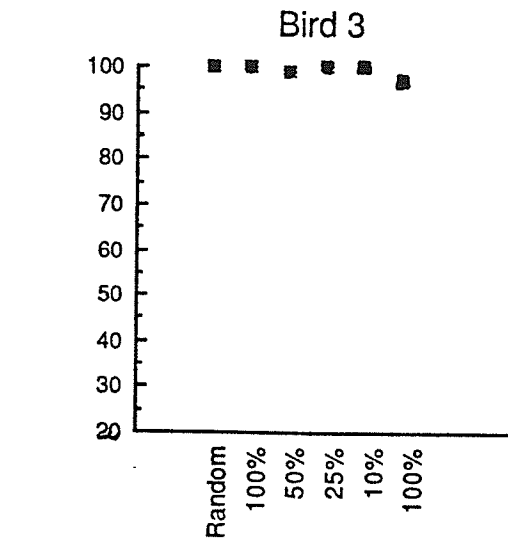
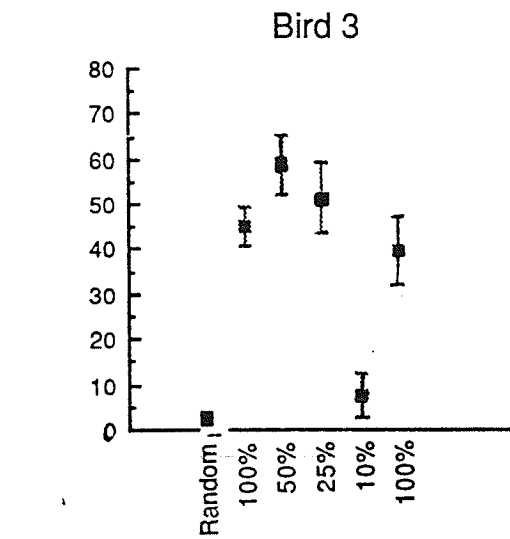
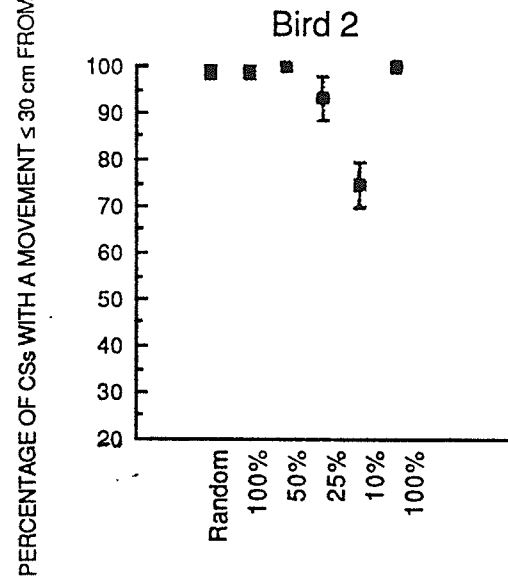
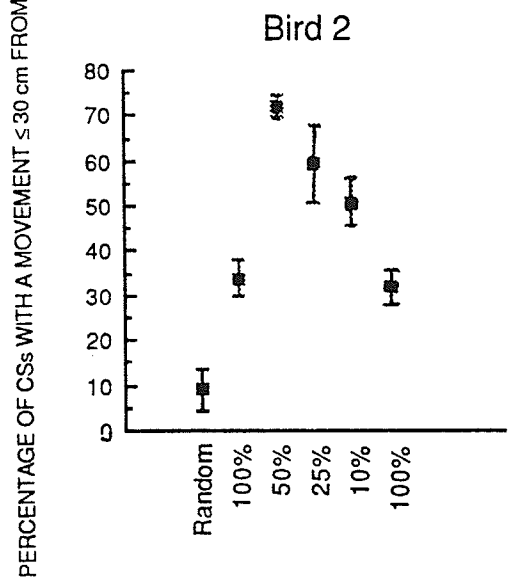
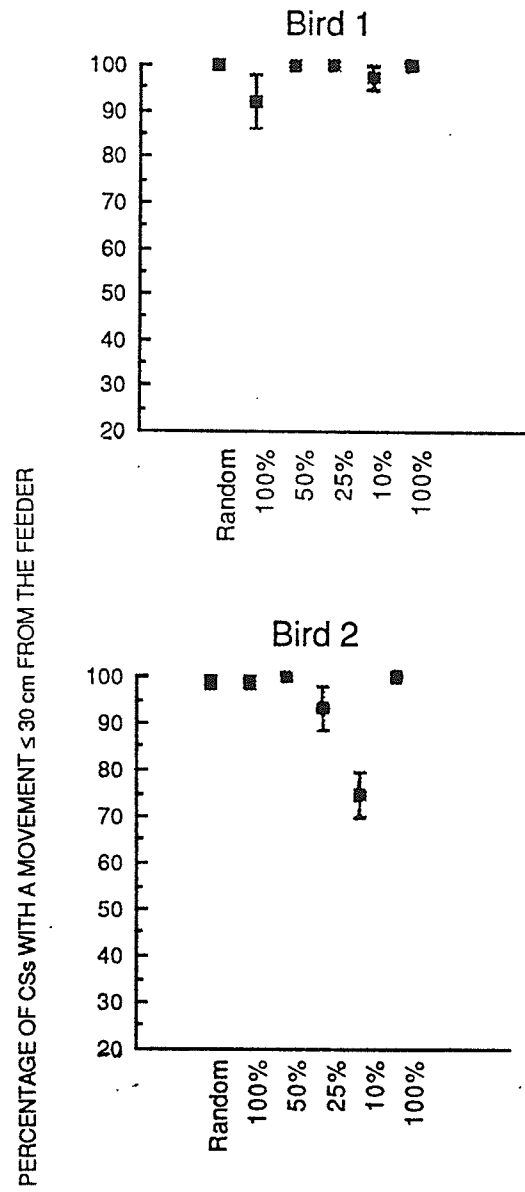
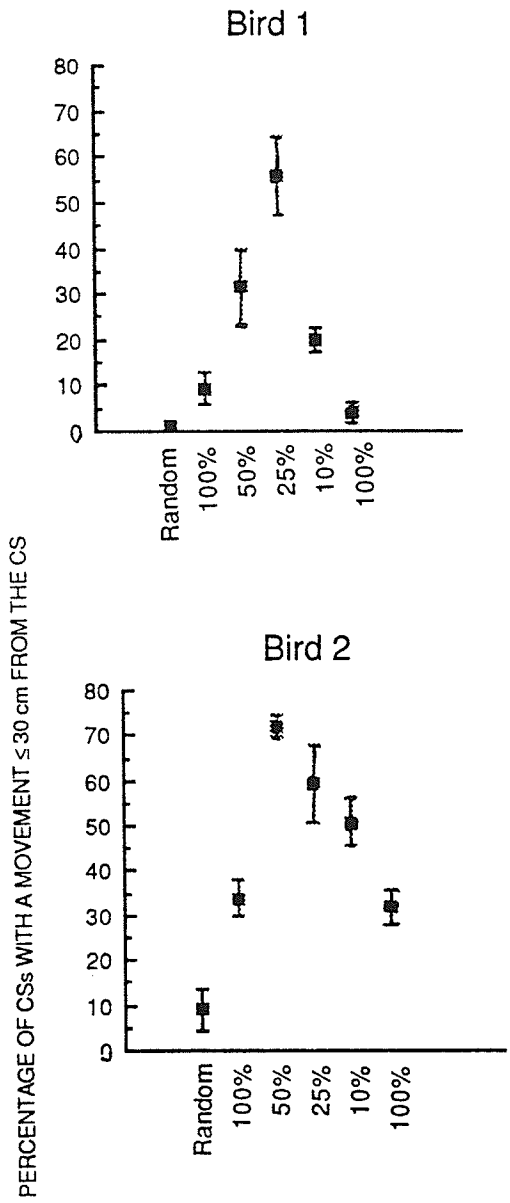
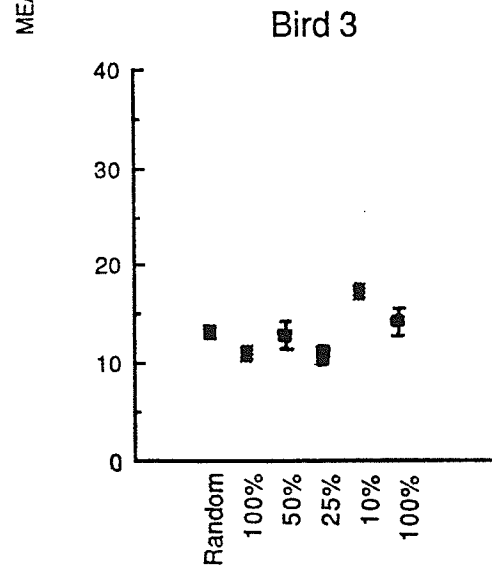
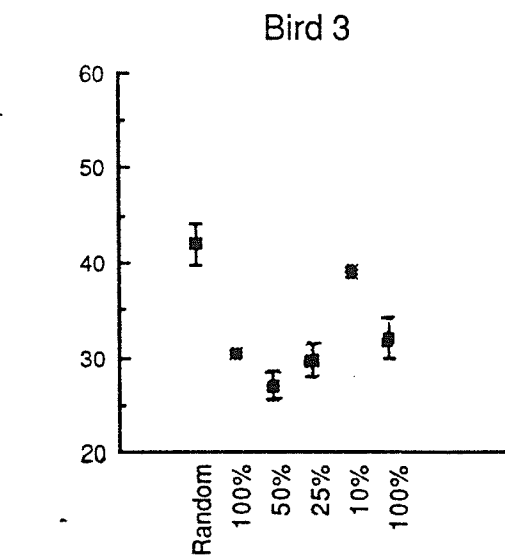
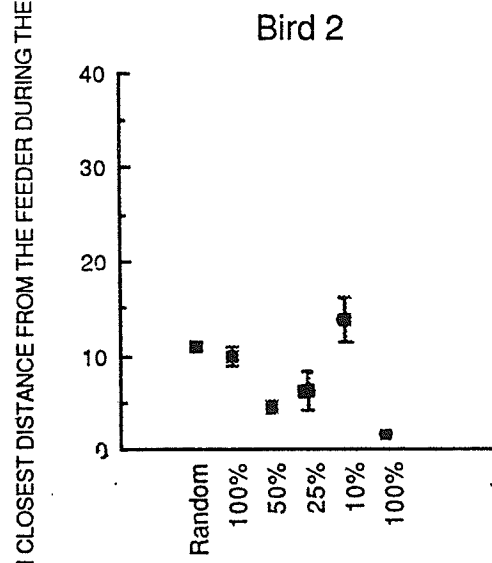
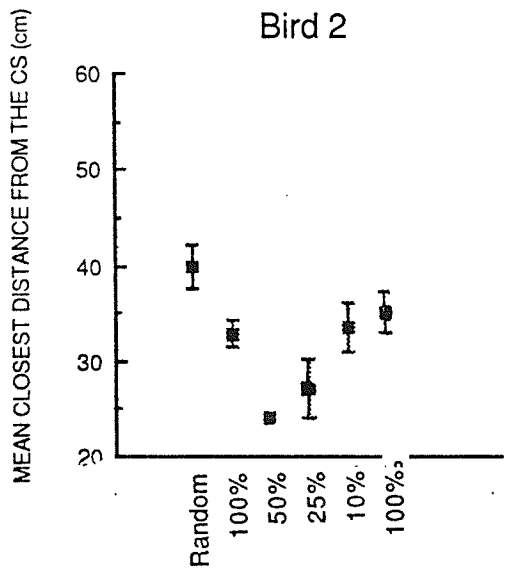
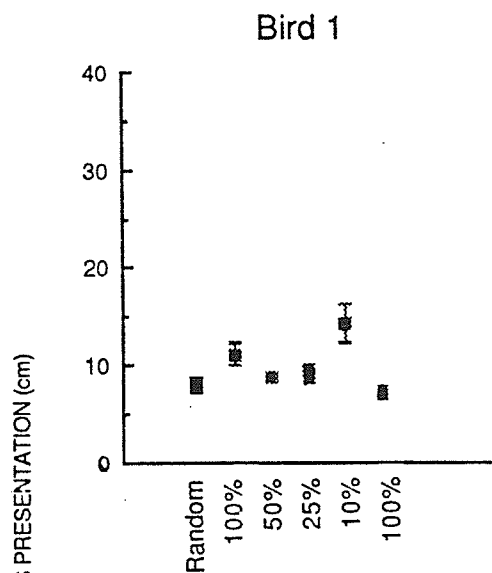
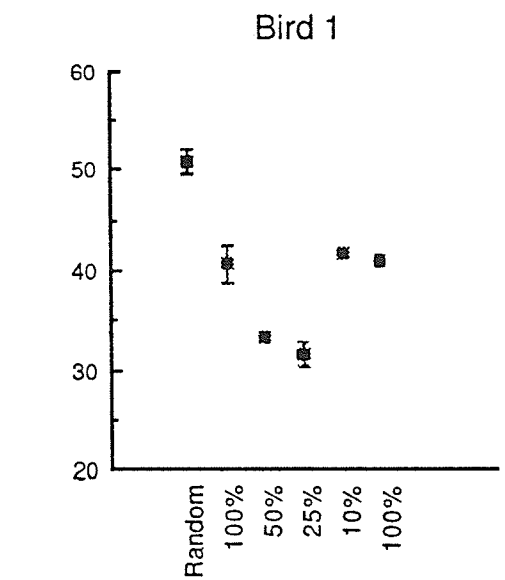


Figure 8. Each birds' mean closest distance from the CS (left graphs) and from the feeder during the CS (right graphs) averaged across the last three sessions of each experimental condition. Each error bar represents the standard error of the mean of the last three sessions of each experimental condition.



during 10% CS-US pairings. Upon reinstatement of the 100% condition, Birds 1 and 3 showed a return to the levels established during the initial 100% condition, whereas Bird 2 showed a lower level than the one established during the initial 100% condition.

To determine if the birds' increased movement toward the CS during 50% and 25% CS-US pairings (Figure 8, left graphs) was a result of their decreased distance from the CS at the beginning of its presentation, Figure 9 shows the birds' mean distance from the ITS and from the feeder at the end of the ITI, 0.1 s before the onset of the CS, averaged across the last three sessions of each experimental condition. Examining the graphs on the left side, the data shows that there were no consistent effects across birds.

The graphs on the right side of Figure 9 show the birds' mean distance from the feeder at the end of the ITI, 0.1 s before the onset of the CS, averaged across the last three sessions of each experimental condition. Bird 1 showed an increase in its distance from the feeder at the end of the ITI when the experimental conditions were changed from random to 100% CS-US pairings, followed by a decrease at 50%. There was no additional change at 25% CS-US pairings, but there was an increase at 10%. Bird 2 showed no change when the experimental conditions were changed from random to 100% CS-US pairings, but showed a decrease at 50% CS-US pairings. There was an increase at 25% CS-US pairings and no additional change at 10%. Bird 3 showed an increase when the experimental conditions were changed from random to 100% CS-US pairings. There was no additional change at 50%, 25%, and 10% CS-US pairings; however, the level at 10% was lower than the level at 50%. Upon reinstatement of the 100% condition, Bird 1 returned to a lower level than the one established during the initial 100% condition, whereas Birds 2 and 3 showed a return to the levels established during the initial 100% condition.

Figure 10 shows the difference between the birds' mean distance from the ITS at the end of the ITI and its closest distance from the CS averaged across the last three sessions of each experimental condition. (Thus, this measure measures the distance that the birds travelled toward the CS when it was presented.) Birds 1 and 2 showed increases in their distances travelled during the CS as the experiment progressed from random to 100% to 50% CS-US pairings. For Bird 1, there was no additional change at 25% and there was a decrease at 10% CS-US pairings. For Bird 2, there was a decrease

Figure 9. Each bird's mean distance from the ITS (left graphs) and from the feeder (right graphs) at the end of the ITI, 0.1 s before the onset of the CS, averaged across the last three sessions of each experimental condition. Each error bar represents the standard error of the mean of the last three sessions of each experimental condition.

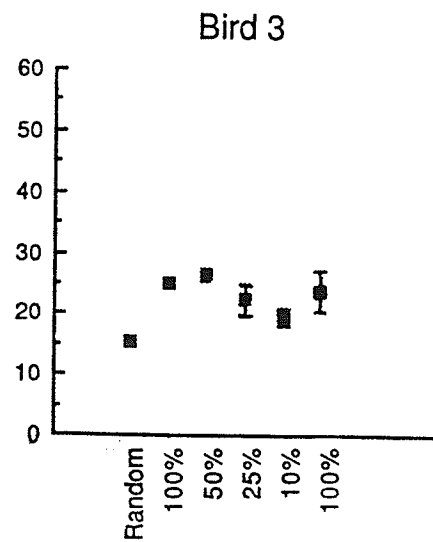
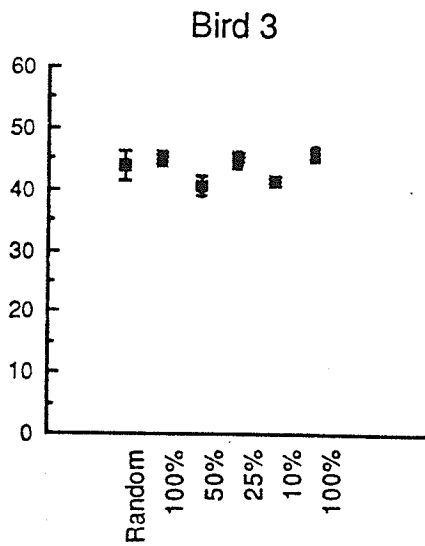
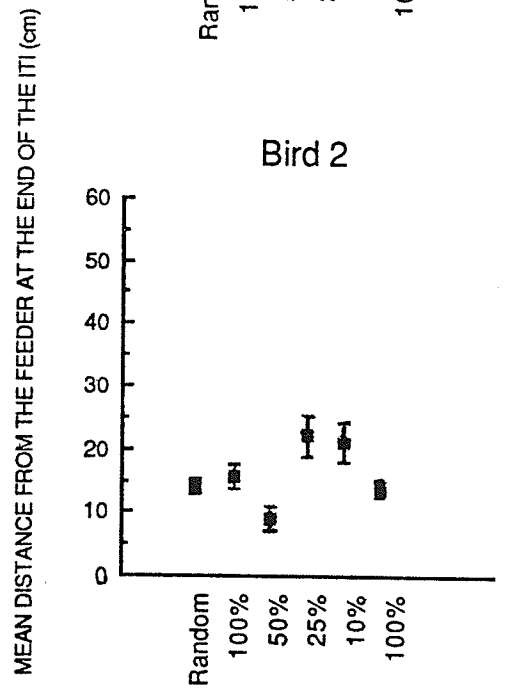
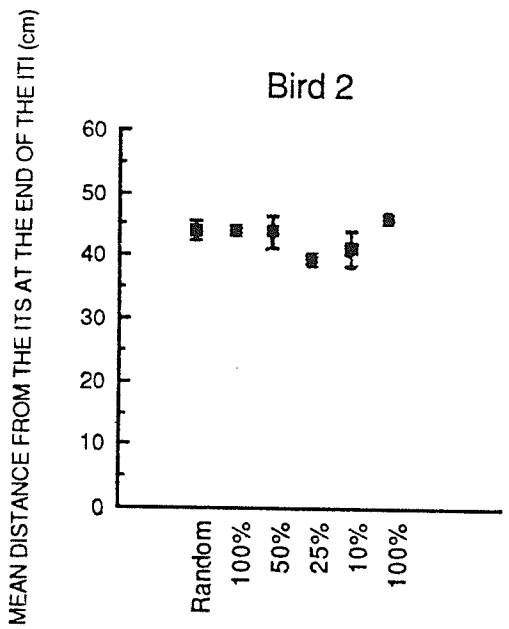
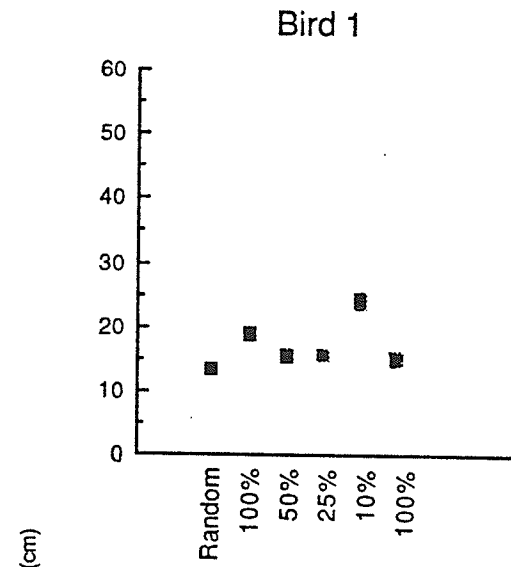
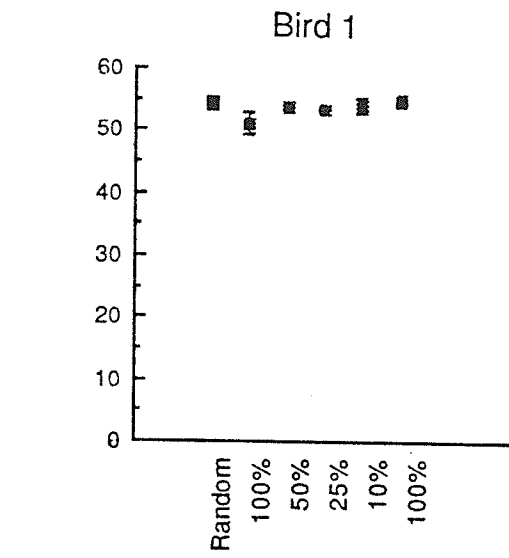
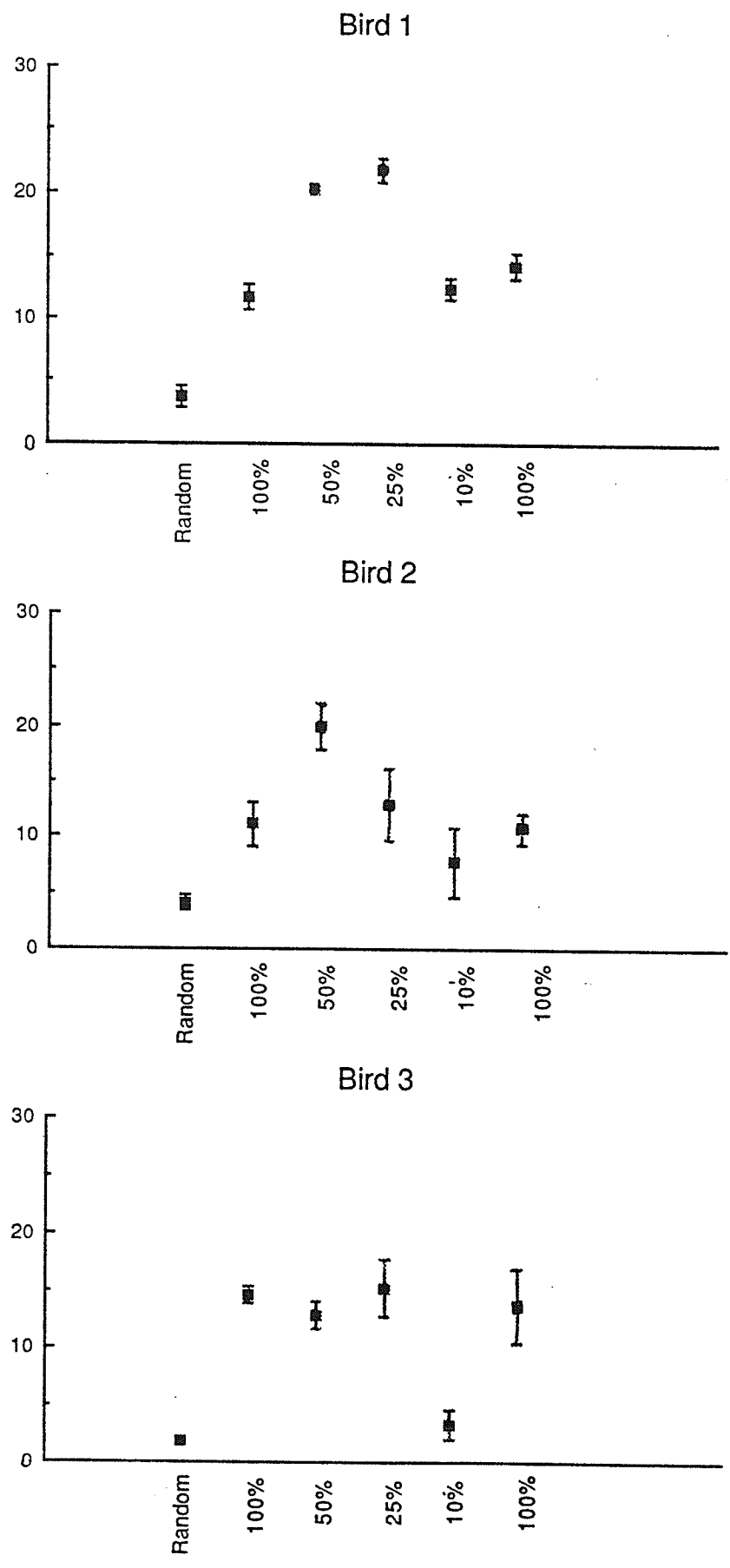


Figure 10. Each bird's mean distance from the ITS at the end of the ITI minus the mean closest distance from the CS (i.e., this measures the distance the bird travelled toward the CS when it was presented) averaged across the last three sessions of each experimental condition. Each error bar represents the standard error of the mean of the last three sessions of each experimental condition.

MEAN DISTANCE FROM THE ITS AT THE END OF THE ITI - MEAN CLOSEST DISTANCE FROM THE CS (cm)



at 25% and no additional change at 10% CS-US pairings, although the level at 10% was lower than the level at 50%. Bird 3 showed an increase in its distance travelled toward the CS when conditions changed from random to 100% CS-US pairings. There were no additional changes at 50% and 25% CS-US pairings; however, there was a decrease at 10% CS-US pairings. Upon reinstatement of the 100% condition, all birds showed a return to the levels established during the initial 100% condition.

Figure 11 shows the birds' mean distance from the CS and the mean distance from the feeder during the CS presentation plotted across all sessions. Note that varying the percentage of CS-US pairings had virtually no effect on the mean distance from the CS and from the feeder during the CS presentation for all birds, except for Bird 2's mean distance from the CS which was slightly higher during the reversal to 100% CS-US pairings and its mean distance from the feeder during CS presentations which was slightly lower.

Figure 12 shows the mean distance from the ITS and from the feeder during the ITI plotted across each session of each phase. Note that varying the percentage of CS-US pairings had little effect on the mean distance from the ITS for all birds. With regard to mean distance from the feeder during the ITI, Birds 1 and 2 showed a slight increase between the 50% and 10% conditions, whereas Bird 3 showed a slight decrease. Upon reinstatement of the 100% CS-US pairings, all birds' mean distances from the ITS and from the feeder during the ITI returned to levels established during the initial 100% condition, except for Bird 3's mean distance from the feeder which was higher than the level established during the initial 100% condition.

Figure 13 shows the mean percentage of CSs with a mean distance ≤ 18 cm from the CS and from the feeder during the CS presentation for each session of each phase. Varying the percentage of CS-US pairings had no effect on the percentage of CSs with a mean distance ≤ 18 cm from the CS for all birds. In fact, the birds rarely showed a mean distance from the CS ≤ 18 cm. However, there were some effects with respect to the percentages of CSs in which the birds' mean distance from the feeder during the CS presentation was ≤ 18 cm. Although difficult to interpret because of the variability, Bird 1 showed no change in this dependent measure when shifted from random to 100% CS-US pairings, an initial increase followed by a decrease when shifted from 100% to 50% CS-US pairings and when shifted from the 50% to the 25% condition, before decreasing at 10% CS-US pairings and remaining at this lower level through most the reversal to 100% CS-US pairings. Bird 2 showed an initial increase in the level of this dependent measure

Figure 11. Mean distance from the CS (open squares) and the feeder during the CS presentation (solid squares) across all sessions for all birds.

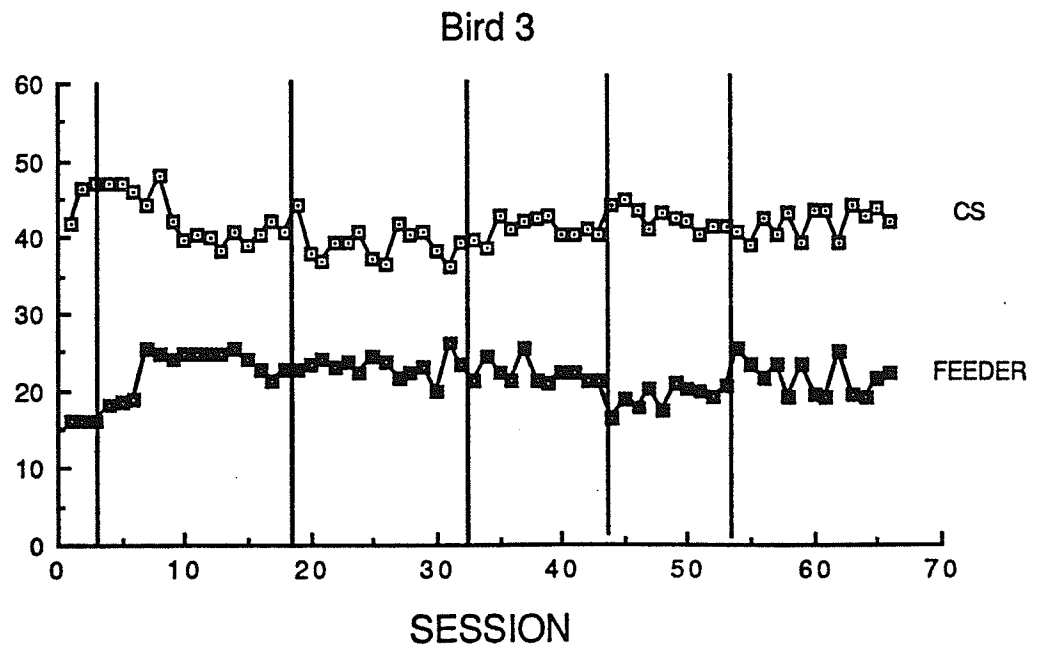
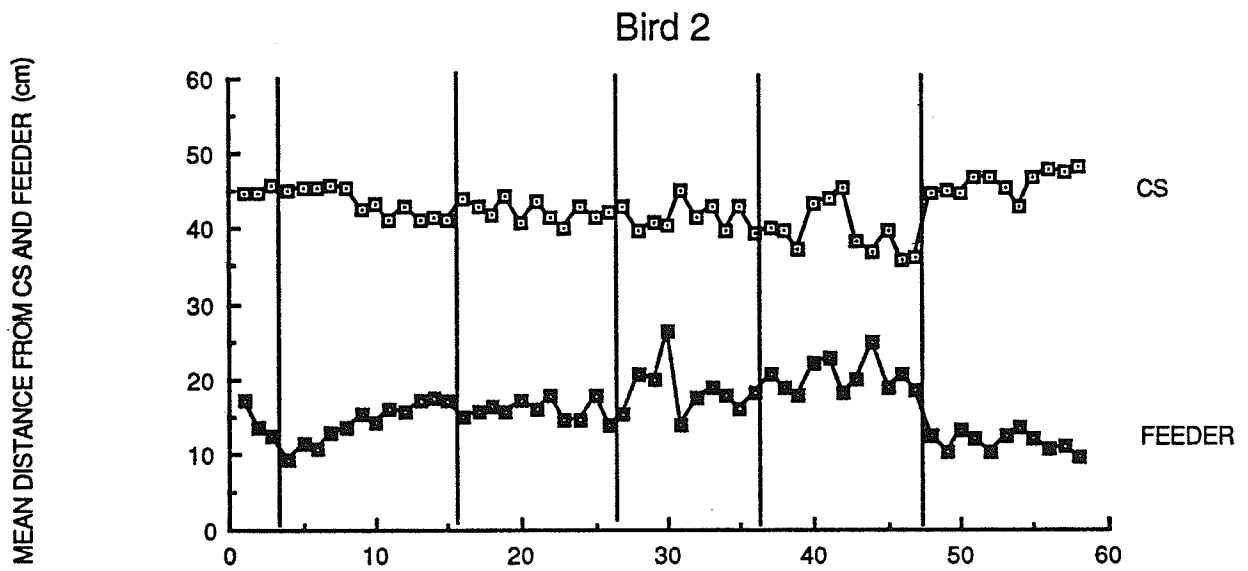
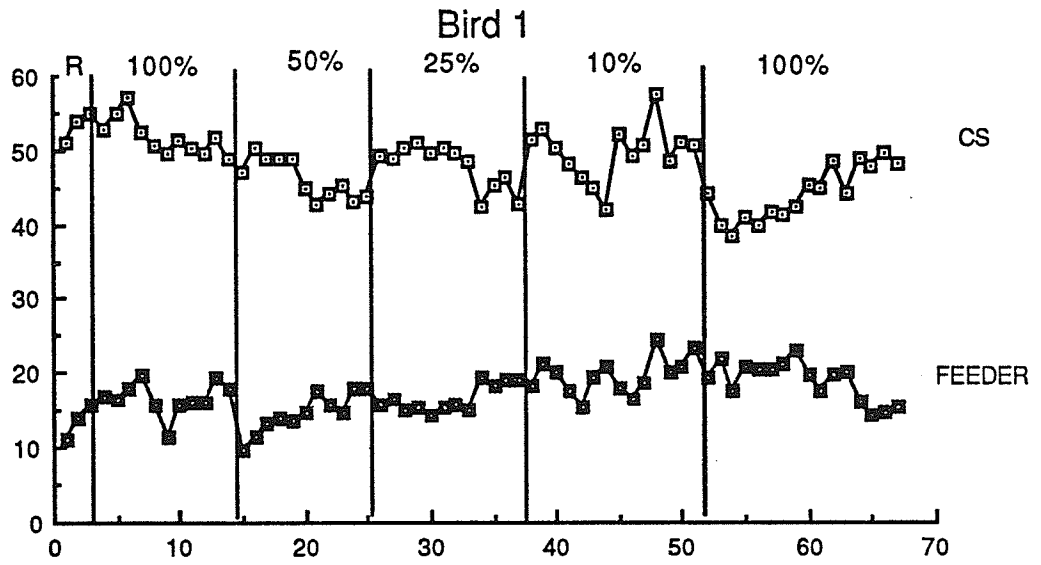


Figure 12. Mean distance from the ITS (open squares) and the feeder during the ITI (solid squares) across all sessions for all birds.

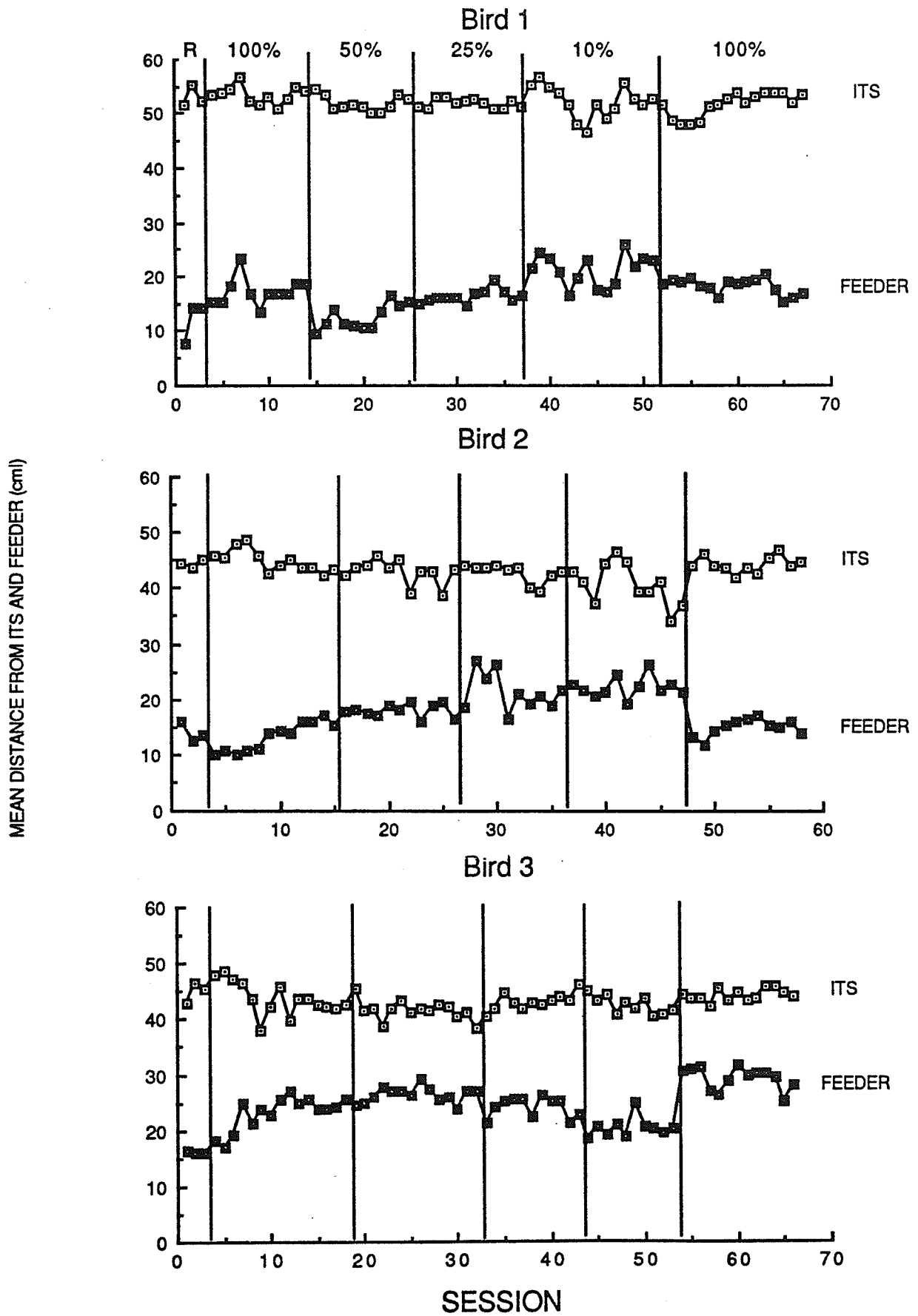
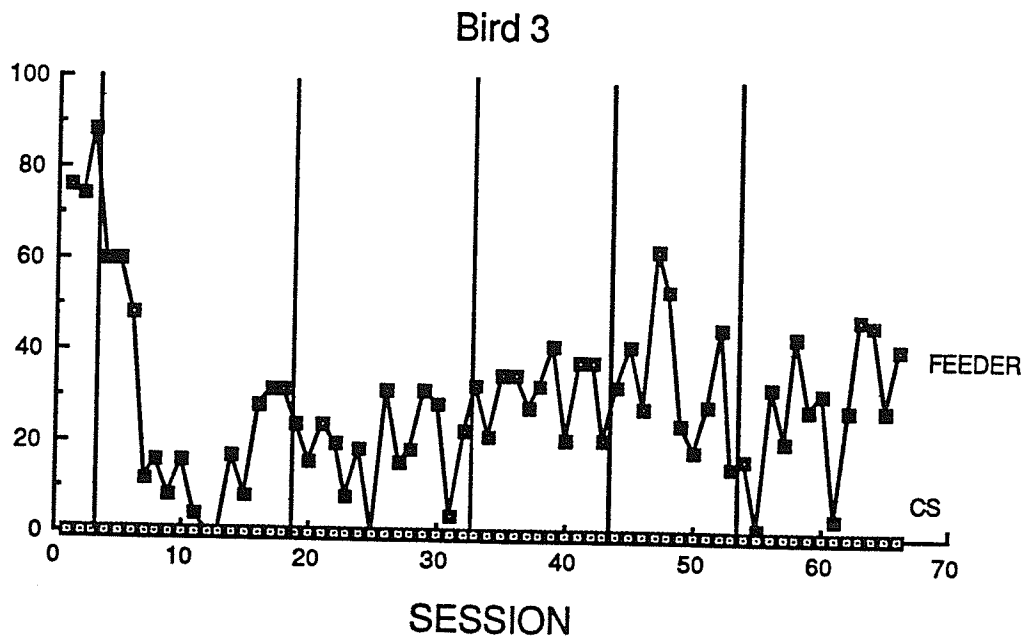
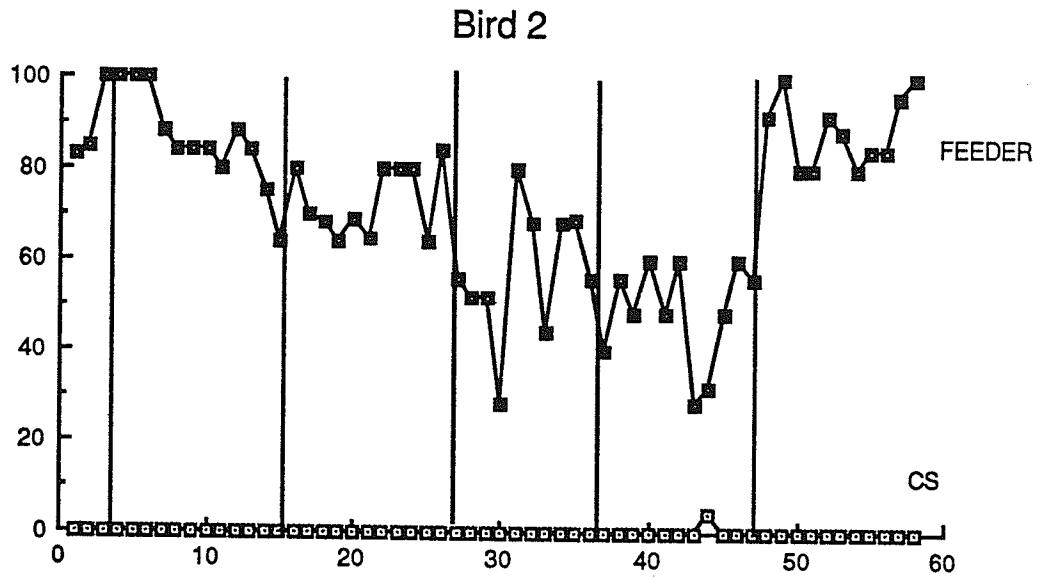
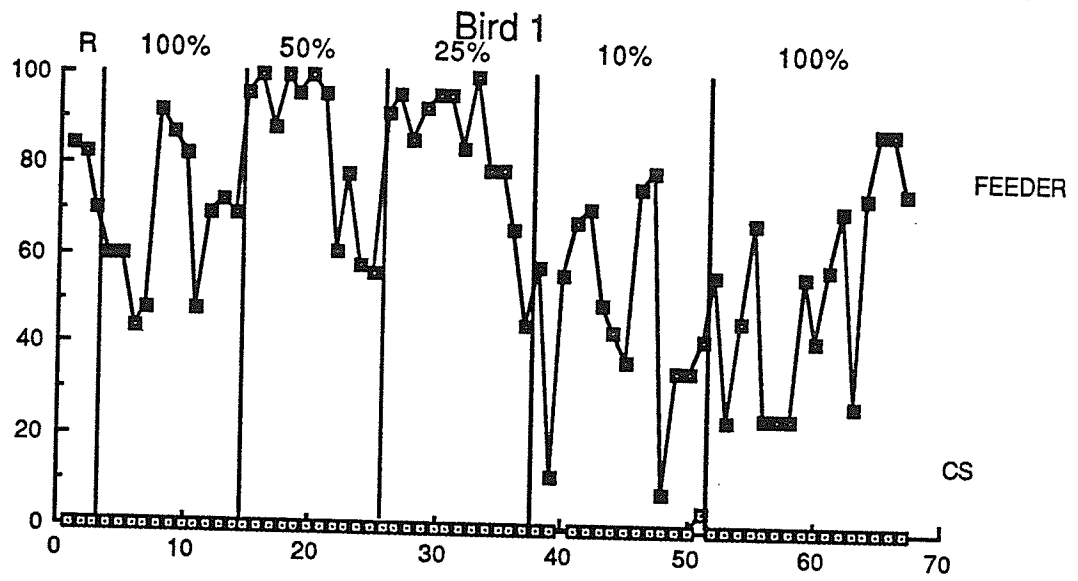


Figure 13. Percentage of CSs in which the mean distance from the CS (open squares) and the feeder during the CS (solid squares) was ≤ 18 cm across all sessions for all birds.

PERCENTAGE OF CSs WITH A MEAN DISTANCE \leq 18 cm FROM THE CS AND FEEDER



when shifted from random to 100% CS-US pairings before decreasing later in the 100% condition. Bird 2 remained at this level through 50% CS-US pairings. It did, however, show a decrease during 25% and 10% CS-US pairings. The level of this dependent measure increased during the reversal to 100% CS-US pairings to the level established during the initial 100% condition. Bird 3 showed a decrease in the percentage of CSs with a mean distance ≤ 18 cm when shifted from random to 100% CS-US pairings. It remained at this lower level through the 50% condition, but increased during 25% and 10% CS-US pairings, remaining at this level during the reversal to 100% CS-US pairings.

In summary, horizontal plots of the movement patterns suggested that there was an increase in sign-tracking and a decrease in goal-tracking during 50% and 25% CS-US pairings. When measured by the percentage of CSs with an approach ≤ 30 cm, all birds showed an increase in sign-tracking during 50% CS-US pairings. When measured by the closest distance from the CS, all birds showed a decrease in their closest distance from the CS during 50% CS-US pairings. The absence of movement during 10% CS-US pairings was evident across most dependent measures.

Discussion

Measuring Sign- and Goal-tracking

Before discussing the implications of the results, it is necessary to first decide which dependent measure used in the present study best represents changes in sign- and goal-tracking. As described in the Introduction, previous studies have measured sign- and goal-tracking behavior in rats and in pigeons by recording the amount of time or how often the animal steps on a platform in front of the CS and in front of the feeder (Boakes, 1979; Peden et al., 1977; van Hest et al., 1986), or by recording how often the animal intersects a photobeam projected in front of the CS and in front of the feeder (Holland, 1979). Using the aforementioned measures, research has shown that PRF increases sign-tracking (Peden et al., 1977) and decreases goal-tracking (Boakes, 1979) when pigeons are used as subjects. The results of Experiment 1 suggest that PRF increases sign-tracking, but has inconsistent effects on goal-tracking in pigeons. The inconclusive effects of PRF on goal-tracking, and the lack of consistent effects across some measures of sign-tracking may be due to the difficulty in measuring sign- and goal-tracking. Before proceeding, it should be noted that the movement plots contain information regarding distance of approach, proximity of approach, and angle of approach to the CS and to the feeder during CS presentations across time. The quantitative measures contain information about

distance only.

The present experiment measured sign- and goal-tracking by recording the bird's distance from the CS and from the feeder during CS presentations. According to the operational definitions established a priori, goal-tracking occurred if the bird's mean distance from the feeder during the CS was ≤ 18 cm. Similarly, sign-tracking occurred if the bird's mean distance from the CS was ≤ 18 cm. Four dependent measures of sign- and goal-tracking were calculated on the basis of these definitions: (a) percentage of CSs with a mean distance ≤ 18 cm from the CS, (b) percentage of CSs with a mean distance ≤ 18 cm from the feeder, (c) mean distance from the CS, and (d) mean distance from the feeder during CS presentations. Furthermore, topview plots of each bird's movement patterns during the CS and during the ITI were collected.

Examination of the movement patterns suggests that PRF increases sign-tracking and decreases goal-tracking. As shown in Figure 4, during 100% CS-US pairings, the birds primarily moved toward the feeder at the onset of the CS and remained there until food was delivered. However, during 50% and 25% CS-US pairings, the birds moved toward the CS at the onset of the CS and then moved toward the feeder where they remained until food was delivered or until the next ITI started. Thus, during 50% and 25% CS-US pairings, if the birds were moving toward the CS when it is presented, then they must have spent less time in front of the feeder. This result is similar to Boakes' (1979) in which goal-tracking was measured by the amount of time a pigeon spent on a platform in front of the feeder. However, none of the quantitative dependent measures used in the present experiment contained the element of time.

Examination of the mean distance from the CS and the mean distance from the feeder (Figure 11) suggests that PRF has little effect on sign-tracking and goal-tracking. The absence of an effect, however, may be the result of invalid operational definitions of sign- and goal-tracking. Recall that it was hypothesized that the birds would sign-track more during the 50% condition relative to the 100% condition, and that this effect would be evident in the plots of the movement patterns and the mean distance from the CS and from the feeder during CS presentations. This hypothesis was based, seemingly erroneously, on the expectation that the birds would approach the CS and remain near it until food was delivered (as during traditional partially reinforced autoshaping preparations). However, during 50% and 25% CS-US pairings, the birds moved toward the CS at the beginning of the CS presentation and then moved toward the feeder later in the presentation. Simply approaching the CS at the start of the CS presentation was insufficient to greatly change the mean distance from the CS and from the feeder. The data collected while the

bird was moving from the feeder area to the CS and back to the feeder were averaged into the distance from the CS and the distance from the feeder. Hence, the definitions of sign- and goal-tracking were modified so that data were not "leaked" into each measure of sign- and goal-tracking.

Sign- and goal-tracking were redefined so that the change in behavior that was evident from the movement plots could be detected by quantitative measures of distance. Thus, as they were redefined, sign-tracking occurred if the bird's closest distance from the CS was ≤ 18 cm, and goal-tracking occurred if the bird's closest distance from the feeder during the CS presentation was ≤ 18 cm. Four new dependent measures of sign- and goal-tracking were calculated on the basis of these definitions: (a) mean closest distance from the CS, (b) mean closest distance from the feeder during the CS presentation, (c) mean percentage of CSs on which sign-tracking occurred, and (d) mean percentage of CSs on which goal-tracking occurred.

Examination of the percentage of CSs with a movement ≤ 18 cm from the CS and from the feeder during the CS presentation showed that PRF had inconsistent effects on sign- and goal-tracking (see Figure 6). The percentage of CSs with an instance of sign-tracking (movement ≤ 18 cm from the CS) showed an increase for Bird 2 but not for Birds 1 and 3 during 50% and 25% CS-US pairings, and the percentage of CSs with an instance of goal-tracking (movement ≤ 18 cm from the feeder during the CS presentation) showed an increase for Birds 1 and 2 but not for Bird 3 during 50% CS-US pairings.

Examination of the mean closest distance from the CS and from the feeder during the CS presentation showed that PRF has inconsistent effects on sign- and goal-tracking (see Figure 8). First, none of the birds' showed a mean closest distance from the CS ≤ 18 cm; however, they all showed a decrease in closest distance when shifted from 100% to 50% CS-US pairings. Second, all the birds' mean closest distance from the feeder during CS presentations was ≤ 18 cm across all experimental conditions; however, any effects resulting from PRF were inconsistent across birds with the exception of an increase at 10% CS-US pairings.

Based upon the effect shown by all birds with regard to their mean closest distance from the CS (see Figure 8), it appears that measuring how close a subject comes to the CS, may be a sensitive and reliable measure of sign-tracking. However, it appears the whether a particular subject shows a change in sign-tracking depends on the distance criterion that is used. It may be possible to obtain consistent effects that reflect the changes shown in the movement plots by relaxing the criteria for sign-tracking (e.g., increasing 18 cm to 30 cm). Eighteen centimeters was initially chosen as the criterion for sign- and goal-tracking

because previous research has used this value or similar values (Boakes, 1979; van Hest et al., 1986). These same studies, however, fail to provide a rationale for using 18 cm as their criterion for sign- and goal-tracking. Peden et al.'s (1977) criterion for sign-tracking was any approach made by the subject that brought it within 18 cm and 34 cm from the CS. Given the somewhat arbitrary manner in which a distance criterion for sign-tracking are chosen, the present distance criterion for sign-tracking was relaxed from 18 cm to 30 cm to see if this would result in consistent results. Thirty centimeters was chosen because it was the midpoint between the feeder and the CS. This criterion was also applied to goal-tracking since sign- and goal-tracking were defined as equivalent but opposite phenomena; however, because the birds routinely moved within 18 cm of the feeder, it was not essential to do this. It was done simply for the sake of making sign- and goal-tracking comparisons symmetrical.

Examination of the mean closest distance from the CS indicated that PRF increased sign-tracking for Birds 2 and 3 but not for Bird 1 (see Figure 8) when the distance criterion of 30 cm was used. In contrast, the percentage of CSs with a movement ≤ 30 cm from the CS increased for all birds (see Figure 7). Naturally, neither measure showed a consistent change in the goal-tracking behavior across birds.

Although there were some inconsistent effects irrespective of the definition of sign- and goal-tracking used, there were consistent effects when we just examined changes in mean closest distance from the CS (without specifying a distance criterion for sign- and goal-tracking). Examination of the mean closest distance from the CS showed a decrease in distance across all birds when the percentage of CS-US pairings was changed from 100% to 50% (see Figure 8). Similar effects were not noted for the mean closest distance from the feeder during the CS.

In light of the fact that the presence of an effect was related to the dependent measure, the issue of how to operationally define sign- and goal-tracking needs to be addressed. If a valid and reliable definition of these phenomena cannot be devised, then we must question the validity of distinguishing between sign- and goal-tracking. Perhaps it is neither heuristically nor theoretically meaningful to talk about sign- and goal-tracking. Instead, it may be more profitable to talk simply about changes in a subject's distance from the CS. The following conclusions are derived from the results of Experiment 1: (a) the movement plots in Figure 2 suggest that PRF increases movement toward the CS and movement away from the feeder; (b) the percentage of CSs with an instance of sign-tracking shows that PRF increases sign-tracking when the distance criterion used in the definition of sign-tracking is 30 cm; and (c) the mean closest distance from the CS shows that PRF results in

closer approaches to the CS. No consistent changes were noted in goal-tracking.

There may be at least two problems with the definitions of sign- and goal-tracking used in the present study. First, sign- and goal-tracking have been defined as the opposite of each other. Instead, it may be necessary to define sign- and goal-tracking as qualitatively different phenomena. For example, sign-tracking may be defined as a change in direction (within some specified angular range) toward the CS, while goal-tracking may be defined by the amount of time a subject spends in front of the feeder. Second, sign- and goal-tracking were defined unidimensionally in terms of distance without regard to change in direction or even change in distance. For example, the movement patterns during 10% CS-US pairings show the birds generally motionless during the CS. Any bird standing within 18 cm (or 30 cm) of the CS would appear to be sign-tracking even if it remained motionless during the CS. Furthermore, it is theoretically possible that a subject can move along a plane in such a way that its distance from one location (e.g., feeder) changes while its distance from another location does not (e.g., CS). Therefore, a definition based solely on distance appears to be incomplete.

There is an additional problem that is specific to the definition of goal-tracking used in the present experiment. Because the birds were almost always near the feeder at the end of the CS presentation during all experimental conditions (except 10% CS-US pairings), dependent measures such as closest distance from the feeder during the CS presentation and percentage of CSs with a movement ≤ 18 cm from the feeder during the CS presentation are less likely to reflect any movement away from the feeder during PRF that is apparent from the movement plots shown in Figure 4.

In light of the potential problems with definitions of sign- and goal-tracking based on distance, plots of the movement patterns appear to be a more complete measure for assessing changes in sign- and goal-tracking compared to the distance measures. In addition to containing information regarding distance of approach, the movement plots also contain information regarding proximity of approach, and angle of approach to the CS and to the feeder during CS presentations across time. Therefore, the remaining discussion will be based primarily upon the results shown in Figure 4.

Motivational Interpretation

If we focus on the results that are shown in Figure 4, as per the discussion above, then the present data appear to be consistent with research showing that PRF increases sign-tracking and decreases goal-tracking (Boakes, 1979; Davey & Cleland, 1982; Holland, 1979). Previously, this effect of PRF on sign- and goal-tracking was assessed at

only 50% CS-US pairings (typically using rats as subjects). The present experiment showed that the increase in sign-tracking and the decrease in goal-tracking that occurred during 50% CS-US pairings was maintained during 25% CS-US pairings; however, both behaviors decreased during 10% CS-US pairings relative to previous conditions. Second, the movement plots suggest that pigeons often engage in a mixture of sign- and goal-tracking or something intermediate when the CS and the feeder are far apart (Silva et al., in press).

In order to understand the data of the present study, it is necessary to explain the increase in sign-tracking during PRF. In other words, what is required is an explanation for the PRF Effect (the effect that PRF produces higher levels of responding than CRF).

Frustration theory (Amsel, 1958, 1962) has been used to explain increases in signal-directed behavior during PRF (e.g., Gibbon et al., 1980). Frustration theory asserts that during CRF organisms learn to anticipate when and where biologically relevant events will occur. During PRF, instances of nonreward arouse a drive (frustration) that energizes or motivates responding, thereby increasing the level of behavior above the level established during CRF (Gibbon et al., 1980).

Gibbon et al. (1980) discovered that pigeons exposed to lower percentages of CS-US pairings pecked the CS more than pigeons exposed to higher percentages of CS-US pairings. The authors postulated that the unreinforced trials (i.e., instances in which the CS was not followed by food) produced frustration that resulted in increased rates of behavior on subsequent trials.

Frustration can be induced by altering the environment such that it is not as reinforcing to the organism as it was before the change (e.g., decreasing the frequency of food that follows a CS or erecting a glass barrier over the feeder aperture). When the environment is altered such that a high probability behavior cannot be performed, a conflict situation is produced (Brown, 1961). Conflict situations differ from frustration situations in that in conflict situations there is a tendency to make a response incompatible with the one being reinforced or associated with reinforcement, rather than make more of the reinforced response.

Numerous studies have postulated that sign- and goal-tracking behaviors compete with each other (Boakes, 1977, 1979; Davey et al., 1981; Holland, 1979; Peden et al., 1977). During traditional autoshaping preparations, the tendency to approach a signal for food competes with the tendency to approach the location where food occurs (Boakes, 1977). During CRF, sign-tracking is relatively weak because of a strong tendency to goal-tracking. During PRF, sign-tracking increases because the tendency to goal-track

decreases. The tendency to goal-track decreases because food occurs less frequently at the feeder aperture. Evidence in support of the competitive nature of sign- and goal-tracking accrues from data showing that, in rats, placing one of the two behaviors on omission causes the other behavior to increase (Davey et al., 1981; Holland, 1979). Furthermore, during 100% CS-US pairings where the CS and the US are spatially separated, subjects oscillate between the locations of the CS and the US (Boakes, 1977; Grastyan & Vereczkei, 1974; Silva et al., in press).

Competition between sign- and goal-tracking may explain the results of the present study and other studies that have examined changes in the level of sign-tracking (e.g., Pearce & Collins, 1987). Pigeons may have a tendency to approach the CS and the feeder, but during 100% CS-US pairings, the tendency to approach to the feeder is greater than during PRF. When food no longer follows every CS, the tendency to approach the feeder declines, resulting in the emergence of the competing sign-tracking behavior. Similarly, it is possible to increase the tendency to goal-track during 100% CS-US pairings by spatially separating the CS and the US. Bringing the CS and the US closer together results in the reemergence of the competing sign-tracking behavior (Silva et al., in press).

Konorski's Model

Konorski's (1967) model has been applied to the effects of PRF on sign- and goal-tracking (e.g., Boakes, 1979; Davey et al., 1982), therefore, it may be able to explain the data of the present experiment. Konorski proposes that when food is the US, the CS elicits two CRs, one called a hunger CR (a preparatory response) and the other called a food CR (a consummatory response). The hunger CR is characterized by increased behaviors directed toward the CS and is controlled by the hunger center in the brain. In contrast, the food CR is characterized by behaviors directed towards the site of the US and is controlled by the US representation center in the brain. Hence, the hunger CR corresponds to sign-tracking and the food CR corresponds to goal-tracking (Boakes, 1979; Davey et al., 1982).

According to Konorski's model, there is an excitatory and an inhibitory connection linking the centers controlling the hunger and the food CRs. Sign-tracking and goal-tracking may both occur during a specific CS, but the excitatory and the inhibitory interactions between the two centers contribute to determine the relative strengths of the two types of CRs.

According to Konorski's model, PRF would strengthen the hunger CR (sign-tracking) by disrupting the elicitation of the US representation. Thus, the increase in sign-tracking during 50% and 25% pairings in the present study may reflect the hunger center

becoming more excitatory compared to the US-representation that has become inhibitory due to less food being presented. During 10% CS-US pairings, food may have been paired with the CS so infrequently that responding during the CS extinguished. This interpretation has been used to explain the increase in lever pressing and the decrease in feeder-directed behavior in rats during PRF (Davey et al., 1982).

Konorski suggested that the hunger CRs are representative of the animal's motivational state rather than to specific characteristics of the US. In line with this supposition is more recent data showing that signal-directed behavior is often characteristic of behavior systems related to species-specific food-getting in general rather than a particular US (Timberlake & Grant, 1975); however, others have shown that the type of US affects the form of the CR (Davey et al., 1981).

Behavior Systems Interpretation

Recently, signal-centered behavior has been viewed in terms of the manifestation of behavior systems controlled by specific motivational states. A behavior system is a control structure related to a particular function or organismic need, such as feeding, reproduction, defense, or body care (Timberlake & Lucas, 1989).

The feeding system was of primary interest to the present experiment. The feeding system is a hierarchical collection of perceptual-motor modules, subsystems, and modes related to obtaining and ingesting food. Activation of a subsystem, which consists of general strategies related to the system, in turn activate the next level in the feeding system — the mode. The mode is the part of the system that is influenced by temporal characteristics and the probability of reinforcement which, in turn, affects the behavioral output.

Modes are arranged on a continuum ranging from interaction with terminal stimuli (e.g., food) at the one end to general search behaviors at the other end. One end consists of the consummatory mode, where behaviors such as pecking for food have a high probability of occurring. Next along the continuum is the focal search mode, where behaviors directed toward the CS and/or the feeder have a high probability of occurring. On the other end is the general search mode, where nondirected behaviors such as circling and nondirected pacing have high probability of occurring. In autoshaping, the activation of the modes (and thus the emergence of their corresponding behaviors) are influenced by variables such as the amount of time between CS offset and US onset, the duration of the CS, and how accurately the CS predicts the occurrence of the US.

During a typical autoshaping experiment, the duration of the CS is long enough so

that pigeons engage in focal search behaviors directed toward the CS and not directed toward the feeder. However, the decrease in the CS's food predictability resulting from PRF increases the importance of other focal and general search behaviors. Thus, in the present experiment, the increase in movement toward the CS during 50% and 25% CS-US pairings can be interpreted as an increase in focal or general search behavior. During 100% CS-US pairings, the CS activates a mode that produces both CS and feeder-directed behaviors. The presence of these feeder-directed behaviors suppresses the amount of sign-tracking during 100% pairings relative to the amount of sign-tracking during 50% CS-US pairings. This interpretation is also consistent with results obtained during traditional autoshaping studies that have investigated PRF (e.g., Gonzalez, 1974; Gibbon et al., 1981); however, feeder-directed behaviors were not readily observable during these experiments because of the spatial proximity of the CS to the feeder. Moreover, the decrease in movement toward the CS and the feeder during 10% CS-US pairings in the present study may be interpreted as a decrease in search behavior altogether. Timberlake (1990) suggests that a subject may stop moving altogether if food is delivered infrequently enough.

Generalized Matching Relation

Pear's (1988) extension of the generalized matching law (Baum, 1974, 1979) provides an alternative explanation for the increase in sign-tracking during PRF. Pear (1988) describes the relationship between stereotyped behavior, relative frequency of reinforcement, and behavior biases. According to the matching account, a subject may engage in two alternative behaviors, and the amount of each behavior observed depends of the frequency of reinforcement given for each behavior. If the probability of reinforcement is equal for both behaviors, the behavior that is the bias behavior (defined as the residual preference for a behavior class when differences between reinforcement parameters are accounted for) will be more likely to occur; however, if the frequency of reinforcement decreases for one behavior, that behavior should decrease and the alternative behavior should increase.

Numerous studies have shown that pigeons approach and contact a stimulus associated with food in a typical autoshaping situation (Brown & Jenkins, 1968), but approach a CS less when the CS and the US are spatially separate (Boakes, 1977; Silva et al., in press). This is to be expected because in the natural environment, the CS is usually located near the source of the US (Wasserman, 1981). Thus, it could be said that birds have a bias to approach stimuli spatially and temporally contiguous with food; however, if

the distance between the CS and the feeder is large, this bias behavior decreases in favor of an alternate behavior that increases the probability of obtaining reinforcement. When the CS and the US are spatially separate, a decrease in rate of reinforcement may occur due to the time it takes the animal to travel from the CS to the feeder or that travelling a long distance reduces the reinforcing value of sign-tracking because of the aversiveness of the effort required (Silva et al., in press).

During 100% pairings, it is possible that the birds goal-tracked because approaching the CS may have been less reinforcing (for the reasons mentioned above) than being close to the feeder and obtaining more reinforcement. However, during PRF, the frequency of reinforcement decreases so that there is less reinforcement for remaining near the feeder. It may be important to note that there is no additional reinforcement for approaching the CS during PRF. Thus, the increase in sign-tracking during PRF may reflect the emergence of the bias behavior as a result of less reinforcement for being near the feeder. In order for this account to be plausible, it is necessary only to assume that animals have a bias to approach stimuli that reliably predict food when these stimuli are spatially and temporally contiguous with food (such as during traditional autoshaping preparations).

The response-bias account of the data obtained in the present study is compatible with (and is perhaps even complementary to) a behavior systems interpretation emphasizing the phylogenetic or evolutionary aspects of sign-tracking (Davey & Cleland, 1984; Timberlake & Lucas, 1989). Response bias is presumed to have a phylogenetic component (i.e., a component that is difficult or impossible to modify by reinforcement).

Movements during ITI

The present study also raises some questions regarding behavior during the ITI. Sign-tracking studies that have used a CS that is located far from the US typically measure the behavior that occurs during the CS but do not devote much attention to the behavior that occurs during the ITI (e.g., Boakes, 1979; Peden et al., 1977). The plots in Figure 5 show that there was not a substantial change in the movement patterns during the ITI throughout the experiment, except during 10% CS-US pairings. That does not mean that the ITI behavior is unimportant. Consider the following scenario. A bird engages in a behavior pattern during the ITI. When the onset of the CS occurs, the bird moves in the direction of the CS. The bird's location in the experimental chamber at the end of the ITI, and hence the onset of the CS, may influence the movement pattern toward the CS. For example, if a bird spends most of its time along the feeder wall during the ITI, the approach to the CS may look like the movement plot of Bird 1 (see 50% CS-US pairings); however,

if a bird spends its time near the right wall of the chamber during the ITI, the approach to the CS may look like the movement plot of Bird 3 (see 50% CS-US pairings). This may explain why Bird 1's movement plots during the CS during 50% and 25% pairings in Experiment 1 appear consistent, whereas Bird 2 and 3's movement plots are more variable. During the ITI, Birds 2 and 3 moved in a large area of the chamber relative to the area in which Bird 1 moved. Perhaps Birds 2 and 3's increased movement also increased the probability that they would begin their CS pattern in different locations of the chamber.

With the exception of Bird 1, it could not be definitively stated that approach to the CS was not an extension of the behavior pattern during the ITI. This, however, is only a small shortcoming if it is a shortcoming at all. If Birds 2 and 3 were approaching the CS during PRF as a result of "convenience" (i.e., they were already moving in the direction of the CS at the end of the ITI so they passed by the CS on the way to the feeder), then this is still a positive finding in that it raises the possibility of the importance of intertrial behavior on sign-tracking. With this in mind, research could be conducted to investigate how variables such as restraint of movement and redirection of movement affect subsequent sign-tracking.

Random CS-US Pairings

The initial exposure to random CS-US pairings may have had an effect on the birds' behavior during subsequent phases. Research has shown that exposing pigeons to random CS-US pairings prior to 100% CS-US pairings results in retarded acquisition as well as lower rates of asymptotic responding (Brandon & Paul, 1987; see Tomie, 1981 for an extensive discussion). Similarly, studies that have prolonged feeder training phases and or phases in which food is presented independent of behavior have shown similar retardation of conditioning (Downing & Neuringer, 1976; Engberg, Hansen, Welker, & Thomas, 1972). It has been suggested that random CS-US pairings results in the context being the best predictor of food (Tomie, 1981). When conditioning starts (i.e., 100% CS-US pairings), the control exerted by the context as a predictor of food has to be overcome before the CS can start controlling behavior.

However, there may be an additional effect that is not considered in traditional autoshaping experiments that have exposed pigeons to random CS-US pairings. That is, it is possible that random CS-US pairings may strengthen a subject's tendency to goal-track. The data in Figures 2 and 3 are consistent with this possibility. The implication, if this is true, is that exposure to random CS-US pairings may have strengthened the birds tendency to goal-track such that it would be difficult to subsequently reduce this behavior and/or to

increase sign-tracking. In support of this possibility, Timberlake (1986) held a context's predictiveness of food constant, but altered an animal's location to the feeder (i.e., the amount that an animal was allowed to goal-track was varied). He noted that the level of sign-tracking during subsequent CS-US pairings was inversely related to the subject's level of goal-tracking during the previous phase. A high level of goal-tracking in the previous phase resulted in a low level of sign-tracking in the subsequent phase; a lower level of goal-tracking in the previous phase resulted in a higher level of sign-tracking in the subsequent phase.

Experiment 2

Depending on the measure that was used, the birds in Experiment 1 showed the general effect of increased movement toward the CS during 50% and 25% CS-US pairings relative to their movement toward the CS during 100% pairings. Large and consistent effects, however, were lacking on several of the dependent measures. Furthermore, I wanted to be more certain that any increase in movement toward the CS during PRF did not just reflect some bias to move toward the left side of the chamber. Thus, the purpose of Experiment 2 was to (a) replicate any effects, small or large, observed in Experiment 1, and (b) to obtain data showing that the birds would sign-track a CS regardless of its location (provided the CS's distance from the feeder was held constant).

Experiment 2 used two CSs, each located 60 cm from the feeder, presented in either of two locations during different phases. Presumably, the birds would show different trajectories or paths of approach toward each CS depending on which side of the chamber the CS was located. In Experiment 1, any changes in the birds movement patterns was evident at 50% CS-US pairings; therefore, the present experiment changed the location of the CS during 50% CS-US pairings after an initial baseline phase in which the CS and the US were paired 100% of the time. The number of sessions each bird received in each phase is shown in Table 2.

Method

Subjects

The three birds used in Experiment 1 served as subjects in Experiment 2. All housing and general procedures were identical to those described in Experiment 1.

Table 2

Number of Sessions in Each Phase

Phase	Bird 1	Bird 2	Bird 3
100% First Location	8	10	8
50% First Location	9	8	8
50% Second Location	8	8	8
50% First Location	9	11	9

Apparatus

The same apparatus used in Experiment 1 was used in Experiment 2 with the following modifications. Since the presence of the ITS appeared to have little effect on the birds movement patterns during the ITI (i.e., all birds showed different movement patterns during the ITI in Experiment 1), no ITS was used in Experiment 2. Furthermore, the CS located on the right wall was different from the CS located on the left wall (the 4-cm red light used in Experiment 1). The CS located on the right wall was a white 7.5 W General Electric refrigerator light bulb measuring approximately 4 cm in diameter. The light bulb screwed into a standard brass-plated light socket that was attached to an electric cord that was plugged into a relay controlled by the computer. The socket and cord were painted flat white to avoid interference with the tracking system and the entire unit (including the light bulb) was suspended from the ceiling of the chamber within the right dashed region shown in Figures 2, 3, 4, and 5. Both CSs were located 60 cm from the feeder and 25 cm above the mesh floor. The CS used in Experiment 1 could not be used on the right side because it interfered with the tracking system, and using the 7.5 W bulb as the CS on the left side interfered with the tracking system (perhaps because it created a spurious shadow).

Procedure

General experimental procedures. All experimental procedures were identical to those used in Experiment 1.

Experimental design. Bird 1 was exposed to the following sequence of conditions: (a) 100% CS-US pairings with the CS located on the right side of the chamber, (b) 50% CS-US pairings with the CS located on the right side of the chamber, (c) 50% CS-US pairings with the CS located on the left side of the chamber, and (d) 50% CS-US pairings with the CS located on the right side of the chamber. Birds 2 and 3 were exposed to the following sequence of conditions: (a) 100% CS-US pairings with the CS located on the left side of the chamber, (b) 50% CS-US pairings with the CS located on the left side of the chamber, (c) 50% CS-US pairings with the CS located on the right side of the chamber, and (d) 50% CS-US pairings with the CS located on the left side of the chamber. (Due to an error, Bird 3 was initially exposed to four sessions of 100% CS-US pairings with the CS located on the right side.)

Fixed-trial signalled response-independent food presentations (100% CS-US pairings). All birds were exposed to fixed-trial signalled response-independent presentations of food. The CS was presented for a fixed period of 8 s, at the end of which it terminated and food was presented for 3 s. CSs were separated by ITIs averaging 60 s (ITIs ranged from 30 s to 90 s). The lengths of the ITIs were determined by a pseudorandom probability generator.

Partial reinforcement. Following exposure to the 100% condition of CS-US pairings, the reinforcement schedule was changed to 50%. The CS presentations and the ITI lengths during PRF were identical to those during the 100% condition except the feeder presentations followed the CS 50% of the time.

Dependent measures. The dependent measures were: (a) percentage of CSs with a movement ≤ 18 cm from the CS, (b) percentage of CSs with a movement ≤ 30 cm from the CS, (c) mean closest distance from the CS, (d) mean distance from the location of the CS at the end of the ITI, 0.1 s before the onset of the CS, (e) percentage of CSs with a movement ≤ 18 cm from the feeder, (f) percentage of CSs with a movement ≤ 30 cm from the feeder, (g) mean closest distance from the feeder during the CS presentation, (h) mean distance from the feeder at the end of the ITI, 0.1 s before the onset of the CS, (i) topview plots of the movement patterns produced by the subject during the CS, and (j) topview plots of the movement patterns produced by the subject during the ITI. All distances were measured from the bird's head.

Operational definitions. An instance of sign-tracking was any movement ≤ 18 cm from the CS, and an instance of goal-tracking was any movement ≤ 18 cm from the feeder during the CS presentation. The criterion was later relaxed such that an instance of sign-tracking was any movement ≤ 30 cm from the CS, and an instance of goal-tracking was any movement ≤ 30 cm from the feeder during the CS presentation.

Data analysis. Measures (a) through (h) were calculated by taking the mean of these measures during the last three sessions of each phase. Movement plots (measures [i] and [j] above) were computer-graphed from stored data. The movement plots are presented from time periods during the 5th, 12th, and 20th CS presentations and during the ITI before each of these CSs from the last session of each phase.

The percentage of CS-US pairings was shifted when the bird's average mean distance from the CS and the feeder during CS presentations during the last three sessions of a phase was within 15% of the average mean distance from the previous five sessions of the phase. Furthermore, no general increasing or decreasing trend could be present over the

last three sessions of a phase. All analyses were done by visual inspection (Kazdin, 1982).

Results

Figures 14 and 15 present information regarding the specific movements of the birds during the CS and during the ITI during 100% and 50% CS-US pairings. Figure 14 shows the movements of each bird, plotted as a path in the horizontal plane (topview) during the 5th, 12th, and 20th CS presentations of the last session of each phase. The phases are shown in the order in which they were presented starting at the top of the figure. The position of the bird at the beginning of each CS presentation is indicated by a black square in each plot. The dot at the top of each plot indicates the position of the feeder and the dot at the lower right or lower left side of the plot indicates the position of the CS.

During 100% CS-US pairings, all birds generally moved toward the feeder at the start of the CS presentation and remained in front of the feeder until food was presented. During the first exposure to 50% CS-US pairings, none of the birds were definitively moving toward the CS when it was presented. Bird 1 occasionally moved in a counterclockwise circle toward the back of the chamber, Bird 2 moved in a clockwise circle toward the back of the chamber, and Bird 3 did not show a significant change in its movement patterns relative to the 100% condition.

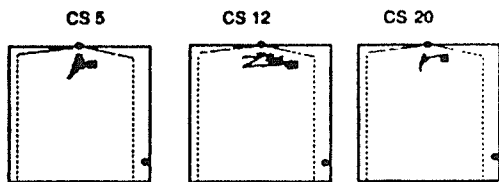
When the CS was moved to the second location during the next 50% condition, the trajectory of the birds' movement patterns changed. Birds 1 and 2 made occasional movements toward the CS and Bird 3 generally moved toward the CS (except for CS 12). During the reinstatement of the first 50% condition, Bird 1 moved toward the CS and made counterclockwise circles toward the back of the chamber and Birds 2 and 3 moved toward the CS. Independent judges confirmed this interpretation of the data (i.e, it was difficult to tell in some instances which side of the chamber the birds were actually moving toward [see Appendix B]).

Figure 15 shows the movements of each bird, plotted as a path in the horizontal plane that occurred during the ITIs prior to the CSs shown in Figure 14. In general, Bird 1 paced along the feeder wall throughout the experiment and Bird 2 remained relatively close to the feeder, although it made occasional excursions away from the feeder. Bird 3 generally engaged in behavior near the feeder and near the back of the chamber during 100% CS-US pairings. Visual observation of this bird, as well as Bird 2, revealed that it "checked" the feeder periodically. Bird 3 became more active during 50% CS-US pairings, although the location of the CS appeared to have little impact upon

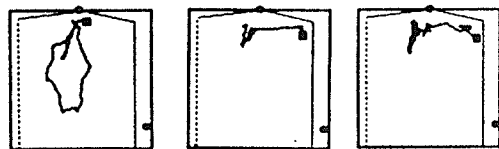
Figure 14. Paths followed by each bird during the 5th, 12th, and 20th CS presentations of the last session of each phase in which the CS was located 60 cm from the feeder plotted from a top view perspective (i.e., the xy or horizontal plane). The position of the feeder is indicated by the dot at the top center of each plot. The position of the CS is indicated by the other dot on the lower left side or the lower right side of each plot. The phases are shown in the order in which they were presented starting at the top of the figure. The explanation of the plots is the same as for Figure 2.

BIRD 1

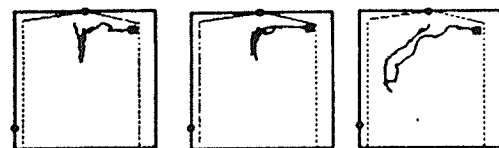
100% CS-US PAIRINGS (CS RIGHT)



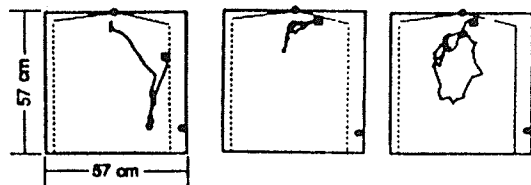
50% CS-US PAIRINGS (CS RIGHT)



50% CS-US PAIRINGS (CS LEFT)

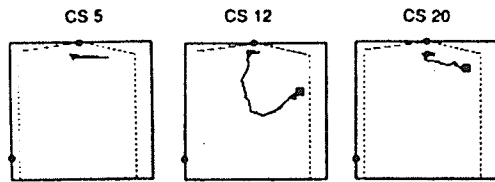


50% CS-US PAIRINGS (CS RIGHT)

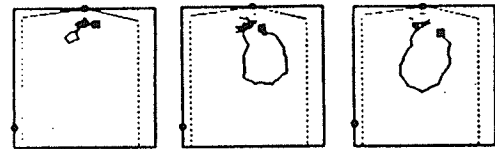


BIRD 2

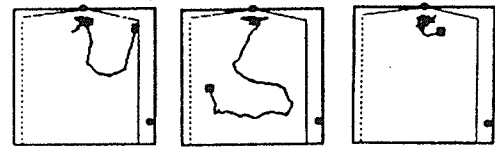
100% CS-US PAIRINGS (CS LEFT)



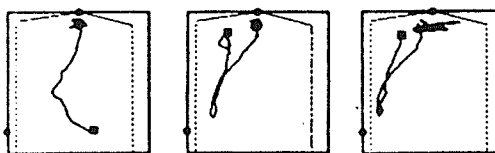
50% CS-US PAIRINGS (CS LEFT)



50% CS-US PAIRINGS (CS RIGHT)

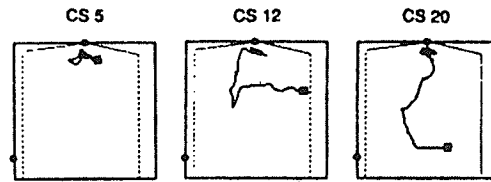


50% CS-US PAIRINGS (CS LEFT)

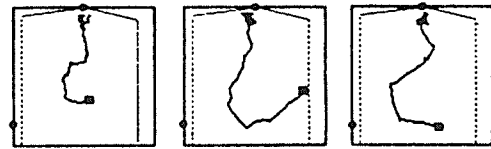


BIRD 3

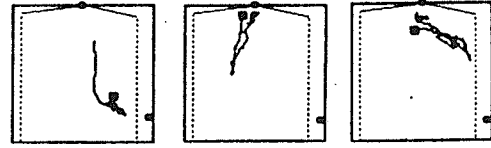
100% CS-US PAIRINGS (CS LEFT)



50% CS-US PAIRINGS (CS LEFT)



50% CS-US PAIRINGS (CS RIGHT)



50% CS-US PAIRINGS (CS LEFT)

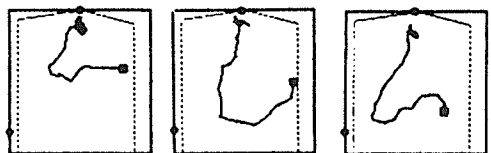
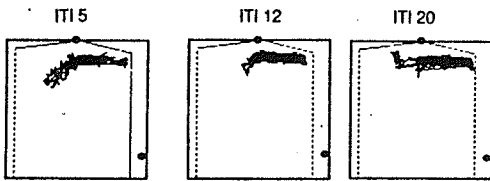


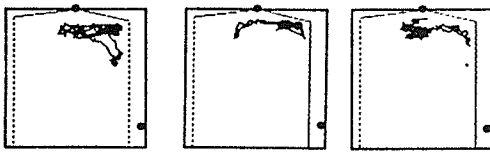
Figure 15. Paths followed by each bird during the ITIs prior to the CS presentations shown in Figure 14. The explanation of the plots is the same as for Figure 14, except that the dot on the lower left side or the lower right side of each plot indicates the position of the CS.

BIRD 1

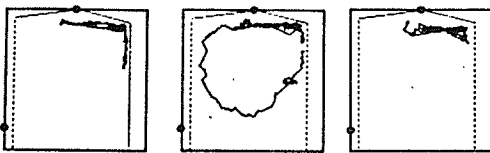
100% CS-US PAIRINGS (CS RIGHT)



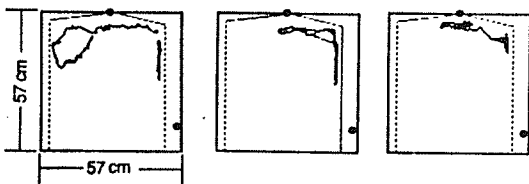
50% CS-US PAIRINGS (CS RIGHT)



50% CS-US PAIRINGS (CS LEFT)

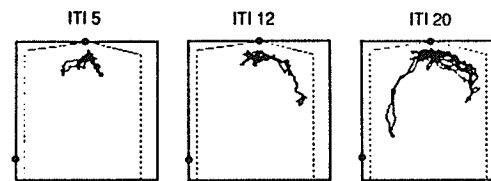


50% CS-US PAIRINGS (CS RIGHT)

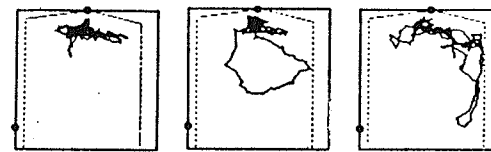


BIRD 2

100% CS-US PAIRINGS (CS LEFT)



50% CS-US PAIRINGS (CS LEFT)



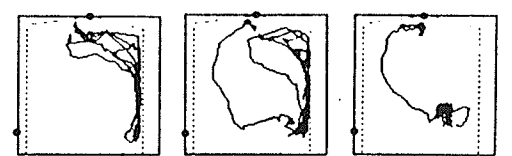
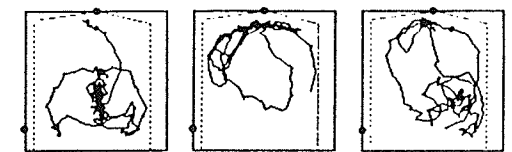
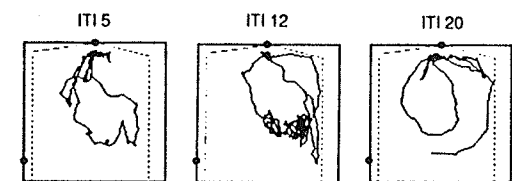
50% CS-US PAIRINGS (CS RIGHT)



50% CS-US PAIRINGS (CS LEFT)



BIRD 3



its behavior during the ITI.

Figure 16 shows the percentage of CSs with a movement ≤ 18 cm from the CS and from the feeder averaged across the last three sessions of each experimental condition. The wall of the chamber on which the CS was located is indicated on the abscissa by an "R" (right wall) or an "L" (left wall). The solid squares indicate the dependent measure taken from the CS and the open squares indicate the dependent measure taken from the point located 60 cm from the feeder on the wall opposite to the CS. (hereafter referred to as the "opposite location"). During the first and the second phases, this point represents the to-be-location of the CS in the third phase of the experiment. During the third phase, this point represents the initial location of the CS during the first and the second phases. During the fourth phase, this point represents the location of the CS during the third phase. This location was used as part of the dependent measure to determine the relative approach to both CS locations used in the experiment. Each error bar represents the standard error of the mean of the last three sessions of each experimental condition. Data from the opposite location during 100% CS-US pairings were not available.

The graphs on the left side of Figure 16 show the percentage of CSs with a movement ≤ 18 cm from the CS (solid squares) and the percentage of CSs with a movement ≤ 18 cm from the opposite location (open squares). When the percentage of CS-US pairings decreased from 100% to 50%, all birds showed an increase in the percentage of CSs with a movement ≤ 18 cm from the CS regardless of which side the CS was located during 100% CS-US pairings.

Comparing the open squares to the solid squares reveals that only Bird 1 reliably moved within 18 cm from the CS more than it moved within 18 cm from the location opposite the CS. Bird 2 moved within 18 cm from the CS more than it moved within 18 cm from the opposite location when the CS was located on the left, but failed to show this effect when the CS was located on the right. Bird 3 moved within 18 cm from the CS more than it moved within 18 cm from the opposite location when the CS was located on the right, but failed to show this effect when the CS was located on the left.

The graphs on the right side of Figure 16 show the percentage of CSs with a movement ≤ 18 cm from the feeder averaged across the last three sessions of each experimental condition. There were no notable changes in this dependent measure across birds and across conditions, except for a decrease during 50% CS-US pairings for Bird 3 when the CS was located on the right side.

Figure 16. Percentage of CSs with a movement ≤ 18 cm from the CS (left graphs) and from the feeder (right graphs) averaged across the last three sessions of each experimental condition. The solid squares indicate the dependent measure taken from the CS and the open squares indicate the dependent measure taken from a point located 60 cm from the feeder on the wall opposite to the CS (referred to as the "opposite location"). (During the first and the second phases, this point represents the to-be-location of the CS in the third phase of the experiment. During the third phase, this point represents the initial location of the CS during the first and the second phases. During the fourth phase, this point represents the location of the CS during the third phase.) The side of the chamber on which the CS was located is indicated on the abscissa by an "R" (right wall) or an "L" (left wall). Each error bar represents the standard error of the mean of the last three sessions of each experimental condition.

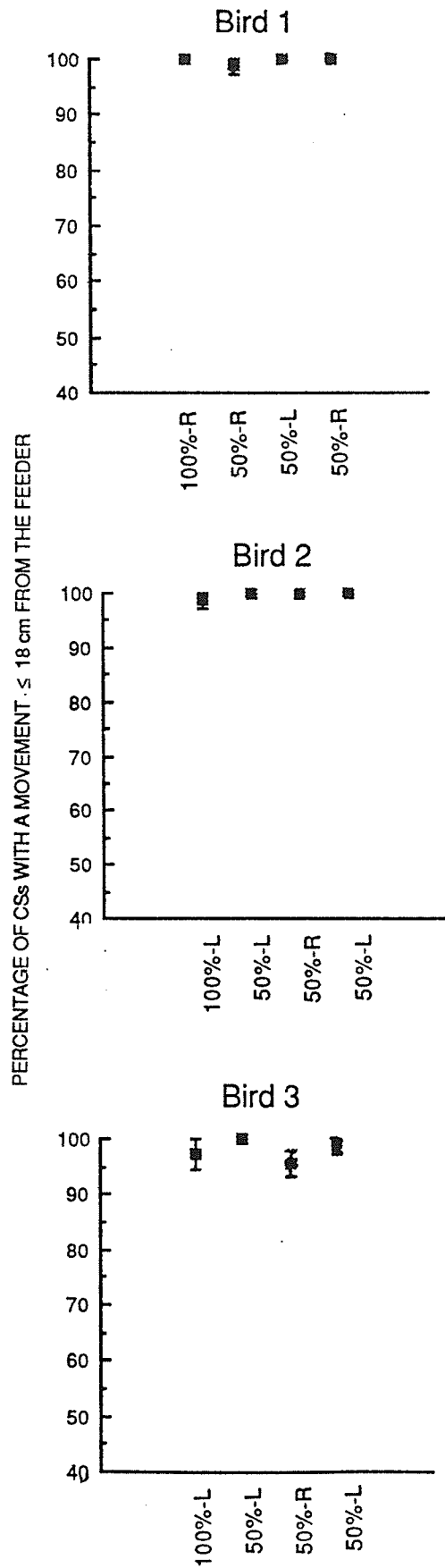
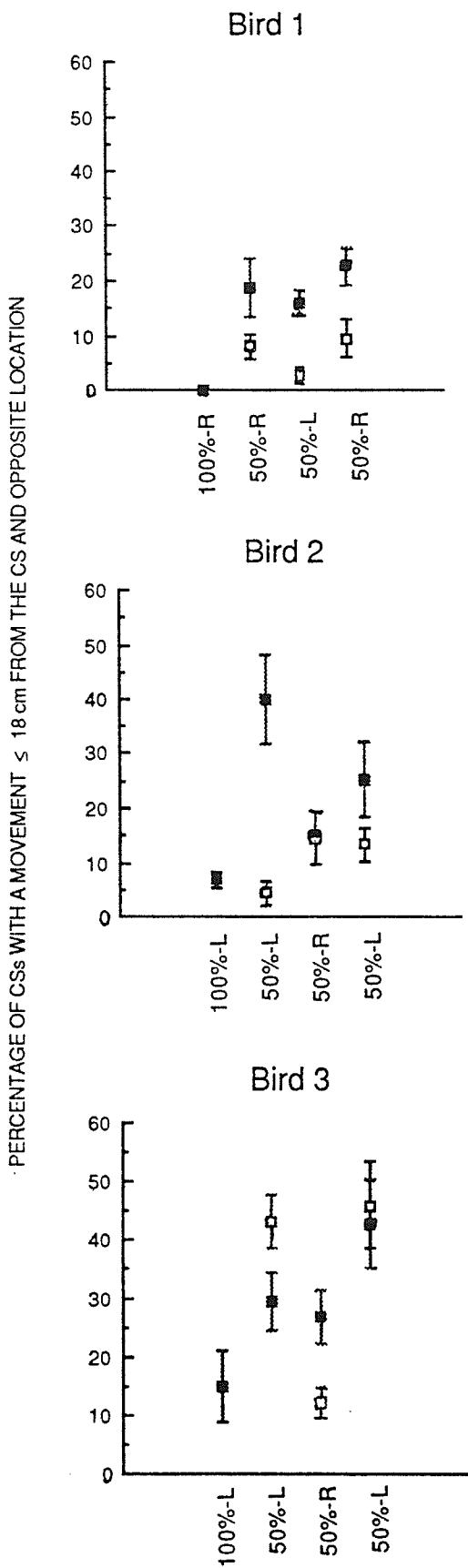


Figure 17 shows the percentage of CSs with a movement ≤ 30 cm from the CS and from the feeder averaged across the last three sessions of each experimental condition plotted according to the format of Figure 16. The graphs on the left side of Figure 17 show the percentage of CSs with a movement ≤ 30 cm from the CS (solid squares) and the percentage of CSs with a movement ≤ 30 cm from the opposite location (open squares). When the percentage of CS-US pairings decreased from 100% to 50%, all birds showed an increase in the percentage of CSs with a movement ≤ 30 cm from the CS.

Comparing the open squares to the solid squares reveals that only Bird 1 reliably moved within 30 cm from the CS more than it moved within 30 cm from the opposite location. Bird 2 moved within 30 cm from the CS more than it moved within 30 cm from the opposite location when the CS was initially located on the left side. However, Bird 2 failed to show this effect when the CS was located on the right side and upon returning the CS to the left side. Bird 3 moved within 30 cm from the CS more than it moved within 30 cm from the opposite location when the CS was located on the right, but failed to show this effect when the CS was located on the left side.

The graphs on the right side of Figure 17 show the percentage of CSs with a movement ≤ 30 cm from the feeder averaged across the last three sessions of each phase. There were no notable changes in this dependent measure across birds and across conditions.

Figure 18 shows the birds' mean closest distance from the CS and from the feeder during the CS averaged across the last three sessions of each experimental condition plotted according to the format of Figure 16. The graphs on the left side of Figure 18 show the mean closest distance from the CS (solid squares) and the mean closest distance from the opposite location (open squares). When the percentage of CS-US pairings decreased from 100% to 50%, all birds showed a decrease in mean closest distance from the CS regardless of which side the CS was located during 100% CS-US pairings.

Comparing the open squares to the solid squares reveals that Bird 1 failed to show any difference between its distance from the CS and its distance from the opposite location during the initial 50% condition when the CS was located on the right side. However, Bird 1 moved closer to the CS than to the opposite location during the subsequent phases. Bird 2 moved closer to the CS than to the opposite location when the CS was located on the left side, but failed to show this effect when the CS was located on the right side. Bird 3 moved closer to the opposite location than to the CS when the CS

Figure 17. Percentage of CSs with a movement ≤ 30 cm from the CS (left graphs) and from the feeder (right graphs) averaged across the last three sessions of each experimental condition. Each error bar represents the standard error of the mean of the last three sessions of each experimental condition. The explanation of the plots is the same as for Figure 16.

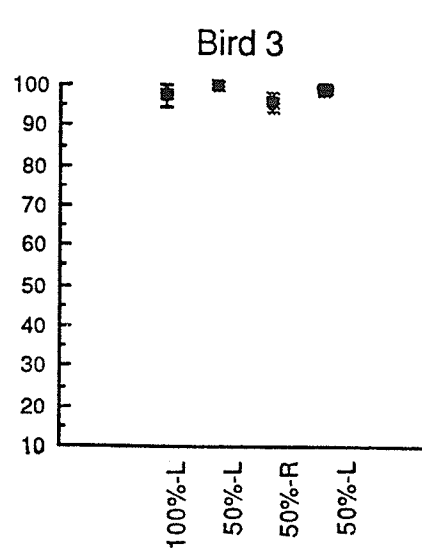
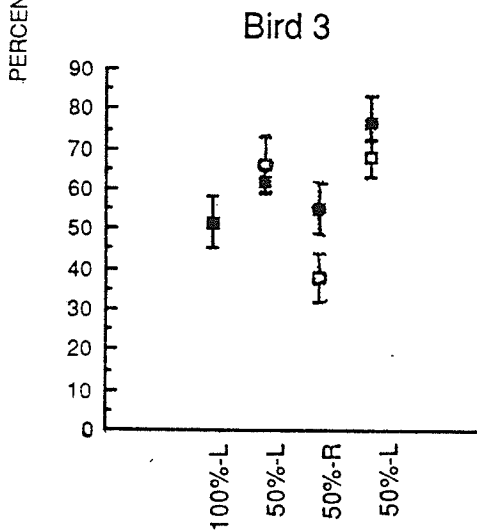
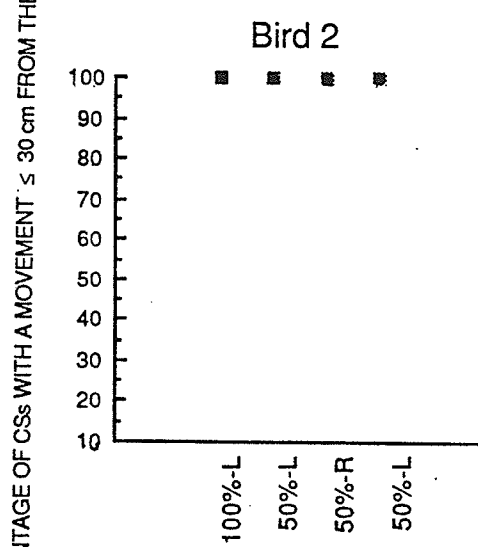
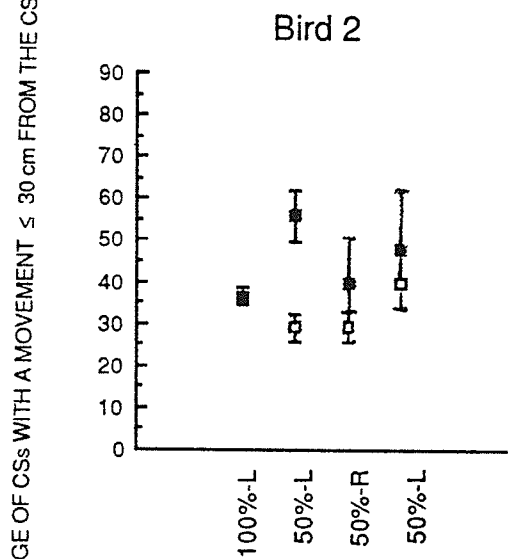
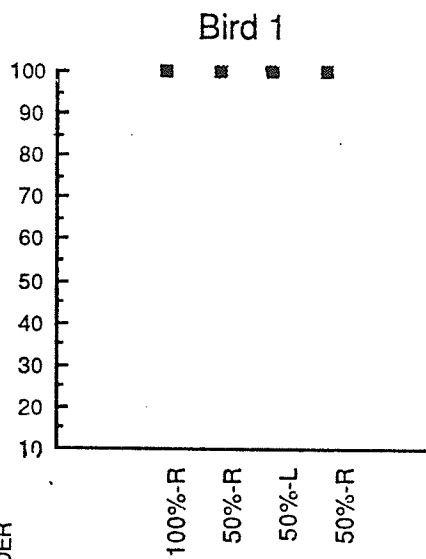
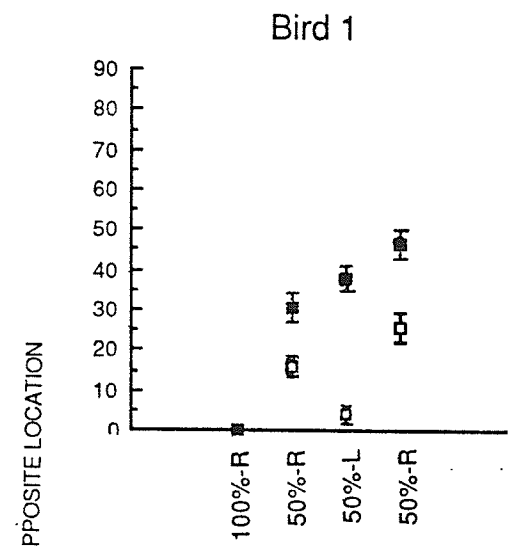
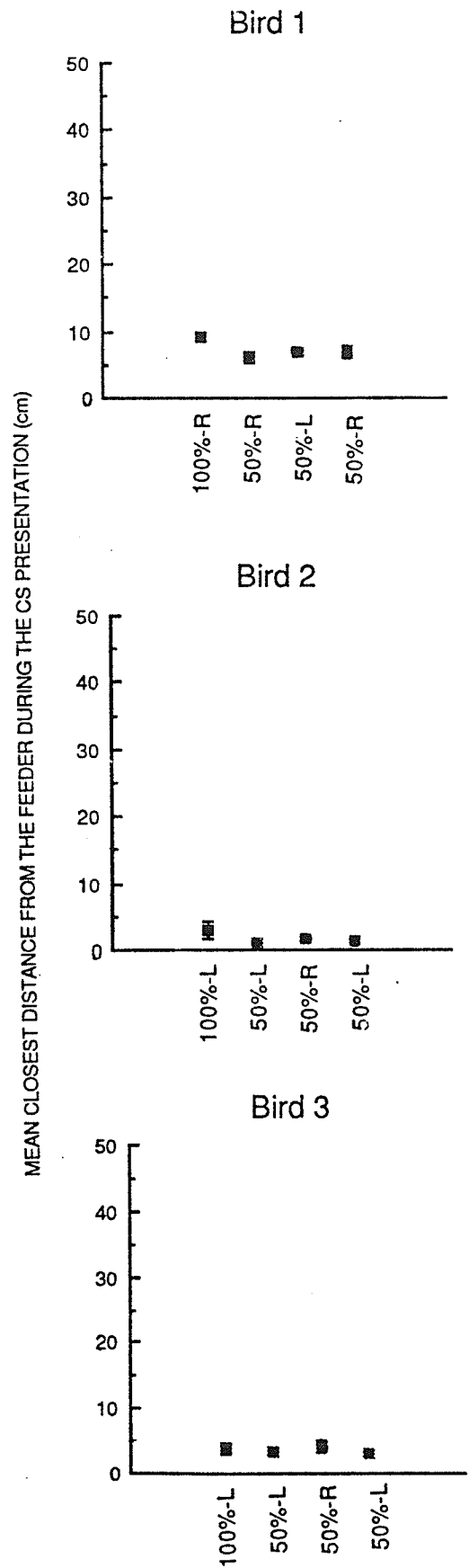
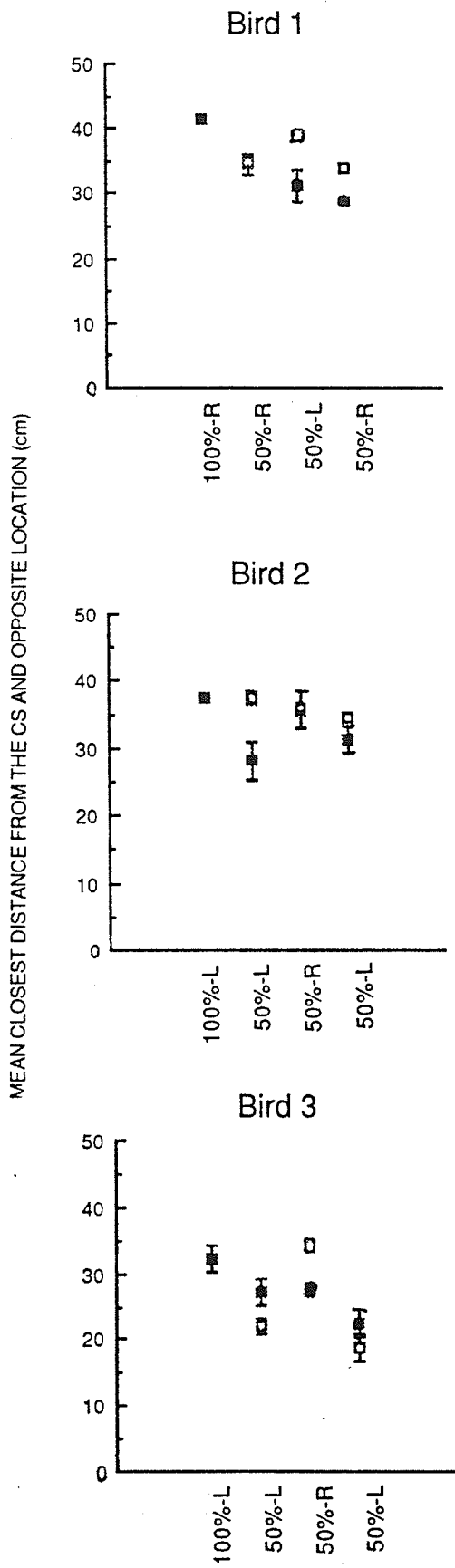


Figure 18. Each bird's mean closest distance from the CS (left side graphs) and from the feeder during the CS (right side graphs) averaged across the last three sessions of each experimental condition. Each error bar represents the standard error of the mean of the last three sessions of each experimental condition. The explanation of the plots is the same as for Figure 16.



was initially located on the left side. This bird was closer to the CS than to the opposite side when the CS was located on the right side, but failed to show any difference between its distance from the CS and its distance from the opposite location upon returning the CS to the left side.

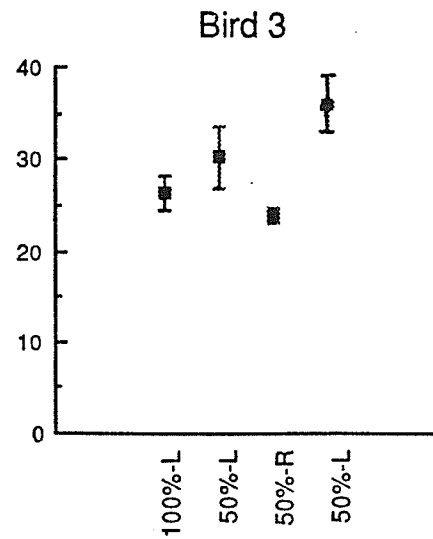
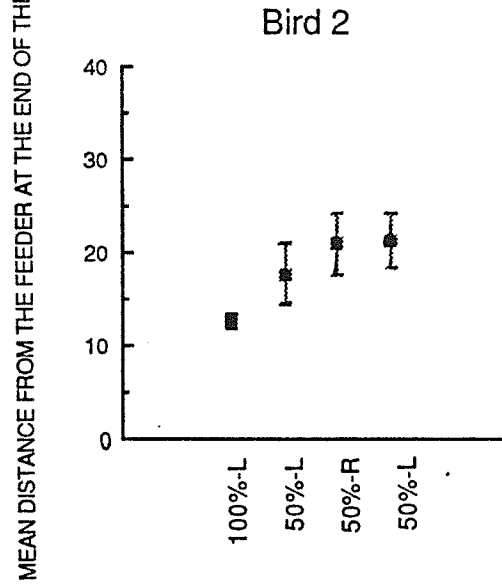
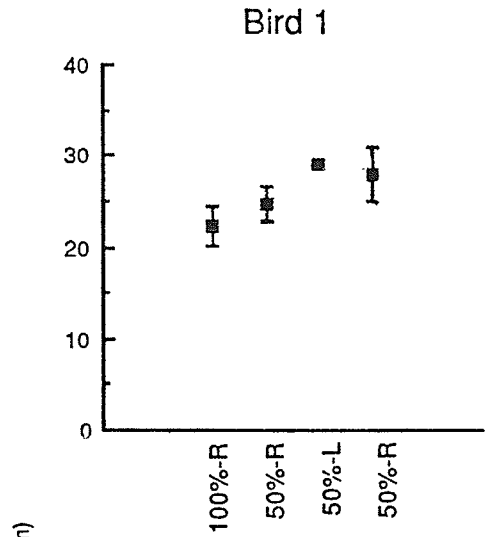
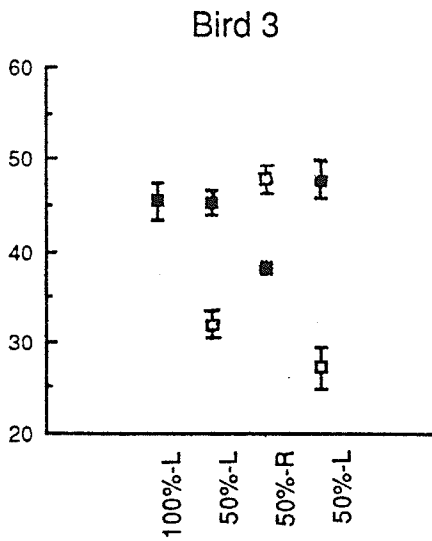
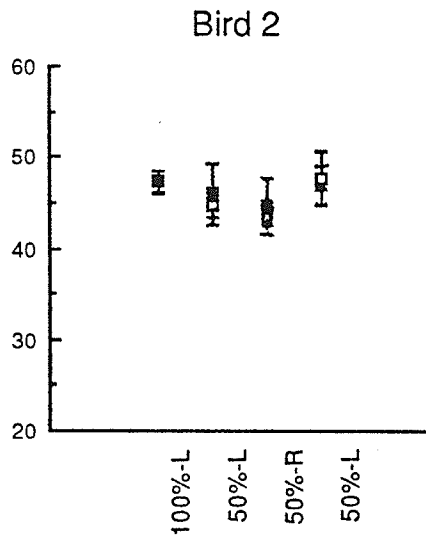
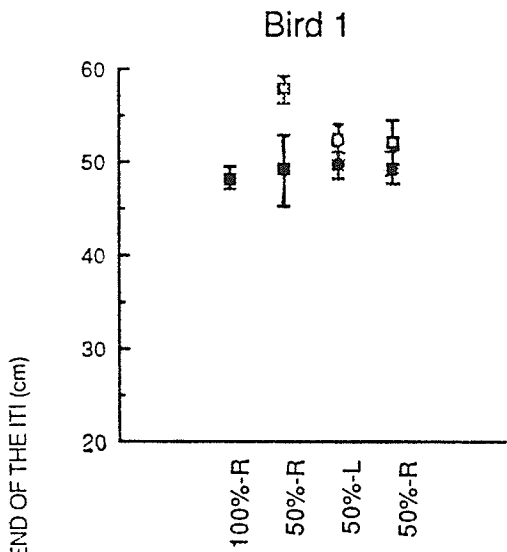
The graphs on the right side of Figure 18 shows the birds' mean closest distance from the feeder averaged across the last three sessions of each experimental condition. When the percentage of CS-US pairings decreased from 100% to 50%, Bird 1 showed a decrease in its distance from the feeder and remained at this level during subsequent phases. There were no notable changes in this dependent measure for Birds 2 and 3 across conditions.

Figure 19 shows the birds' mean distance from the location of the CS and the feeder at the end of the ITI, 0.1 s before the onset of the CS, averaged across the last three sessions of each experimental condition and plotted according to the format of Figure 16. The graphs on the left side of Figure 19 show the mean distance from the location of the CS at the end of the ITI (solid squares) and the mean distance from the opposite location at the end of the ITI (open squares). All birds failed show a change in mean distance from the location of the CS immediately before the onset of the CS across experimental conditions, except for Bird 3 which showed a decrease in the level of this dependent measure when the CS was located on the right side.

Comparing the open squares to the solid squares reveals that Bird 1, at the end of the ITI, was closer to the location of the CS than to the opposite location during the initial 50% condition when the CS was located on the right side, but failed to show this effect during subsequent phases. Bird 2, at the end of the ITI, failed to show any difference between its distance from the location of the CS and its distance from the opposite location during all 50% CS-US pairings conditions. Bird 3, at the end of the ITI, was closer to the opposite location than to the location of the CS when the CS was located on the left side during 50% CS-US pairings. However, this bird was closer to the location of the CS than to the opposite location when the CS was located on the right side.

The graphs on the right side of Figure 19 show the birds' mean distance from the feeder at the end of the ITI averaged across the last three sessions of each phase. When the percentage of CS-US pairings decreased from 100% to 50%, Bird 1 failed to show a change in its distance at the end of the ITI, but showed an increase in this dependent measure when the CS was moved to the second side. Bird 2 showed an increase when the percentage of CS-US pairings decreased from 100% to 50%, and remained at this level

Figure 19. Each birds' mean distance from the location of the CS at the end of the ITI (left graphs) and from the feeder at the end of the ITI (right graphs), 0.1 s before the onset of the CS, averaged across the last three sessions of each experimental condition. Each error bar represents the standard error of the mean of the last three sessions of each experimental condition. The explanation of the plots is the same as for Figure 16.



throughout the experiment. Bird 3 failed to show a change when the percentage of CS-US pairings decreased from 100% to 50%, but showed a decrease when the location of the CS was moved to the second side and an increase in the level of this dependent measure when the CS was switched back to the original side.

Discussion

The purpose of Experiment 2 was to replicate the effects shown in Experiment 1 that the birds were sign-tracking during 50% CS-US pairings more than during 100% CS-US pairings. Furthermore, Experiment 2 sought to provide data showing that the birds were not just moving to the left side of the chamber as a result of some bias or predisposition to approach the left side.

Although it was suggested in Experiment 1 that plots of the birds' movements during the CSs were the best representation of sign- and goal-tracking, the results of Experiment 2 show the importance of supplemental quantitative measures. The data in Figure 16 (and a similar effect shown in Figures 17 and 18) shows that the birds increased their instances of sign-tracking when the percentage of CS-US pairings decreased from 100% to 50%, and added some additional support to the conclusions obtained in Experiment 1 and those of previous research (Boakes, 1979; Davey & Cleland, 1982) that PRF increases sign-tracking. As shown in Figures 16 to 18, the results of Experiment 2 suggest that PRF increases sign-tracking regardless of which side the CS was initially located during 100% CS-US pairings. A lack of definitive effects (when we compare the data from the CS to the data from the opposite location) may have been partially due to the fact that the birds had an extensive history of approaching the CS on the left side of the chamber. Even so, there were clear instances of approach to the CS when it was located on the right side (see Figure 14). There were no large changes in the quantitative measures of goal-tracking.

Experiment 2 also raises questions regarding the measurement of sign- and goal-tracking. The movement plots during the CS presentations did not reveal changes in sign-tracking resulting from PRF as clearly as those in Experiment 1. However, when sign-tracking did occur, the movement plots did capture the behavior (see Figure 14, Bird 1, 50% CS left-US pairings, CS 20; Bird 1, 50% CS right (reversal)-US pairings, CS 5; Bird 2, 50% CS right-US pairings, CS 12; Bird 2, 50% CS left (reversal)-US pairings, CSs 12 and 20; Bird 3, 50% CS right-US pairings, CSs 5 and 20; Bird 3, 50% CS left (reversal)-US pairings, CSs 12 and 20). In Experiment 2, consistent effects were noted in the percentage of CSs with a movement ≤ 18 cm from the CS.

In addition to their history of approaching the CS on the left side, the failure of some of the dependent measures to capture an effect may be related to the birds' movement patterns during ITI. Consider the following example. The data of Bird 3 shows that it had a higher percentage of CSs with a movement ≤ 18 cm from the opposite side than to the CS, during its first exposure to the CS on the left side at 50% CS-US pairings (see Figure 16). As shown in Figure 15, during 50% CS-US pairings, Bird 3 generally engaged in a movement pattern during the ITI that took it near the right wall. Similarly, the black square in this bird's plots shown in Figure 14 show that, in general, this bird was located near the right wall at the onset of the CS. Thus, the combination of the movement pattern during the ITI and the approach path during the CS could produce data like that shown in Figure 16, suggesting that this bird made more frequent closer approaches to the opposite side than to the CS. Note that this effect was not observed when the CS was located on the right side. The opposite side is now the left side where the bird spends little time during the ITI.

If the movement patterns during the ITI keep the bird away from either side wall (i.e., away from the vicinity of the CS and the opposite location), then the data become clearer. Consider Bird 1's data in Figures 14, 15, 16, and 17. The plots in Figure 15 show that this bird paced along the feeder wall during the ITI. Because of this, any approach to the CS will be distinct from the ITI pattern and the bird's location at the end of the ITI. However, even a bird that engages in ITI behavior away from the CS could yield quantitative data like that of Bird 3 if its approach pattern to the CS takes it closer to the opposite location than to the CS, independent of whether the bird was going to approach the opposite location. Thus, the movement plots shown in Figure 14 best allow the researcher to make informed decisions regarding sign- and goal-tracking, although having quantitative data facilitates interpretation. Furthermore, it may be necessary to present the movement patterns in another form (discussed below).

Two shortcomings of Experiment 2 limit interpretations of the results. First, the location of the CS was not changed during 100% CS-US pairings; hence, it was not possible to compare the effects noted during the second CS location (i.e., the third experimental phase) to the effects of the same CS location during 100% CS-US pairings. Second, data from the opposite location were not available during the 100% condition. These shortcomings, however, do not appear to be serious because (a) sign-tracking increased for all birds when shifted from 100% to 50% CS-US pairings regardless of the initial location of the CS and (b) the movement plots in Figure 14 show instances of movements highly directed toward the CS.

General Discussion

The results of Experiment 1 suggest that 50% CS-US pairings increases sign-tracking and, therefore, must also decrease goal-tracking if we consider the movement plots in Figure 4, which contain information regarding length, angle, and proximity of approach over time. If we consider quantitative measures based solely on distance, then it appears the PRF increases sign-tracking but has little effect on goal-tracking. A reduction in all behavior was noted at 10% CS-US pairings. The quantitative measures of Experiment 2 replicated the results of Experiment 1, showing that PRF increases movement toward the CS regardless of the initial location of the CS and provided that the CS-US distance is held constant.

Difficulties in measuring sign- and goal-tracking were discussed above and suggest that the movement plots of the birds during the CS were the best way to assess sign- and goal-tracking. However, movement plots alone, without supplemental quantitative measures would probably not have been sufficient to draw conclusions regarding the effect of PRF on sign- and goal-tracking behavior (especially in Experiment 2). In order for movement plots to be sufficient, the method of data presentation will likely require some improvements. The method used in the two experiments presented here involved presenting three CSs (CSs 5, 12, and 20) from the final session of each experimental condition. Consider the following example illustrating how this method of presentation may be insufficient. Let us suppose that a bird sign-tracks a CS located 60 cm from the feeder on 5% of the trials during 100% CS-US pairings and that there are 25 trials per session. Let us suppose further that PRF increases instances of sign-tracking to 25%; thus, PRF increased sign-tracking by an additional 20%. Even though there was a significant increase in sign-tracking, the probability of presenting one or more of these CSs with an instance of sign-tracking as one of the three CSs presented is quite low. The method of arbitrarily choosing three CSs from the data may not be the best way to present the data unless the same behavior is occurring on many trials (see Silva et al., in press). An alternate method of presentation could involve plotting every CS from a session overtop of each other. The density of the plot would then allow you to more readily interpret changes in the data, partly alleviating the experimenter of making decisions regarding the representativeness of the sampled plots since all trials would be represented. Similarly, as a means of addressing the question of whether behavior during the CS presentation represents an extension of the ITI behavior, an 8-s random sample taken from each ITI of a session could be plotted overtop of each other in a similar fashion. This plot could then be compared to the plot of the CSs.

Another alternative to measuring approach behavior is to measure approach as a two-dimensional vector having length (distance) and angle (direction) across the dimension of time (see Batschelet, 1981). Using this method, it may be possible to detect a "purposeful" approach to the CS versus an "inadvertent" approach to the CS that occurs as part of the approach pattern to the feeder.

A potential problem with both experiments concerns the use of a CS-US distance equal to 60 cm. Specifically, using an intermediate distance (e.g., 39 cm) that is known to result in moderate rates of sign-tracking and goal-tracking (in contrast to the 60 cm distance which produces relatively no sign-tracking and high rates of goal-tracking; Silva et al., in press) may have resulted in larger changes in sign- and goal-tracking during PRF. It may, for example, be easier to increase sign-tracking and decrease goal-tracking when these occur at more moderate levels than when they occur at extreme levels.

Finally, a comment should be made regarding the size of some of the effects observed in the two experiments. Sidman (1960) has pointed out that small consistent effects are potentially important effects. The effects observed in the present study were generally small. This, however, is not unusual in sign- and goal-tracking research when the percentage of reinforcement is manipulated (Holland, personal communication, January, 1991). Recently, Janssen, Farley, and Hearst (1991) reported statistically significant changes in sign-tracking behavior with mean effects as small as 0.1 s. It will be left to future research to determine what PRF procedures, if any, can substantially alter the sign-/goal-tracking relation.

References

- Amsel, A. (1958). The role of frustrative nonreward in noncontinuous reward situations. Psychological Bulletin, 55, 102-119.
- Amsel, A. (1962). Frustrative nonreward in partial reinforcement and discrimination learning. Psychological Review, 69, 306-328.
- Antip, G. W. (1974). Stimulus- and response-reinforcer contingencies in autoshaping, operant, classical, and omission training procedures in rats. Journal of the Experimental Analysis of Behavior, 28, 59-69.
- Barrera, F. J. (1974). Centrifugal selection of signal-directed pecking. Journal of the Experimental Analysis of Behavior, 22, 341-355.
- Batschelet, E. (1981). Circular statistics in biology. London: Academic Press.
- Baum, W. M. (1974). On two types of deviation from the matching law: Bias and undermatching. Journal of the Experimental Analysis of Behavior, 22, 231-242.
- Baum, W. M. (1979). Matching, undermatching, and overmatching in studies of choice. Journal of the Experimental Analysis of Behavior, 32, 269-281.
- Brandon, S. E. & Paul, H. (1987). The effects of activity conditioned in random CS/US training on performance in autoshaping. Animal Learning and Behavior, 15, 263-284.
- Bilbrey, J. & Winokur, S. (1973). Controls for and constraints on autoshaping. Journal of the Experimental Analysis of Behavior, 20, 323-332.
- Boakes, R. A. (1977). Performance on learning to associate a stimulus with positive reinforcement. In H. Davis & H. M. B. Hurwitz (Eds.), Operant-Pavlovian interactions (pp. 67-101). Hillsdale, N.J.: Erlbaum.
- Boakes, R. A. (1979). Interaction between type I and type II processes involving positive reinforcement. In A. Dickinson & R. A. Boakes (Eds.), Mechanisms of Learning and Motivation (pp. 234-268). Hillsdale, N.J.: Erlbaum.
- Brown, J. S. (1961). The motivation of behavior. New York: McGraw Hill.
- Brown, P. L., & Jenkins, H. M. (1968). Auto-shaping of the pigeon's key-peck. Journal of the Experimental Analysis of Behavior, 11, 1-8.
- Cleland, G. G., & Davey, G. C. L. (1983). Autoshaping in the rat: The effects of localizable visual and auditory signals for food. Journal of the Experimental Analysis of Behavior, 40, 47-56.

- Davey, G. C. L., & Cleland, G. G. (1982). The effect of partial reinforcement on the acquisition and extinction of sign-tracking and goal-tracking in the rat. Bulletin of the Psychonomic Society, 19, 115-118.
- Davey, G. C. L., & Cleland, G. G. (1984). Food anticipation and lever-directed activities in rats. Learning and Motivation, 15, 12-36.
- Davey, G. C. L., Cleland, G. G., & Oakley, D. A. (1982). Applying Konorski's model of classical conditioning to signal-centered behavior in the rat: Some functional similarities between hunger CRs and sign-tracking. Animal Learning and Behavior, 10, 257-262.
- Davey, G. C. L., Oakley, D. A., & Cleland, G. G. (1981). Autoshaping in the rat: Effects of omission on the form of the response. Journal of the Experimental Analysis of Behavior, 36, 75-91.
- Davey, G. C. L., Phillips, S., & Cleland, G. G. (1981). The topography of signal-centered behaviour in the rat: The effects of solid and liquid reinforcers. Behaviour Analysis Letters, 1, 331-337.
- Downing, K., & Neuringer, A. (1976). Autoshaping as a function of prior food presentations. Journal of the Experimental Analysis of Behavior, 26, 463-469.
- Eldridge, G. D., & Pear, J. J. (1987). Topographical variations in behavior during autoshaping, automaintenance, and omission training. Journal of the Experimental Analysis of Behavior, 47, 319-333.
- Engberg, L. A., Hansen, G., Welker, R. L., & Thomas, D. R. (1972). Acquisition of key-pecking via autoshaping as a function of prior experience: "Learned laziness". Science, 178, 1002-1004.
- Farwell, B. J., & Ayres, J. J. B. (1979). Stimulus-reinforcer and response-reinforcer relations in the control of conditioned appetitive head-poking ("goal tracking") in rats. Learning and Motivation, 10, 295-312.
- Gamzu, E., & Williams, D. R. (1971). Classical conditioning a complex skeletal response. Science, 171, 301-303.
- Gibbon, J., & Balsam, P. (1981). The contingency problem in autoshaping. In C. M. Locurto, H. S. Terrace, & J. Gibbon (Eds.), Autoshaping and conditioning theory. New York: Academic Press.
- Gibbon, J., Farrell, L., Locurto, C. M., Duncan, H. J., & Terrace, H. S. (1980). Partial reinforcement in autoshaping with pigeons. Animal Learning and Behavior, 8, 45-59.

- Gonzalez, F. A. (1974). Effects of varying the percentage of key illuminations paired with food in a positive automaintenance procedure. Journal of the Experimental Analysis of Behavior, 22, 483-489.
- Grastyan, E., & Vereczkei, L. (1974). Effects of spatial separation of the conditioned signal from the reinforcement: A demonstration of the conditioned character of the orienting response or the orientational character of conditioning. Behavioral Biology, 10, 121-146.
- Hearst, E. (1975). Pavlovian conditioning and directed movements. In G. Bower (Ed.), The psychology of learning and motivation (Vol. 9, pp. 215-262). New York: Academic Press.
- Hearst, E. (1979). Classical conditioning as the formation of interstimulus association: Stimulus substitution, parasitic reinforcement, and autoshaping. In A. Dickinson & R. A. Boakes (Eds), Mechanisms of learning and motivation: A memorial volume to Jerzy Konorski (pp. 19-52). New York: Wiley.
- Hearst, E., & Franklin, S. R. (1977). Positive and negative relations between a signal and food: Approach-withdrawal behavior to the signal. Journal of Experimental Psychology: Animal Behavior Processes, 3, 37-52.
- Hearst, E., & Jenkins, H. M. (1974). Sign tracking: The stimulus-reinforcer relation and directed action. Monograph of the Psychonomic Society: Austin, Texas.
- Holland, P. C. (1977). Conditioned stimulus as determinant of the form of the pavlovian conditioned response. Journal of Experimental Psychology: Animal Behavior Processes, 3, 77-104.
- Holland, P. C. (1979). Differential effects of omission contingencies on various components of pavlovian conditioned responding in rats. Journal of Experimental Psychology: Animal Behavior Processes, 5, 178-193.
- Hollis, K. L. (1982). Pavlovian conditioning of signal-centered action patterns and autonomic behavior: A biological analysis of function. In J. S. Rosenblatt, R. F. Hinde, C. Beer, & M. C. Busnel (Eds.), Advances in the study of behavior (Vol. 8, pp. 1-64). New York: Academic Press.
- Janssen, M., Farley, J., & Hearst, E. (1991, March). Temporally specific effects of unsignalled food presentation in conditioned excitation and conditioned inhibition autoshaping procedures with pigeons. Paper presented at the meeting of the Sixth Annual Indiana-Purdue-Kentucky Conference on Animal Learning and Behavior, Lexington, KY.

- Jenkins, H. M., & Moore, B. R. (1973). The form of the autoshaped response with food or water reinforcers. Journal of the Experimental Analysis of Behavior, 20, 163-182.
- Kazdin, A. E. (1982). Single-case research designs Methods of clinical and applied settings. New York: Oxford University Press.
- Konorski, J. (1967). Integrative activity of the brain. Chicago: University Press of Chicago.
- Locurto, H. S., Terrace, H. S., & Gibbon, J. (Eds.) (1981). Contributions of autoshaping to the partitioning of conditioned behavior. Autoshaping and conditioning theory. New York: Academic Press.
- Locurto, C., Terrace, H. S., & Gibbon, J. (1976). Autoshaping, random control, and omission training in the rat. Journal of the Experimental Analysis of Behavior, 26, 451-462.
- Matthews, T. J., & Lerer, B. E. (1987). Behavior patterns in pigeons during autoshaping with an incremental conditioned stimulus. Animal Learning and Behavior, 15, 69-75.
- Pear, J. J. (1985). Spatiotemporal patterns of behavior produced by variable-interval schedules of reinforcement. Journal of the Experimental Analysis of Behavior, 44, 217-231.
- Pear, J. J. (1988). Behavioral stereotypy and the generalized matching equation. Journal of the Experimental Analysis of Behavior, 50, 87-95.
- Pear, J. J., & Eldridge, G. D. (1984). The operant- respondent distinction: Future directions. Journal of the Experimental Analysis of Behavior, 42, 453-467.
- Pearce, J. M. & Collins, L. (1987). An evaluation of the associative strength of a partially reinforced serial CS. The Quarterly Journal of Experimental Psychology, 39, 273-305.
- Peden, B. F., Browne, M. P., & Hearst, E. (1977). Persistent approaches to a signal for food despite food omission for approaching. Journal of Experimental Psychology: Animal Behavior Processes, 3, 377-399.
- Perkins, C. C., Beavers, W. O., Hancock, R. A. Jr., Hemmendinger, P. C., Hemmendinger, D., & Ricci, J. A. (1975). Some variables affecting the rate of Key-pecking during response-independent procedures (autoshaping). Journal of the Experimental Analysis of Behavior, 24, 59-72.

- Schwartz, B., & Williams, E. (1972). The role of the response-reinforcer contingency in negative automaintenance. Journal of the Experimental Analysis of Behavior, *17*, 351-357.
- Sidman, M. (1960). Tactics of scientific research: Evaluating experimental data in psychology. New York: Basic Books.
- Silva, F. J., Silva, K. M., & Pear, J. J. (in press). Sign- vs. goal-tracking: The effects of CS-US distance. Journal of the Experimental Analysis of Behavior.
- Skinner, B. F. (1971). A technical comment on auto-shaping. Science, *173*, 752.
- Timberlake, W. (1983). The functional organization of appetitive behaviour: Behaviour systems and learning. In M. D. Zeiler & P. Harzem (Eds.), Advances in analysis of behaviour (Vol. 3): Biological factors in learning. New York: Wiley.
- Timberlake, W. (1986). Unpredicted food produces a mode of behavior that affects rats' subsequent reactions to a conditioned stimulus: A behavior-system approach to "context blocking". Animal Learning and Behavior, *14*, 276-286.
- Timberlake, W. (1990). Natural learning in laboratory paradigm. In D. A. Dewsbury (Ed.), Contemporary issues in comparative psychology (pp. 31-54). Sunderland, M.A.: Sinauer Associates.
- Timberlake, W., & Grant, D. L. (1975). Autoshaping in rats to the presentation of another rat predicting food, Science, *190*, 690-692.
- Timberlake, W. & Lucas, G. (1989). Behavior systems and learning: From misbehavior to general principles. In S. B. Klein & R. R. Mower (Eds.), Contemporary learning theories: Instrumental conditioning theory and the impact on biological constraints on learning (pp. 237-275). Hillsdale, N. J.: Erlbaum Associates.
- Timberlake, W., Wahl, G., & King, D. (1982). Stimulus and response contingencies in the misbehavior of rats. Journal of Experimental Psychology: Animal Behavior Processes, *8*, 62-85.
- Tomie, A. (1981). Effects of unpredictable food on the subsequent acquisition of autoshaping: Analysis of the context blocking hypothesis. In C. M. Locurto, H. S. Terrace, & J. Gibbon (Eds.), Autoshaping and conditioning theory (pp.181-210). New York: Academic Press.
- Tomie, A., Brooks, W., & Zito, B. (1989). Sign-tracking: The search for reward. In S. B. Klein & R. R. Mower (Eds.), Contemporary Learning Theories: Pavlovian conditioning and the status of traditional learning theory (pp. 191-217). Hillsdale, N. J.: Erlbaum Associates.

- van Haaren, F., van Hest, A., & van de Poll, N. (1987). Acquisition and reversal of a discriminated autoshaped response in male and female rats: Effects of long or short fixed or variable intertrial interval durations. Learning and Motivation, 18, 220-233.
- van Hest, A., van Haaren, F., Kopp, P., & van der Schoot, F. (1986). Stimulus-and-feeder-directed behavior in a long-box: Effect of fixed versus variable time schedules of food presentation. Animal learning and Behavior, 14, 168-172.
- Wasserman, E. A. (1973). The effect of redundant contextual stimuli on autoshaping the pigeon's keypeck. Animal Learning and Behavior, 1, 198-296.
- Wasserman E. A. (1981). Response evocation in autoshaping: Contributions of cognitive and comparative-evolutionary analyses to an understanding of directed action. In C. M. Locurto, H. S. Terrace, & J. Gibbon (Eds.), Autoshaping and conditioning theory (pp. 21-47). New York: Academic Press.
- Wasserman, E. A., Franklin, S. R., & Hearst, E. (1974). Pavlovian appetitive contingencies and approach versus withdrawal to conditioned stimuli in pigeons. Journal of Comparative and Physiological Psychology, 86, 616-627.

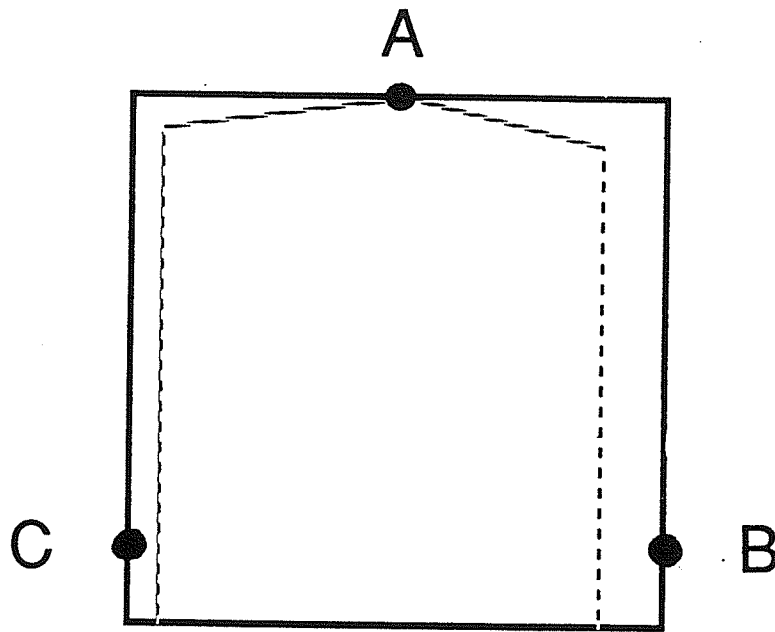
Appendix A

The judges were not trained to examine the data; therefore, their responses are not reported as interobserver agreements (IOA). In order for IOA data to be meaningful, the judges should have been trained on what to look for and provided with operation definitions of the phenomenon to increase the probability of agreement (Kazdin, 1982). Thus, the data are presented as a raw frequency count, rather than percent agreement. The subjects were given the following instructions:

"Each diagram represents the floor of a chamber for an experimental animal. (Judges shown an outline of the floor of the chamber with the three locations indicated.) Note the three locations labelled "A," "B," and "C." I am going to show you some plots representing the movements of the animal in the chamber (location "A" corresponded to the location of the feeder; location "B" corresponded to the location of the right side-CS in Experiment 2; location "C" corresponded to the left side-CS in Experiments 1 and 2). For each plot, I would like you to write on this sheet (judges handed a sheet), next to the number of the plot, the location or locations (if any) that the animal appears to have been approaching. If the animal appears to have approached more than one location, I would like you to indicate in what order the animal approached the different locations. For example, if the animal just approached location A, just write "A" beside the number corresponding to the plot. If the animal approached A and then B, write "AB." And so on. If the animal did not appear to approach any of the locations, write "none." Do you have any questions? (Any questions were answered) Here is the first plot. Note the line showing the path the animal took. The black square (I pointed to the black square) represents the animal's starting point. Do you have any questions on how to interpret the plot? (Any questions were answered. I then handed the subject each individual plot shown in Figures 2, 4, and 14 in a random order (for a total of 90 individual plots). When the judge finished with a plot, the next plot was presented, and so forth until all 90 plots were judged."

Judge 1 was an undergraduate business major who had not previously seen the data; Judge 2 was an undergraduate psychology major who had not previously seen the data. Judge 3 was a psychology graduate student who had previously seen the data. Judge 4 was a psychology graduate student who had not previously seen the data.

Each value in the table corresponds to the total number of approaches to a location summed across all four judges. Note that judges indicated more than one approach to single location (e.g., A -B- A) for some plots. These approaches are also included in the total number of approaches. The judges were not permitted to compare plots.



Bird 1				
Location/ Phase	Feeder	CS	Opposite Location	None
Random	7	0	1	5
100%	4	3	0	6
50%	9	10	0	3
25%	12	11	0	0
10%	8	1	0	4
100%	10	2	0	2

Bird 2				
Location/ Phase	Feeder	CS	Opposite Location	None
Random	4	0	0	8
100%	7	3	0	4
50%	10	8	0	2
25%	12	11	0	0
10%	7	0	0	5
100%	11	0	0	1

Bird 3				
Location/ Phase	Feeder	CS	Opposite Location	None
Random	7	0	0	5
100%	12	1	0	1
50%	12	11	1	0
25%	12	6	1	1
10%	8	0	0	6
100%	12	2	0	0

Appendix B

The data presented in Appendix B were collected at the same time and according to the procedure described in Appendix A.

Bird 1				
Location/ Phase	Feeder	CS	Opposite Location	None
100%-R	8	0	0	3
50%-R	10	2	7	3
50%-L	10	4	0	1
50%-R	9	6	3	3

Bird 2				
Location/ Phase	Feeder	CS	Opposite Location	None
100%-L	10	2	0	2
50%-L	11	1	4	1
50%-R	12	5	2	0
50%-L	12	10	0	0

Bird 3				
Location/ Phase	Feeder	CS	Opposite Location	None
100%-L	11	5	0	1
50%-L	12	8	0	0
50%-R	12	7	4	0
50%-L	12	10	1	0