Sign tracking in domesticated quail with one trial a day: Generality across CS and US parameters

MELISSA BURNS and MICHAEL DOMJAN
University of Texas, Austin, Texas

When the conditioned stimulus (CS) is located some distance from the unconditioned stimulus (US), pairings of the CS and US can yield either conditioned approach to the CS (sign tracking) or conditioned approach to the US (goal tracking). However, goal tracking is the more common outcome, and, because of that, goal tracking has come to serve as a "standard" measure of associative learning in several laboratories. In contrast, in previous studies of sexual conditioning with domesticated quail, only sign tracking was observed. In the present study, quail continued to show sign tracking rather than goal tracking whether or not the US was highly localized (Experiment 1), whether food or a sexual US was used (Experiment 2), whether the CS was mobile or immobile (Experiment 3), and whether the CS was 91 or 233 cm from the US compartment (Experiment 4). The present findings encourage caution in the routine use of goal tracking as a measure of learning. The possible mechanisms of goal tracking are discussed in terms of occasion setting and behavior systems theory.

A conditioned stimulus (CS) that is reliably paired with an appetitive unconditioned stimulus (US), such as food or sexual reinforcement, becomes a "sign" for the US and comes to elicit approach and contact conditioned responses ("sign tracking"; Hearst & Jenkins, 1974). The conditioned approach behavior is quite pronounced when the CS and the US are located near each other, with the result that approaching the CS, or sign, also brings the organism closer to the appetitive US, or the "goal." Increasing the spatial separation between the CS and the US (by, for example, placing them on opposite sides of an experimental chamber) forces a choice between approaching the CS (sign tracking) and approaching the US (goal tracking).

The effects of spatial separation between the CS and US were first evaluated in an unpublished experiment by Ronald Black in Jenkins's laboratory (see Jenkins, 1973). Black used an unusually long experimental chamber and found that pigeons would approach and peck an illuminated keylight that signaled the delivery of grain into a food cup located 91 cm away. The behavior persisted even though food delivery was not contingent on keypecking, and pecking the keylight "caused a substantial loss in the amount of grain received" (Jenkins, 1973, p. 192).

Since this long-box experiment, sign tracking has been investigated in a variety of situations. Although all of the experiments involved pairings of a CS with an appetitive US, unique procedures and equipment have been used depending on the species and behavior of interest. CSs have included a keylight for pigeons (Hearst & Jenkins,

1974; Peden, Browne, & Hearst, 1977; F. J. Silva, K. M. Silva, & Pear, 1992) and rats (Cleland & Davey, 1983), a response lever for rats (Atnip, 1977; Cleland & Davey, 1982; Karpicke, 1978) and guinea pigs (Poling & Poling, 1978), a wood block for Japanese quail (Burns & Domjan, 1996), a lighted panel for dogs (Jenkins, Barrera, Ireland, & Woodside, 1978) and monkeys (Likely, 1974), a Plexiglas target for reptiles (Loop, 1976) and fish (Brandon & Bitterman, 1979), and a loudspeaker for rats (Cleland & Davey, 1982) and cats (Grastyan & Vereczkei, 1974). USs have included food (Grastyan & Vereczkei, 1974; Holland, 1980; F. J. Silva et al., 1992), water (Goddard & Jenkins, 1987), heat (Wasserman, Hunter, Gutowski, & Bader, 1975), and sexual reinforcement (Burns & Domjan, 1996). The spatial separation of the CS and the US has also varied, from a few centimeters (Karpicke, 1978; Wasserman, 1978) to 1–2 m (Black, in Jenkins, 1973; Grastyan & Vereczkei, 1974).

Investigators have measured both conditioned approach to the CS (sign tracking) and conditioned approach to the location of the US (goal tracking) in the various experiments. Although some species appear to have a stronger propensity for one type of conditioned response rather than the other, most species have been found to exhibit both sign tracking and goal tracking. In addition, previous studies with food reinforcement have identified some of the factors that determine whether sign tracking or goal tracking occurs. Increasing the distance between the CS and the US has a detrimental effect on sign tracking. Holland (1980) found that moving the CS about 30 cm away from the US disrupts sign tracking in rats, and F. J. Silva et al. (1992) found that a 60-cm separation disrupts sign tracking in pigeons. When the CS and the US are located far apart, both rats (Holland, 1980) and pigeons (F. J. Silva et al., 1992) show a stronger tendency to goal track than to sign track. The likelihood of goal

The research was supported by Grant MH39940 from the National Institute of Mental Health. Correspondence should be addressed to either author, Department of Psychology, University of Texas, Austin, TX 78712 (e-mail: burns@psy.utexas.edu or domjan@psy.utexas.edu).

tracking also increases if a trace interval is introduced between the CS and the US. With a trace conditioning procedure, pigeons shift from sign tracking during the CS presentation to goal tracking during the trace interval (Brown, Hemmes, Cabeza de Vaca, & Pagano, 1993). In general, experiments with food as the US have provided evidence for a reciprocal relationship between sign tracking and goal tracking (Boakes, 1977; Davey, Oakley, & Cleland, 1981; Holland, 1980; F. J. Silva et al., 1992).

Although both sign tracking and goal tracking have been reported in most common laboratory animals, only sign tracking has been observed in studies of sexual conditioning with Japanese quail (Burns & Domjan, 1996). Male Japanese quail approached and spent significant amounts of time near a CS that had been paired with the opportunity to copulate with a female, regardless of whether the CS was located 25, 61, or 91 cm from the door through which the female quail was released. This sign tracking persisted even when the location of the CS was changed between the training and test trials.

The sign tracking observed in the sexual conditioning studies with quail contrasted with previous findings in several respects. The sign tracking was not disrupted by increasing the distance between the CS and the US, during either training or testing. Increasing the CS-US distance and introducing a trace interval between the CS and the US did not produce more goal tracking behavior. In addition, a reciprocal relation between sign tracking and goal tracking was not found in the quail experiments.

The present investigation was conducted in an effort to identify why Burns and Domjan (1996) found only sign tracking in their experiments, whereas previous investigations reported primarily goal tracking with such distances between the CS and the US. The factors examined were spatial specificity of the US (Experiment 1), use of copulatory opportunity rather than food as the US (Experiment 2), mobility of the CS (Experiment 3), and the distance between the CS and the US (Experiment 4).

EXPERIMENT 1

One notable difference between the sexual conditioning procedure used by Burns and Domjan (1996) and previous studies with food reinforcement is the spatial specificity of the US. In sexual conditioning, the opportunity to copulate with a female serves as the US. Although the door to the female compartment was always in the same place in the experiments by Burns and Domjan, once the door was opened, the female bird could move about the entire 1.2 m² of the experimental chamber. This made the spatial specificity of the US less distinctive than is the case with food delivered into a stationary food cup (Holland, 1980; F. J. Silva et al., 1992). Goal-tracking conditioned responses may be less likely when the location of the goal (copulation with the female) varies from trial to trial than when the goal is restricted to a single location within the apparatus.

Experiment 1 was designed to determine whether spatial specificity of the US facilitates the development of goal-tracking behavior. Two groups of male quail were compared. Group U (for unrestricted female) was presented with a 30-sec CS followed by the opportunity to copulate with a female that was released from the goal area and could move anywhere in the experimental chamber. The procedure for Group U was the same as for Group Paired in Experiment 1 of Burns and Domjan (1996). Group R (for restricted female) was presented with a 30-sec CS followed by the opportunity to copulate with a female that was restricted to a small compartment behind the goal door. An unpaired control group was not included in the present experiment (or in Experiments 2 and 3) because such a group failed to show any discernible evidence of learning in the previous study by Burns and Domjan.

Method

Subjects. Twelve sexually mature male Japanese quail (*Coturnix japonica*) were obtained from a colony maintained at the University of Texas at Austin. At 30 days of age, the subjects were removed from mixed-sex brooders and housed individually in metal cages. Females were housed in group cages until they were selected for the experiment. The experimental and colony rooms were set on a 16:8-h light:dark schedule to maintain the birds in reproductive condition. Food (Purina poultry feed) and water were available at all times. A pretest for copulatory behavior established that all subjects selected for the experiment would make cloacal contact within 5 min after a female was placed in their home cage. All subjects in this experiment and the subsequent experiments were experimentally naive before their participation.

Apparatus. Six identical experimental chambers were used (see Figure 1). Each was made of plywood and painted white, measuring 122 cm long $\times$ 122 cm wide $\times$ 69 cm high. One side wall was made of wire mesh to allow visual access to the chamber. Male quail were housed in the chamber during the training trials, while a female was located in a smaller side cage (31 $\times$ 61 cm), the goal box. The large experimental chamber was joined to the goal box by a doorway (20.3 cm²). The doorway was normally closed by a wood panel door. Raising the wood panel allowed visual access into the goal box through a wire-mesh screen. The screen was hinged on top and could be pushed open to permit one-way entry into the goal box. With this arrangement, the female was restricted to the goal area, and once the male entered the goal box, it could not go back into the experimental chamber. The screen door was used for males assigned to Group R (for restricted female), but was removed for males assigned to Group U (for unrestricted female).

A wood block (14.6 $\times$ 10.2 $\times$ 1.27 cm) was suspended from the top of the experimental chamber near the middle of the back wall of the apparatus, as in Burns and Domjan (1996). The block could be easily lowered and raised with nylon cord and was 91 cm from the female's door when it was in the lowered position. The block lowered to the floor of the experimental chamber served as the CS.

Procedure. The 12 subjects were assigned to one of two running squads, each containing 3 subjects from each group (see below). The first 20 days involved habituation to the experimental chambers. During this phase, the subjects were housed in the home and experimental chambers during alternate 24-h periods. The wood door between the experimental chamber and goal box was opened to allow access to both compartments. During the 1st week of the habituation phase, a small swinging mesh door one third the height of the doorway was placed between the experimental chamber and

the goal box. During the 2nd week of habituation, the size of the wire-mesh swinging door was increased to two thirds of the height of the doorway. During the last 6 days of habituation, the wire-mesh swinging door was increased to the full size of the doorway between the experimental chamber and the goal box. All subjects learned to enter the goal box by pushing through the wire-mesh door.

Following the habituation phase, the wood door was put back in place between the experimental chamber and the goal box, and a pretraining procedure analogous to magazine training was conducted. One pretraining trial was conducted daily for 6 days. During each trial, the male subjects were permitted to copulate with a female. The amount of time permitted for copulatory activity was decreased from 30 min to 5 min across the pretraining trials. For subjects in Group U ($n = 6$), the wood door to the goal box was raised, and the female was manually moved through the doorway and placed into the experimental chamber. For Group R ($n = 6$), the wood door was opened, leaving the wire screen in place, and the male had to push through the wire screen to gain access to the female in the goal box. By the 6th pretraining trial, all subjects copulated with the female within 30 sec.

Each training trial began when the wood block CS was lowered from the ceiling to the floor of the test chamber. Thirty seconds after the CS reached the floor, the goal door was raised, and the subject was given the opportunity to copulate with a female. For Group U, the female was placed through the goal doorway into the large experimental chamber. The male was then free to chase and catch the female in order to copulate. Sexual behavior could be consummated anywhere in the 1.2-m² area. Group R males gained access to the female by pushing open the swinging mesh door and entering the goal box. Thus, Group R males always consummated their sexual behavior in the goal box. After 5 min together, the male and the female were separated and returned to their respective compartments of the apparatus.

Because the female could move over a much larger area when she was placed into the experimental chamber rather than kept in the goal box, males in Group U were slower to copulate with the female than were males in Group R. To ensure that the CS-US interval was comparable for the two groups, a yoked control procedure was used. The time between the introduction of the female into the experimental chamber for Group U and their first cloacal contact response was designated as the *chase time*. Each Group U subject

was yoked to a Group R subject within the same squad. On a particular trial, the chase time for the Group U subject was recorded. Then, on the trial for its yoked Group R partner, after the goal door was raised, the swinging door was held closed with a wooden dowel for an amount of time equal to the chase time. Thus, during the chase time, the Group R subject could see the female through the mesh door but could not open the door to enter the goal box. At the end of the chase time, the dowel was removed, and the male was permitted to enter the goal box, whereupon it copulated with the female immediately. The assignment of yoked partners was counterbalanced across trials so that each Group U subject was paired with each of the three Group R subjects in its squad five times in a random order.

Fifteen training trials were conducted, one daily for 15 consecutive days. The 1st, 5th, 10th, and 15th conditioning trials were recorded on videotape. Measurements were made of the amount of time that the subjects spent in each of two zones (42 cm² each) marked on the floor of the experimental chamber (see Figure 1). A subject was considered to be in a zone when the center of one foot was within the marks. Time spent in a zone directly around the wood block CS was designated as sign tracking. Time spent in the zone directly in front of the female's door was considered to be goal tracking. Data were recorded for a 30-sec period before the trial began, as well as for the 30-sec period when the CS was present. All measurements were made from videotape by two independent observers. The interobserver reliability correlation was .99. The .05 level of significance was used for all statistical decisions.

Results and Discussion

Figure 2 shows how long each group spent in the sign zone and the goal zone on Trials 1, 5, 10, and 15 during the pre-CS and CS periods. When the CS was absent, the subjects in both groups tended to spend more time in the goal zone than in the sign zone (top panel). However, when the CS was present, both groups spent more time in the sign zone than in the goal zone (bottom panel). Thus, both groups showed sign-tracking behavior, as observed by Burns and Domjan (1996).

The pre-CS and CS data were analyzed separately using repeated measures analyses of variance (ANOVAs)

Figure 1. Floor plan of the experimental apparatus. The scoring areas for the sign zone around the CS and the goal zone in front of the female's door are marked in gray.

Figure 2. Mean ($\pm$ SE) seconds spent near the CS (sign tracking) and the US (goal tracking) during the pre-CS period (top panel) and the CS period (bottom panel) in Experiment 1. For Group Restricted US (black bars), the female that provided copulatory opportunity was restricted to a small compartment behind the goal door. For Group Unrestricted US (gray bars), the female was released from the goal box, and copulation could occur anywhere in the experimental chamber.

in which trials (1, 5, 10, and 15) and zone (sign and goal) served as within-subjects variables and group (restricted and unrestricted) served as the between-subjects variable. Results for the pre-CS data indicated that the main effect of zone was not significant [$F(1,10) = 3.68, p > .05$]. The trials $\times$ zone interaction [$F(3,30) = 1.90$] and the trials $\times$ zone $\times$ group interaction ($F < 1.0$) were also not significant ($ps > .05$). Thus, during the pre-CS periods, the two groups did not spend significantly more time in the sign zone than in the goal zone.

Analysis of the CS period data revealed a significant trials $\times$ zone interaction [$F(3,30) = 9.16, p < .05$]. As indicated in Figure 2, the subjects spent increasing

amounts of time in the sign zone from Trial 1 to Trial 5. In contrast, goal times remained low throughout conditioning. Separate analyses of time spent in the sign zone and the goal zone revealed a significant trials effect for both measures [$F(3,30) = 7.25, p < .05$, and $F(3,30) = 3.74, p < .05$, respectively]. The subjects showed a dramatic increase in sign-tracking behavior after the 1st trial, quickly reaching asymptote. Goal-tracking times decreased after the 1st trial and reached a low asymptotic level after the 5th trial. The trials $\times$ group interaction was not significant for either the sign times ($F < 1.0$) or the goal times [$F(3,30) = 1.84, p > .05$]. The groups did not behave differently during the CS period across trials. The trials $\times$ zone $\times$ group interaction was not significant [$F(3,30) = 1.66, p > .05$]. Thus, as conditioning progressed, when the CS was present, both groups showed an increase in time spent in the sign zone but not the goal zone.

We previously suggested that the absence of goal tracking in the study by Burns and Domjan (1996) may have been due to the fact that the female US was unrestricted in that study. If spatial specificity of the US had been important to the development of goal tracking, then Group R should have shown more goal tracking than Group U. In addition, Group R should have shown less sign tracking than Group U. Given that neither of these predictions were confirmed, the results of Experiment 1 suggest that the preponderance of sign tracking in the quail sexual conditioning paradigm is not related to the spatial specificity of the female US.

Another factor that might have produced less sign tracking in Group R than in Group U is the distance between the CS and the US. Since Group R subjects had to enter the goal box to copulate with the female, the CS-US distance was never less than 91 cm for them. In contrast, because the female could enter the male's chamber when the goal door was opened for Group U, the CS-US distance for this group could have been considerably less than 91 cm. Given that spatial contiguity can facilitate associative learning (Rescorla & Cunningham, 1979), Group U might have been expected to show stronger sign tracking than Group R. The fact that this did not occur suggests that the difference in the CS-US distance for the two groups was not a significant factor under the conditions of the present experiment.

EXPERIMENT 2

A second possible reason why Burns and Domjan (1996) found mainly sign tracking is that they used sexual reinforcement rather than food as the US. Food and sexual USs differ in numerous respects. Presentation of a sexual US activates the sexual behavior system, with its unique set of appetitive and consummatory responses. In contrast, periodic presentation of food to hungry animals activates the feeding system, which involves a different set of appetitive and consummatory action patterns. Among other differences, food is encountered with greater

frequency and is typically more familiar than sexual reinforcement. In addition, the foods that are usually consumed by rats and pigeons are inanimate, whereas sexual reinforcers involve social interactions with an active (and reactive) conspecific.

Experiment 2 was conducted to determine whether the unique features of the Burns and Domjan (1996) results were due to the use of a sexual US rather than a food US. Two groups were trained with the same procedure except that, following a 30-sec CS, Group Food was reinforced with food, whereas Group Sex was reinforced with the opportunity to copulate with a female quail.

Method

Subjects. Twenty-one sexually mature male Japanese quail served as subjects. All were selected from the University of Texas colony and raised as described above. Each subject passed a 5-minute pretest for copulatory behavior in the home cage. Prior to the start of the experiment, each subject was weighed to determine its free-feeding body weight.

Apparatus. The six experimental chambers described in Experiment 1 were also used in Experiment 2, and, again, the CS was a wood block lowered to the floor of the experimental chamber, 91 cm away from the goal door.

Procedure. The procedure was the same as in Experiment 1 in all unspecified respects. The experiment was conducted in two identical replications, with 10 subjects in the first replication and 11 subjects in the second. The experiment began with a 20-day habituation phase. During this phase, the wood door separating the experimental chamber from the goal box was removed. Food (Purina poultry feed) was available in the home cage for 90 min each day. With the limited feeding time, the subjects experienced gradual weight loss until they reached 80% of their free-feeding body weight. The body weight of each subject was recorded daily following the 90-min feeding period. If a subject fell below its 80% weight, it was given supplemental food equal to the difference in grams between its weight and the 80% target weight. Water was available continuously in both the experimental chamber and the home cages.

A pretraining phase followed habituation. Unlike Experiment 1, the subjects did not live in the experimental chambers but were placed in the chambers 1 h before each pretraining and conditioning trial. During pretraining, all subjects were exposed to each US type (food and sex) on alternating days for 6 consecutive days, for a total of three presentations of each US. The goal door was open and the wire-mesh swinging door was in place. On food-exposure trials, a dish containing 10 g of food was placed in the goal box. On sex-exposure trials, a female quail was available in the goal box. The subjects that failed to enter the goal box within 5 min were gently pushed through the wire-mesh door by the experimenter. The subject was then allowed access to the US for 5 min before being returned to the home cage. The US-access period was decreased across trials from 5 min to 30 sec. By the end of the pretraining phase, all subjects entered the goal box for either US in less than 60 sec.

In each replication, the subjects were assigned one of two groups, Group Sex or Group Food. A conditioning trial began when the wood block CS was lowered from the ceiling to the floor of the experimental chamber. The distance between the lowered wood block and the goal door was 91 cm. Thirty seconds after the CS was lowered into position, the wood goal door was raised. The subject could then push through the wire-mesh door to enter the goal box for reinforcement. The reinforcer provided in the goal box for Group Food was 5-min access to a food dish full of Purina poultry feed. The reinforcer provided for Group Sex was opportunity to copulate with a sexually mature female quail for 5 min. At the end of the US period, the subject was gently removed from the goal box and re-

turned to its home cage. After all conditioning trials for the day were completed, all subjects were fed as described above. The subjects from Group Food were given 5 min to copulate with a female in the home cage 90 min after each trial. Thus, the two groups were equated for exposure to both USs.

Each subject received one conditioning trial a day for 15 consecutive days. As in Experiment 1, Trials 1, 5, 10, and 15 were recorded on videotape for later analysis. The amount of time spent in the sign zone and the goal zone during a 30-sec pre-CS period and the 30-sec CS period during each recorded trial were measured by two independent observers (reliability correlation = .99).

Results and Discussion

A preliminary analysis indicated that there were no significant differences between replications ($F < 1.0$). Therefore, the data from the two replications were pooled for further analyses.

Figure 3 illustrates the amount of time spent in both the sign zone and the goal zone during the pre-CS and CS

Figure 3. Mean ($\pm$ SE) seconds spent near the CS (sign tracking) and the US (goal tracking) during the pre-CS period (top panel) and the CS period (bottom panel) in Experiment 2. Food and sexual reinforcement (gray bars and black bars, respectively) were used as the US for independent groups.

periods for the recorded conditioning trials. During the 30-sec pre-CS period when the wood block was absent (top panel), the subjects of both groups spent very little time in either the sign zone or the goal zone. However, when the wood block was present during the CS period (bottom panel), both groups spent much more time in the sign zone near the wood block, than in the goal zone near the reinforcer.

The pre-CS period and CS period data were analyzed separately with repeated measures ANOVAs, with trials (1, 5, 10, and 15) and zone (sign and goal) as within-subjects variables and group (food vs. sex) as a between-subjects variable. The analysis of the pre-CS data revealed no significant differences in time spent in the sign zone and the goal zone. The trials $\times$ zone interaction and the trials $\times$ zone $\times$ group interaction were nonsignificant ($F_s < 1.0$).

Results from the CS period data revealed a significant trials $\times$ zone interaction [$F(3,57) = 24.41, p < .05$]. As trials progressed, the subjects spent more time in the sign zone than in the goal zone. Furthermore, the trials $\times$ zone $\times$ group interaction was also significant [$F(3,57) = 3.79, p < .05$]. Although both groups increased sign tracking across trials while goal tracking values did not change, Group Sex showed higher rates of sign tracking than Group Food. In subsequent analyses of each group individually, both groups showed a significant trials $\times$ zone interaction [Group Sex, $F(3,30) = 20.70, p < .05$; Group Food, $F(3,27) = 5.63, p < .05$]. In the presence of the CS, as conditioning progressed, both Group Sex and Group Food showed predominantly sign-tracking behavior rather than goal-tracking behavior.

Overall, both groups showed strong sign tracking and little goal tracking in response to the 30-sec CS presentation. The sign tracking was less dramatic among the subjects reinforced with food, perhaps because the food US had weaker reinforcement value than the sexual US. However, the use of food as the US did not cause a shift from sign tracking to goal tracking. These results suggest that the presence of sign tracking and the absence of goal tracking in previous studies with Japanese quail were not due to the use of a sexual US. Sign tracking also occurs when a more familiar appetitive US, food, is used.

EXPERIMENT 3

Previous research has shown that the extent of sign tracking depends on the nature of the CS. In general, a CS that is distinctive from its surroundings and easily located in space, such as a keylight or a response lever, is more likely to elicit conditioned approach and contact responses than a CS that is diffusely present throughout an experimental chamber, such as a tone (Bilbrey & Winokur, 1973). A characteristic of the CS that has not received much attention is the amount of motion involved in its presentation. A mobile CS may be more distinctive from

its surroundings than a stationary CS and may therefore come to elicit more sign tracking.

A notable difference between the sexual conditioning procedure used by Burns and Domjan (1996) and earlier studies with rats and pigeons is that the CS was not stationary. In the typical sign-tracking procedure with pigeons, illumination of a stationary keylight serves as the CS. In the typical procedure used with rats, a response lever is introduced at the beginning of each trial. This involves about 2 cm of horizontal movement. In contrast, in the Burns and Domjan procedure, the CS was lowered 57 cm from the top to the floor of the experimental chamber at the start of each trial. Experiment 3 was designed to evaluate the importance of this factor in the development of sign tracking. For half of the subjects, illumination of a stationary light served as the CS. For the remaining subjects, the CS was a wood block lowered 57 cm from the ceiling to the floor of the experimental chamber. All subjects received an opportunity to copulate with a female conspecific following presentation of the CS.

Method

Subjects. Twenty-four sexually mature, experimentally naive, male Japanese quail served in the experiment.

Apparatus. The experimental chambers were similar to those used in the previous experiments except that two conditioned stimuli were used, a moving wood block and a stationary green light. The wood block ($14.6 \times 10.2 \times 1.27$ cm) was suspended from the ceiling of the experimental chamber 57 cm above the floor. When lowered using nylon string, the block came to rest on the floor of the test chamber 112 cm from the female's door. The stationary CS was a small green light bulb (5 W, 110 V ac). The light bulb was 2.5 cm in diameter, protruded 9.9 cm into the chamber, and was mounted 10 cm above the cage floor in the middle of the wall opposite the goal door. The tip of the light bulb was 112 cm from the goal door.

Procedure. The procedure was similar to the previous experiments in all unspecified respects. The subjects spent alternate 24-h periods in the experimental chambers. After the 20-day habituation phase, six pretraining trials were conducted (one per day) so that the subjects would learn to gain access to the goal box by pushing open the swinging wire-mesh door. During the pretraining phase, the food and water containers were moved from the experimental chamber into the goal box, and the wooden sliding door to the goal box was removed. Thus, the subjects were required to enter the goal box to eat and drink. The size of the wire screen was gradually increased during the pretraining trials. All subjects learned to push through the swinging door to enter the goal box.

The subjects were then assigned to two groups. For Group Block CS ($n = 12$), each training trial involved lowering the wood block from the ceiling to the floor of the experimental chamber. Thirty seconds after the block reached the floor, the goal door was raised, giving the subject access to a female in the goal box. After 5 min with the female, the male was returned to the experimental chamber, and the goal door was closed. For Group Light CS ($n = 12$), the training trials were similar except the CS was 30-sec illumination of the green light at the back of the experimental chamber.

Results and Discussion

Figure 4 shows how much time each group spent in the sign zone and the goal zone during the pre-CS and CS periods for Trials 1, 5, 10, and 15. During the pre-CS pe-

Figure 4. Mean ($\pm$ SE) seconds spent near the CS (sign tracking) and the US (goal tracking) during the pre-CS period (top panel) and the CS period (bottom panel) in Experiment 3. For independent groups, the CS was a stationary green light (gray bars) or a mobile wood block (black bars) presented 112 cm from the goal door.

riod on all trials, Group Light CS and Group Block CS spent similar modest amounts of time in the sign and goal areas (top panel). During the CS period, after the first training trial, both groups spent much more time in the sign zone than in the goal zone (bottom panel).

Pre-CS data were analyzed with a repeated measures ANOVA, with trials and zone as within-subjects variables and group (block CS and light CS) as the between-subjects variable. The results revealed a significant interaction of trials $\times$ zone [$F(3,66) = 7.76, p < .05$]. There was an increase in goal tracking across trials before the CS was presented. This behavior was common to both groups. The trials $\times$ zone $\times$ group interaction was not significant [$F(3,66) = 1.26, p > .05$].

When the CS was present, the subjects showed the opposite pattern of responding. More time was spent in the sign zone with conditioning, whereas goal times re-

mained very low. This was evident in a significant trials $\times$ zone interaction [$F(3,66) = 9.92, p < .05$]. However, this effect did not differ between groups. The trials $\times$ zone $\times$ group interaction was not significant ($F < 1.0$). Thus, conditioning with both the block CS and the light CS resulted in sign tracking when the CS was present.

Unlike previous experiments, goal tracking developed in both groups during the pre-CS periods. This attraction to the goal area may have been a response to auditory and other cues produced by the female in the goal box. However, despite goal tracking during the pre-CS periods, the subjects showed predominantly sign tracking when the CS was presented. Thus, their sign tracking overcame baseline tendencies to approach the goal area. This outcome occurred regardless of the type of CS that was used. The present results suggest that the preponderance of sign tracking observed by Burns and Domjan (1996) was not due to their use of a moving CS. Evidently, similar results occur when a more conventional stationary light CS is used.

EXPERIMENT 4

Experiment 4 was conducted to determine whether the sign tracking observed in quail would give way to goal tracking with an increase in the spatial separation between the CS and the US.

Examination of the sign-tracking literature reveals an interesting pattern. When the CS and the US are situated close together (within 10 cm of each other), rats show sign-directed behaviors (Cleland & Davey, 1982; Holland, 1980). Increasing the distance between the CS and the US results in oscillation between CS-directed and US-directed behavior (Holland, 1980; Karpicke, 1978). However, when the CS and the US locations are far enough apart so that approaching the CS might interfere with obtaining the food US, US approach predominates (Holland, 1980; Karpicke, 1978).

A similar, but less robust, pattern is evident in studies with pigeons. Pigeons sign track at CS-US distances of 22 cm (F. J. Silva et al., 1992) and 35 cm (Peden et al., 1977). However, contrary to the original long-box experiment (see Jenkins, 1973), some researchers have reported that CS-directed behavior becomes less consistent at distances greater than 50 cm. F. J. Silva et al. (1992) described oscillation between the sign and the goal at CS-US distances of 22–50 cm, and distinct goal tracking occurred when the CS and the US were separated by 60 cm. However, van Hest, van Haaren, Kop, & van der Schoot (1986) observed pigeons to sign track when a keylight CS was located 60 cm from the food magazine.

In contrast to rats and pigeons, Japanese quail consistently approached and remained near a CS paired with reinforcement when the CS was located 25, 61, 91, and 112 cm from the site of the US (Experiments 1–3: Burns & Domjan, 1996). In addition, there was no significant evidence of goal tracking even with the largest spatial separation between the CS and the US. However, the dif-

ference between the quail experiments and the pigeon/rat experiments may be quantitative rather than qualitative. This suggests that sign tracking would give way to goal tracking in quail just as in the other species if the CS were moved far enough away from the US. To test this idea, in Experiment 4, the CS was moved 233 cm from the US, a distance that far exceeds the largest spatial separation tested with rats and pigeons. For the paired group, opportunity to copulate with a female was signaled by a wood block CS presented 233 cm from the female's door. The CS and the US were unpaired for the control group.

Method

Subjects. Twenty-four sexually mature male Japanese quail served as subjects. All passed a 5-min pretest for copulatory behavior and were experimentally naive prior to the experiment.

Apparatus. Six experimental chambers were used. Each consisted of a large compartment (244 cm long $\times$ 122 cm wide $\times$ 69 cm high), with a small adjacent goal box (31 $\times$ 61 cm) at one end. The experimental chamber and the goal box were separated by a vertically sliding wood door and a unidirectional wire-mesh swinging door, as in the previous experiments. A wooden block hung from the ceiling of the experimental chamber, near the wall opposite of the goal door. When lowered to the floor of the experimental chamber, the block was 233 cm from the goal box door.

Procedure. The experiment was conducted in two replications, with 12 birds in each replication. The procedures were identical to those of Experiment 1 except as specified. After habituation to the experimental chambers and pretraining to teach the subjects to push through the wire-mesh door to gain access to a female in the goal box, the subjects were assigned to Group Paired or Group Unpaired ($n_s = 12$). During the training phase, all subjects spent alternate 24-h periods in the experimental chamber and home cage. For Group Paired, a training trial began when the CS was lowered from the ceiling of the experimental chamber. Thirty seconds after the CS came to rest on the floor of the chamber, the wood goal door was raised. The male was allowed 5 min to push through the swinging door and copulate with the female in the goal box. At the end of the 5-min US period, the wood door was closed, and the male was gently removed from the goal box and returned to the experimental chamber.

The subjects in Group Unpaired were exposed to unpaired presentations of the CS and the female, with at least 90 min between the two events. A CS presentation involved lowering the wood block to the floor of the test chamber and then raising it after 30 sec. The US was presented by raising the wood door and allowing 5 min for the male to open the swinging door and copulate with the female in the goal box. After 5 min, the wood door was closed, and the male was returned to the experimental chamber. The order of the CS and US presentations was varied randomly across trials.

Results and Discussion

No significant differences between the two replications were found with a repeated measures ANOVA; therefore, the data from both replications were combined for further analysis.

Figure 5 shows how much time the subjects spent in the goal and sign zones during the two 30-sec periods for each recorded training trial. Neither group of subjects spent much time in either zone during the pre-CS period (top panel). When the CS was present, the subjects in Group Paired spent increasingly more time in the sign

Figure 5. Mean ($\pm$ SE) seconds spent near the CS (sign tracking) and the US (goal tracking) during the pre-CS period (top panel) and the CS period (bottom panel) in Experiment 4. The CS was presented 233 cm from the goal door; paired (black bars) or unpaired (gray bars) with copulatory opportunity.

zone than in the goal zone. Group Unpaired, however, spent little time in either zone during the CS period (bottom panel).

The pre-CS data were analyzed with a repeated measures ANOVA. Group (paired and unpaired) served as the between-subjects variable and trials (1, 5, 10, and 15) and zone (sign and goal) were within-subjects variables. The analysis indicated nonsignificant trial $\times$ zone and trial $\times$ zone $\times$ group interactions [$F_s(3,66) = 2.26$ and 1.18, respectively, $p_s > .05$]. Both groups spent a similar amount of time in each zone across all training trials.

The CS period data were subjected to a similar analysis. The results showed a significant trials $\times$ zone interaction [$F(3,66) = 15.44$, $p < .05$]. Across trials, more time was spent sign tracking than goal tracking. This difference in tracking behavior in the presence of the CS varied across groups, as indicated by a significant trials

$\times$ zone $\times$ group interaction [$F(3,66) = 11.52, p < .05$]. When the CS was present, Group Paired spent much more time in the sign zone than group Unpaired. During the CS period, both groups spent very little time in the goal zone.

These results indicate that the male quail learned an association between the wood block CS and opportunity to copulate with a female 233 cm away from the CS. The learning was evident in approach and contact with the CS. The sign tracking developed as a conditioned response even though the CS and the US were separated by a longer distance than in previous studies with rats and pigeons. If there is a CS-US distance at which quail will shift their conditioned behavior from sign tracking to goal tracking, evidently that distance exceeds 233 cm.

We previously reported that increasing the distance between the CS and the US goal door from 25 cm to 91 cm did not reduce the sign tracking that occurred (Burns & Domjan, 1996, Experiment 2). Although we did not compare directly the effects of different CS-US distances in the present study, a comparison of Figures 2 and 5 suggests that increasing the CS-US distance from 91 cm to 233 cm also did not have a visible deleterious effect on sign tracking. These findings contrast with earlier reports indicating that much smaller increases in CS-US distance can significantly disrupt learning (Rescorla & Cunningham, 1979; Testa, 1975). Sign-tracking behavior may have persisted at this large separation in the quail because moving away from the goal did not impose an appreciable delay of reinforcement, as was the case with rats and pigeons. At the beginning of the US period, the quail subjects were able to cross the length of the experimental chamber to gain access to the female within 2–3 sec. This is a very short delay relative to the 5-min US period that was provided. Arranging negative consequences for moving away from the goal box (by further increasing the CS-US distance and/or decreasing the US period) may be more effective in disrupting sign tracking and producing goal tracking.

GENERAL DISCUSSION

In a previous study of sexual conditioning, Burns and Domjan (1996) found sign tracking, but not goal tracking, in domesticated quail when the CS was presented up to 91 cm from the door that provided the males access to a copulation partner. This finding was remarkable because, in more conventional laboratory preparations, goal tracking has been the predominant conditioned response when the CS was located just 30 or 60 cm from the source of food (e.g., Holland, 1980; F. J. Silva et al., 1992). The present experiments were conducted to examine several factors that might have been responsible for the development of sign tracking, rather than goal tracking, in the quail studies.

Experiment 1 demonstrated that restricting copulatory reinforcement to a small goal box did not facilitate the development of goal tracking. Male quail showed pre-

dominantly sign tracking whether or not copulation was restricted to a small goal box. Experiment 2 showed that sign tracking is not a specialization of the sexual behavior system. Quail conditioned with food as the US showed sign-tracking behavior comparable to birds that were conditioned with copulatory opportunity as the US, and goal tracking did not develop in either group. Experiment 3 demonstrated that the unusual CS (a wood block lowered from the ceiling) used by Burns and Domjan (1996) was also not responsible for the results. Goal tracking was no more likely when a stationary colored light, rather than the mobile wood block, served as the CS. Finally, Experiment 4 showed that increasing the distance between the CS and the US to 233 cm neither enhanced goal tracking nor prevented the development of sign-tracking behavior. These results show that sign tracking occurs under a wide range of circumstances.

Goal tracking (in the form of rats pushing a panel to gain access to a food cup) has been frequently used as a measure of associative learning, with little regard for why this conditioned response occurs rather than some other (e.g., Bennett, Maldonado, & Mackintosh, 1995; Redhead & Pearce, 1995; Reed, 1995; Watt & Honey, 1997). In the present experiments, goal tracking was a much poorer index of learning than sign tracking. Had we only measured goal tracking, we would have missed significant instances of learning. The present findings suggest that investigators should be cautious in their use of goal tracking as a "standard" measure of learning until the mechanisms responsible for such conditioned behavior are better understood.

Why might goal tracking not be a reliable outcome in studies of conditioning? Although both sign tracking and goal tracking (when it occurs) are associative phenomena, they represent control by different stimuli. Sign tracking reflects control by a discrete CS that is not necessarily located near the US. In contrast, goal tracking represents control by spatial cues that identify where the US is presented. In our situation (and many others in which conditioned goal tracking occurs), the location of the US was identified by cues of the door to the goal box. These goal-door cues were not highly correlated with the US because they were always present when the subjects were housed in the experimental chamber. The goal-door cues were paired with the US only when the discrete CS (the wood block or colored light) was introduced. Thus, the procedure may be viewed as a feature-positive discrimination in which the discrete CS was the "feature."

Feature-positive discriminations have been analyzed from the perspective of occasion setting (Schmajuk & Holland, 1998). According to such an analysis, the discrete CS "sets the occasion" for the reinforcement of the goal-area cues. In this account, the discrete CS is the "feature," and the goal-area cues constitute the "target" CS. The feature sets the occasion for reinforcement of the target.

Several studies have shown that a feature is more likely to set the occasion for the conditioning of a target if the

feature is spatially or temporally separated from the target stimulus (Holland, 1992; Swartzentruber, 1995). Although this criterion was satisfied in the present experiments, other aspects of the experiments may not have been ideal for producing occasion setting. Occasion setting has been shown to be enhanced by making the target more salient than the feature stimulus, by using procedures that result in more rapid development of conditioned excitation to the target than to the feature cue, and by having the feature begin and end before the target (Holland, 1992; Swartzentruber, 1995). These conditions were not clearly satisfied by our procedures. Our target (the goal area) was not clearly more salient than the feature (the wood block or light CS). Our procedures probably did not condition excitation to the goal area (target) more rapidly than to the discrete CS (the feature). In fact, the target probably gained excitatory strength more slowly than the feature, since the target was present for long periods during the intertrial interval. Finally, we did not have a temporal gap between presentation of the punctate CS and the target. However, the introduction of such a temporal gap by Burns and Domjan (1996) did not facilitate goal tracking in sexual conditioning.

The above argument suggests that goal tracking did not develop in the present experiments because the procedures used did not include some characteristics that would have facilitated the development of occasion setting. However, these same characteristics were probably also missing in the rat and pigeon experiments that reported goal tracking rather than sign tracking (Holland, 1980; F. J. Silva et al., 1992). In those studies, the target (the food cup or food magazine) was probably less salient than the punctate CS, US presentations were scheduled in such a way that the target should have acquired excitatory properties more slowly than the feature, and a temporal gap did not separate the punctate CS and the target cues. Therefore, an occasion-setting interpretation does not provide any obvious answer to why goal tracking occurred in the rat and pigeon studies but not in the quail experiments.

Sign tracking and goal tracking also may be considered from the perspective of behavior systems theory. The individual behaviors that occur when animals are conditioned with food or sexual reinforcement are part of larger systems of behavior related to the procurement of those reinforcers. Both the feeding system and the sexual behavior system can be analyzed as consisting of general search and focal search responses (which bring the animal closer to the reinforcer) and consummatory responses (which are involved in direct interaction with the reinforcer) (Domjan, 1997; Timberlake & Silva, 1995). Studies of sign tracking and goal tracking provide information about the mechanisms of different forms of search behavior, with sign tracking reflecting an earlier type of search behavior than goal tracking.

Previous studies have indicated that the type of search behavior that develops during appetitive conditioning depends on the CS-US interval that is used. Longer CS-US

intervals result in the conditioning of responses that are farther removed from the terminal consummatory behavior elicited by the reinforcer. For example, Akins, Domjan, and Gutiérrez (1994) found that sexual conditioning of male quail with a 20-min CS-US interval results in the conditioning of an increase in nondirected locomotion (akin to general search behavior), whereas the use of a 1-min CS-US interval results in approach to the CS (akin to focal search behavior). In studies with rats, K. M. Silva and Timberlake (1997) found that nosing the food tray was more likely to develop with the use of a short (2- or 4-sec) CS-US interval rather than a long (16- or 18-sec) CS-US interval. In contrast, behavior indicative of general search (contacting a rolling ball bearing) was more likely when a long CS-US interval was used than when a short CS-US interval was used. (However, this behavior was not CS specific.)

If the CS-US interval helps determine which response mode is activated by a CS, then goal tracking may predominate when a very short CS-US interval is used, and sign tracking may become more evident as the CS-US interval is increased. The CS-US interval used in the present experiments, as well as in the experiments by Burns and Domjan (1996), was 30 sec. This may have been too long to activate goal-tracking responses. Consistent with this interpretation, K. M. Silva and Timberlake (1997) observed more goal tracking when the CS-US interval was 2 or 4 sec than when it was 16 or 18 sec. Other studies with pigeons and rats in which goal tracking has been the predominant outcome have also employed CS-US intervals well short of 30 sec. For example, the CS-US interval was 8 sec in F. J. Silva et al. (1992), and it was 10 sec in Holland (1980).

Other distinctive features of the quail experiments were that only one conditioning trial was conducted each day, and the subjects spent long periods of time in the experimental chamber between trials. In the experiments by Burns and Domjan (1996) and in Experiments 1, 3, and 4 of the present study, the subjects spent alternate 24-h periods in the experimental chambers. In Experiment 2, the subjects were placed in the experimental chambers 1 h before the start of each trial. We provided extensive exposure to the experimental chambers and conducted just one trial each day to facilitate copulatory behavior. However, these procedures probably also had other important consequences.

Extensive exposure to the contextual cues of the experimental chamber (and the goal-area cues) may have resulted in latent inhibition to the goal-area cues (e.g., Lubow, 1989). Extensive exposure to the experimental chamber also ensured that any excitation conditioned to the goal-area cues on one trial could become extinguished by the time the next conditioning trial occurred. It may be that a target CS has to retain some residual excitation between trials for a feature to come to modulate responding to the target.

Although the present experiments failed to identify the reasons why sign tracking, rather than goal tracking,

was the predominant conditioned response, our findings show that sign tracking can occur in a wide range of circumstances. In addition, the present findings and discussion suggest that much additional research is needed before goal tracking is well enough understood to justify using it as a "standard" measure of associative learning.

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