

Stimulus- and feeder-directed behavior in a long-box: Effect of fixed versus variable time schedules of food presentation

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Two groups of 6 pigeons were exposed to either a fixed-time (FT) or a variable-time (VT) schedule of response-independent food presentation. The interval between two successive food presentations (food-food [FF] interval) was either 20 or 40 sec. The duration of stimulus presentation (stimulus-food [SF] interval) was varied relative to the FF interval. All subjects were exposed to different information ratios (IRs; $IR = SF/FF$; $IR = 1.00, 0.50, 0.15$). To study the relative contribution of sign- and goal-tracking behavior to keypecking observed in standard autoshaping procedures, pigeons were autoshaped in a long-box. In the long-box, the stimulus key and the feeder are located 60 cm apart. Stimuli were always presented at one end of the box, and food was presented at the other end. Locomotor behavior and keypecks were recorded. Pigeons engaged in sign-tracking behavior when $IR = 0.15$, but only when presentation of the food was unpredictable on the basis of other variables (e.g., the passage of time since the last food presentation, as in FT schedules). In the case of FT schedules, subjects engaged in feeder-directed activities. No effects of varying the FF interval were found. Keypecking was observed only when the SF interval was short ($IR = 0.15$) and food was presented on a VT schedule.

Pigeons approach and peck an illuminated key which signals response-independent presentation of food (*autoshaping*; Brown & Jenkins, 1968). The term *sign-tracking* was proposed to "refer to behavior that is directed toward or away from a stimulus as a result of the relation between that stimulus and the reinforcer, or between that stimulus and the absence of the reinforcer" (Hearst & Jenkins, 1974, p. 4). Studies on sign-tracking have focused on the relative contribution of stimulus-food (S-S*) and response-food (R-S*) contingencies to keypecking observed in standard autoshaping procedures. A decrease in stimulus-directed keypecking behavior has been observed when responding prevented the delivery of response-independent food (Schwartz & Williams, 1972; Williams & Williams, 1969). As a result of the negative R-S* contingency, however, sustained responding decreased the number of food presentations, thereby weakening the S-S* contingency and preventing an adequate analysis of the relative contributions of S-S* and R-S* relations to the development of keypecking. Gamzu and Williams (1971) studied autoshaping in a truly random control procedure (Rescorla, 1967). In the non-

differential training procedure, keylight and food presentations occurred independently and at random, whereas in the differential procedure, food was not presented in the absence of the stimulus. Although the probability of adventitious reinforcement of keypecking behavior is equally likely in both procedures, only subjects in the differential procedure pecked at the stimulus key. The results of this experiment point to the importance of S-S* contingencies in the development of autoshaped keypecking, but cannot rule out a contribution of R-S* contingencies to the maintenance of stimulus-directed behaviors. Most investigators now agree on the major role of the S-S* contingency in sign-tracking (see Schwartz & Gamzu, 1977, for a review). The critical feature of the S-S* contingency in sign-tracking seems to be the extent to which the stimulus conveys information about the occurrence or nonoccurrence of food presentation. It was shown that autoshaping is most prominent when stimulus duration (the interval between stimulus onset and the presentation of the food, or stimulus-food [SF] interval) is small relative to the time between two successive food presentations (food-food [FF] interval) (Gibbon, Baldock, Locurto, Gold, & Terrace, 1977; Gibbon, Farrell, Locurto, Duncan, & Terrace, 1980; Terrace, Gibbon, Farrell, & Baldock, 1975).

Relative contributions of S-S* and R-S* contingencies to sign-tracking behavior are difficult to assess in the stan-

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dard operant conditioning chamber, due to the close physical proximity of the stimulus key and the feeder. A long-box, in which the stimulus key and feeder are spatially separated, was first employed by Hearst and Jenkins (1974). Pigeons exposed to an autoshaping procedure in such a long-box do engage in sign-tracking behavior, even when stimulus-directed behavior is never directly followed by the ingestion of food. When rats are exposed to an auto-shaping procedure, and a lighted response key is used as a stimulus, they predominantly engage in feeder-directed behavior (Crowell, Bernhardt, & Moskal, 1981). Few have attempted to investigate feeder-directed behavior, or *goal-tracking* (Boakes, 1977), in pigeons. Boakes (1977) reported that pigeons in a long-box did approach the feeder, but only after considerable training, and under nonstandard houselight conditions (no further details were given). Wasserman (1973) and Mackintosh (1974) showed that pigeons tended to peck at the feeder when the intertrial interval was spent in total darkness. Innis, Simmelhag-Grant, and Staddon (1983) found that pigeons exposed to a schedule of periodic food presentation showed distinct feeder-directed behavior when the FF interval duration was short. Farwell and Ayres (1979) proposed that sign- and goal-tracking might well be under control of different experimental variables. Probability of food presentation has been shown to affect goal-tracking behavior in rats. Davey and Cleland (1982) observed little goal-tracking under conditions of partial reinforcement; a drop in reinforcement probability resulted in a decrease in goal-tracking. Furthermore, Boakes (1977) found that extinction of the tray-entry response was far more rapid, than extinction of leverpress response.

In the standard operant conditioning chamber, sign- and goal-tracking are two compatible forms of behavior. Differentiation between the stimulus-directed approach and the feeder-directed approach is therefore not possible. Due to the close temporal contiguity of feeder-directed behavior and ingestion of the food, goal-tracking is a highly probable *terminal behavior* (Staddon & Simmelhag, 1971), and might therefore contribute to sign-tracking in standard autoshaping procedures. The present study was designed to investigate the relative contribution of stimulus- and feeder-directed behaviors in autoshaping procedures, by spatially separating the stimulus key and the feeder. In the present experiment, the stimulus was always presented at one end of the box, and food was delivered at the other end. For one-half of the subjects, the FF interval duration was variable, and thus conditions resembled those of the standard autoshaping procedure except for the spatial separation of stimulus and feeder in the long-box. For the other half of the subjects, the FF interval duration was fixed. The SF interval duration was varied relative to the FF interval duration, on the assumption that smaller information ratios (IRs; $IR = SF/FF$) would be more "informative" than larger ratios (Schwartz & Gamzu, 1977). The value of the IR might very well determine whether sign-tracking or goal-tracking would occur. Because we expected weak goal-

tracking behavior in pigeons, all subjects were first exposed to those experimental conditions in which sign-tracking behavior was expected to be weak ($IR = 1.00$). FF interval duration was varied across groups to identify more fully the variables which might affect the development of goal-tracking.

METHOD

Subjects

Twelve experimentally naive pigeons (White Carneaux) served. Subjects were approximately 2-3 years old at the beginning of the experiment, except for subject LK33, who was 5-6 years old. Subjects were maintained at 80% of their free-feeding weights throughout the experiment.

Apparatus

Two locally constructed pigeon chambers were used, 35 cm wide and 33 cm high. A standard three-key Lehigh Valley Electronics intelligence panel was inserted at each end of the chamber. The distance between the panels was 60 cm. In Box A, locomotor activity was detected by six photoelectric cells, placed 2 cm above the grid floor and spaced 12 cm apart. The two cells at one end of the box corresponded to the stimulus side; the two cells at the other end, to the feeder side. Interruption of the beam of the two remaining cells in the middle was considered as the center. In Box B, the floor consisted of 10 movable panels of equal width, parallel to the intelligence panels. Locomotion was detected by microswitches, which were operated by a force exceeding 50 g. The three panels at one end of the box corresponded to the stimulus side, the three panels at the other end corresponded to the feeder side, and the four panels in the middle were defined as center. Beam interruption of the photoelectric cells in the magazines of the boxes registered when subjects started to eat from the magazine. Key-pecks directed at the stimulus key, both during stimulus presentations and in the absence of the stimulus, were registered.

Procedure

Initially, pigeons were magazine trained in the long-box. During magazine training, the feeder was presented at random on the left or on the right intelligence panel ($p = 0.50$ for both sides). When subjects reliably approached the magazine upon its presentation, the experimental procedure was started. Subjects were randomly assigned to one of four experimental groups. Throughout the experiment, the stimulus was always presented on the intelligence panel at one end of the box, and food was always presented at the other end. Sites of stimulus and feeder presentations were fixed for all subjects throughout the experiment. Houselights were lit throughout the session, except when the feeder was presented. Food was presented independently of the behavior of the subjects, immediately following the termination of stimulus presentation. The magazine was presented for a maximum of 15 sec, unless the beam of the photoelectric cell in the magazine was interrupted. Following beam interruption, the magazine was presented for 4 sec. For one-half of the subjects, the FF interval duration was fixed (FT); for the other half, the FF interval was of variable duration (VT). In addition, for one-half of the subjects in each group (FT and VT) the FF interval lasted 20 sec, whereas for the other subjects the FF interval lasted 40 sec. Within each experimental group, all subjects were exposed to three different IRs in a decreasing sequence (1.00, 0.50, 0.15). For subjects exposed to the VT schedule of food presentation, the actual duration of the SF interval was variable, but the ratios of SF to FF interval duration were kept constant. When $IR = 1.00$, the stimulus key was illuminated during the entire FF interval. When $IR = 0.50$, stimulus presentation was confined to the latter half of the FF interval, and when $IR = 0.15$, the stimulus was presented just prior to the presentation of the food, after 85%

of the FF interval had elapsed. Experimental groups and the order of conditions are shown in Table 1.

Sessions ended after 40 stimulus-food pairings. For each subject, percentages of total session time spent at the stimulus side, at the feeder side, or in the center were calculated, both for the time during stimulus presentations and for the time when the stimulus was not present. When averaged percentages for the last three sessions fell within $\pm 5\%$ of those for the preceding three sessions, experimental conditions were changed for that subject. In addition, each experimental condition was in effect for at least 20 sessions. Number of sessions in each experimental condition for each individual subject is also shown in Table 1.

RESULTS

Locomotor Activity

All data were averaged over the last six sessions in each experimental condition. Figure 1 shows the proportion of total session time spent at the stimulus side and at the feeder side during stimulus presentations for each group of subjects ($n = 3$). Due to heterogeneity of variance, all proportions were subjected to a 2 arcsin (\sqrt{x}) transformation (Winer, 1962).

A three-way analysis of variance (IR \times schedule \times FF interval duration) showed that subjects exposed to the FT schedules of food presentation spent less time at the stimulus side during stimulus presentations than did subjects exposed to the VT schedules of food presentation [$F(1,8) = 6.51, p < .05$]. Decreasing values of IR increased sign-tracking behavior [$F(2,16) = 9.61, p < .01$]. Because the schedule \times IR interaction proved to be significant [$F(2,16) = 7.75, p < .01$], tests on simple main effects were carried out, which revealed that sign-tracking behavior of subjects exposed to FT schedules was not affected by decreasing values of IR [$F(2,8) = 0.64, n.s.$], whereas for subjects exposed to VT schedules, decreasing values of IR increased sign-tracking behavior [$F(2,8) = 11.82, p < .05$]. Subjects exposed to VT schedules engaged significantly more in sign-tracking behavior when IR = 0.15 than when IR = 0.50 (Student's t test; $t = 2.71, p < .05$) or when IR = 1.00 (Student's t test; $t = 3.25, p < .005$). The difference between IR = 1.00

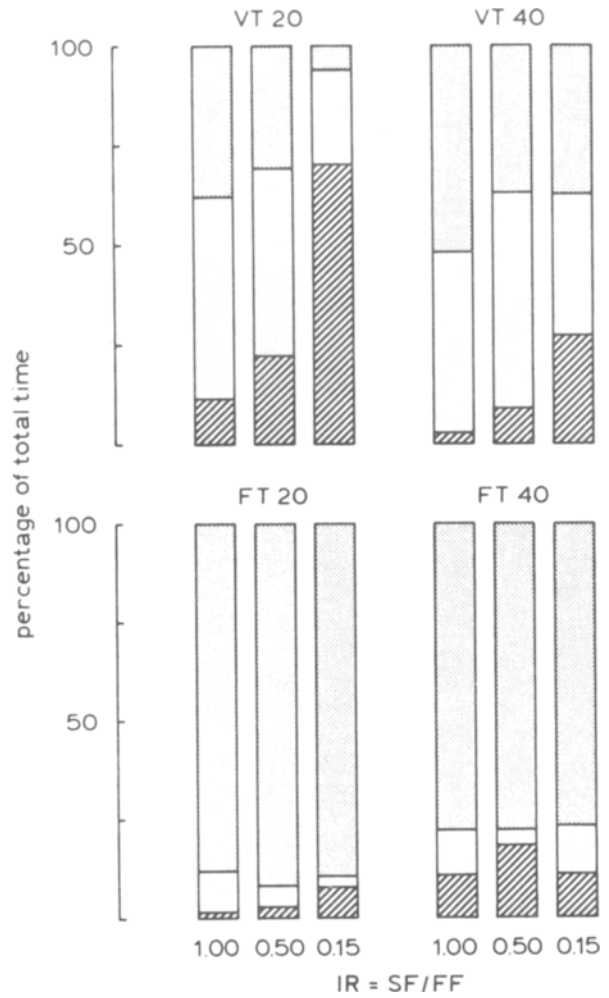


Figure 1. Averaged percentages of total session time spent at the stimulus side (hatched bars) and at the feeder side (stippled bars) during stimulus presentations for different information ratios (IRs) of stimulus-food (SF) to food-food (FF) interval duration (IR = SF/FF).

Table 1
Overview of Experimental Groups and Number of Sessions in Each Experimental Condition

Condition	Subject	IR = 1.00	IR = 0.50	IR = 0.15
FT20	LK21	21	20	20
	LK23	20	20	20
	LK28	20	20	20
FT40	LK24	23	20	20
	LK25	20	26	25
	LK26	28	20	20
VT20	LK29	20	21	21
	LK31	20	20	20
	LK32	20	20	20
VT40	LK30	20	20	26
	LK33	20	22	23
	LK35	20	20	20

and IR = 0.50 did not reach statistical significance (Student's t test; $t = 0.38, n.s.$). Effects of FF interval duration were not observed [$F(1,8) = 0.0005, n.s.$]. However, the schedule \times FF interval interaction did reach significance [$F(1,8) = 5.73, p < .05$]. Pairwise comparisons among groups, using Student's t test, revealed that subjects exposed to the FT 20-sec schedule of food presentation engaged less in sign-tracking behavior than all other experimental groups ($t = 2.88, p < .01$). Other comparisons did not reach statistical significance. Analysis of variance on goal-tracking data showed that subjects exposed to FT schedules of food presentation spent significantly more time at the feeder side during stimulus presentations than did subjects exposed to VT schedules of food presentation [$F(1,8) = 23.16, p < .01$]. Other main or interaction effects did not reach significance.

Keypecking Activity

Keypecking was observed when the SF interval was small ($IR = 0.15$) and food was presented on a VT schedule. Subjects exposed to FT schedules did not peck at the stimulus key during stimulus presentations, whereas 5 out of 6 subjects exposed to the VT schedules did. Subjects exposed to a 20-sec FF interval showed more keypecking behavior than subjects exposed to a 40-sec FF interval (percentage of trials on which at least one keypeck occurred—36.53% vs. 30.53%; keypecks per minute—21.91 vs. 7.14). However, these differences did not reach statistical significance.

DISCUSSION

The present study confirms and extends earlier findings that pigeons approach and peck an illuminated key which signals upcoming delivery of food, even when the stimulus site and the feeder site are spatially separated (Bilbrey & Winokur, 1973; Hearst & Jenkins, 1974). Because the stimulus key and the feeder site were spatially separated in the present study, keypecks were never directly followed by ingestion of food, thus presenting further evidence that sign-tracking is under control of the S-S* contingency. In addition, it was shown that pigeons engaged more in sign-tracking behavior when the IR was small. However, stimulus-directed behaviors were not observed when the FF interval duration was fixed, irrespective of the IR. The extent to which the stimulus conveys information about the occurrence or nonoccurrence of the presentation of food is clearly a critical variable, as subjects exposed to the FT schedule of food presentation did not engage in sign-tracking behavior. When an FT schedule is used, the stimulus is redundant with respect to both place and time of presentation of the food, because place is fixed and time can be inferred by passage of time since the last food presentation. Results of the present experiment are consistent with the results of an experiment by Wasserman (1973), in which stimulus-directed behavior was not observed when the subjects spent the intertrial interval in total darkness. Presentation of the stimulus light in an otherwise dark chamber was held to induce widespread changes in illumination which were as good a predictor of feeder presentation as was the illuminated stimulus key itself, thus making the stimulus key redundant. Subjects tended to peck at the magazine instead.

The present study has shown that pigeons do display considerable goal-tracking behavior, even under standard houselight conditions, when feeder approach instead of head poking is taken as an index of goal-tracking. The data of the present study suggest that sign-tracking behavior and goal-tracking behavior might be sensitive to different experimental variables. Goal-tracking was shown to be rather insensitive to the S-S* contingencies, as considerable goal-tracking behavior was observed in those conditions in which the stimulus was present during the whole FF interval; effects of decreasing values of IR could not be observed. Effects of varying the duration of the

FF interval were not observed in the present study. Innis et al. (1983) reported a distinct feeder-directed terminal response when the FF interval was short (5 or 12 sec). At longer intervals (60 or 300 sec), subjects tended to stay in the part of the chamber near the feeder prior to the presentation of the food, although no distinct feeder-directed response was observed. However, in the present study, no attempt was made to measure head poking or feeder-directed keypecking behavior. Whether high levels of feeder-directed locomotor behavior are accompanied by head poking or other distinct feeder-directed behavior remains to be investigated.

The data of the present study suggest that whenever stimulus-directed and feeder-directed behaviors are compatible, feeder-directed activities may contribute to the observed sign-tracking behavior. In the standard operant conditioning chamber, differentiation between stimulus-directed and feeder-directed behavior is not possible as long as the subject does not contact the stimulus key. To assess the relative contributions of stimulus-directed and feeder-directed behaviors to sign-tracking, further investigations must be conducted on variables affecting goal-tracking and its relation to sign-tracking. Sign-tracking may possibly be observed in FT schedules of food presentation if site of food delivery is not fixed but variable and if the stimulus yields information with respect to the place where the food will be presented. Furthermore, altering the sequence in which subjects are exposed to the different values of IR may yield different results. Development of sign-tracking behavior for subjects exposed to the FT schedules of food presentation may have been superseded by the more potent goal-tracking behavior. Some sign-tracking may be expected to occur when subjects are first exposed to the smallest value of IR, due to close temporal proximity of stimulus presentation and presentation of food.

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