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PREFERENCE FOR SIGNALLED REINFORCEMENT[1]

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Key pecking was reinforced on a two-component multiple schedule. A variable-interval schedule controlled reinforcement in both components. During one component, access to reinforcement was preceded by a tone; in the other component, a standard unsignalled schedule was in effect. After performance stabilized, subjects were given a choice between the signalled and unsignalled schedules. They were placed in the chamber with the unsignalled schedule in effect on the right key. A single response on the left, or changeover, key produced the signalled schedule for 1 min. Both pigeons in Experiment I pecked the changeover key at a rate sufficient to remain under the signalled schedule for over 90% of the session. Removing and reintroducing the tone demonstrated that the changeover-key responses were due to the occurrence of the tone. In Experiment II, when pecking the changeover key produced the *unsignalled* schedule, pecking the changeover key declined. The results may be explained either in terms of Hendry's information hypothesis or as escape from an intermittent positive reinforcement schedule.

Several lines of experimentation show that subjects choose conditions in which stimuli consistently precede either food or shock. For example, rats select the arm of a T-maze where the pattern on the wall consistently predicts the presence or absence of food in the goal box (Lutz and Perkins, 1960; Prokasy, 1956). Similarly, rats placed in an unsignalled shock situation will press a bar to introduce a condition in which each shock is preceded by a brief tone warning signal (Badia and Culbertson, 1972; Badia, Culbertson, and Lewis, 1971).

Hendry (1969) argued that informative events are reinforcing, information being defined as the presentation of stimuli having invariant correlations with reinforcing circumstances. In support of Hendry's view, Bower, McLean, and Meachum (1966) demonstrated that pigeons select stimuli that are correlated with the delay to food (either 10 or 40 sec) over stimuli randomly associated with the same food delays. Also, Wilton and Clements (1971) showed that stimuli providing information about the probability of subsequent reinforcement were more reinforcing than stimuli not providing such information.

In the above experiments, (Bower *et al.*, 1966; Wilton and Clements, 1971) the stimuli indicated whether reinforcement was forthcoming without identifying the particular moment that reinforcement was due. The present experiments gave pigeons a choice between a schedule of food reinforcement in which the moment a response would be reinforced was indicated by a 5-sec tone and a schedule in which the moment of reinforcement was not indicated.

EXPERIMENT I

METHOD

Subjects

One Silver King (A-21) and one White Carneaux (A-39) pigeon purchased from Palmetto Pigeon Plant, Sumter, South Carolina were reduced to between 75 and 80% of their free-feeding body weights. Subject A-21 was conditioned to peck using an autoshaping procedure (Brown and Jenkins, 1968); A-39 was hand shaped.

Apparatus

A standard pigeon conditioning chamber was used. Two keys, 3.5 cm in diameter, requiring approximately 0.44 N pressure, were mounted 20.3 cm apart and 25.4 cm from the floor. Four-seconds access to grain reinforced key pecking. During reinforcement, the house-

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light was off and a light in the grain hopper was on. A tone generator (Mallory Sonalert) produced a 2000-cps tone at 86 dB when required. A ventilating fan and background white noise produced 74 dB masking sound during, but not before or after, each session. Solid-state scheduling equipment and cumulative recorders in an adjacent room were used for scheduling and recording purposes.

Procedure

Sessions were conducted at the same time daily and terminated after 50 reinforcements. Except for initial conditioning, a single 20-interval film tape produced according to Fleshler and Hoffman (1962) tables controlled reinforcement throughout the experiment. The film tape stopped during both the 5-sec pre-food periods and during reinforcement.

Multiple schedule. The first stage of the experiment involved training subjects to respond on both signalled and unsignalled variable-interval (VI) reinforcement schedules. On a VI schedule, pecks are followed by grain at variable intervals with a specified mean. A variable-interval schedule of 20 sec was used at first and gradually increased to 65 sec. Key pecks on the right key (food key) were reinforced on the average, once every 65 sec (VI 65-sec) in the presence of either a green or red key. While the key was green, a 5-sec tone immediately preceded but did not overlap access to reinforcement (signalled schedule). While the key was red, the tone did not occur (unsignalled schedule). The red and green key colors alternated every 5 min. When the key was green, a 10-cps 75-dB click generator (BRS LVE) was always on. The auditory click stimulus ensured that the condition in effect at a given time made contact with the subject without requiring that the pigeon observe the color of the key. Subject A-39 served for 22 sessions on the multiple schedule and Subject A-21 28 sessions.

Changeover schedule. After performance on the multiple schedule stabilized, as determined by inspection of the cumulative records, subjects started the next session in the unsignalled VI condition. The right key was red; the left key, previously dark, was now white. A single peck on the white key (changeover or CO response) darkened it and changed the red key to green (accompanied by the click stimulus). These stimuli remained in effect for 1 min, at the end of which, the click stimulus terminated, the right key changed from green back to red, and the CO key was again illuminated. Pecks on the darkened CO key were without effect. It is convenient, following Verhave (1963), to refer to the schedule in effect in the absence of a CO response as the imposed condition and the schedule produced by a CO response as the alternate condition. The unsignalled VI schedule (imposed condition) was in effect during red and the signalled schedule (alternate condition) was in effect during green. During both conditions, the availability of reinforcement was preceded by a 5-sec period. If the signalled schedule was in effect, the tone was on throughout this 5 sec; if the unsignalled schedule was in effect, the tone was off. The first response following termination of the tone in the signalled condition, and following a comparable period with the tone absent in the unsignalled condition, produced reinforcement. If the signal period was in effect on the unsignalled schedule and a CO response occurred, the tone came on immediately. Each CO response produced the signalled schedule for 1 min. To reduce the likelihood of superstitious grain reinforcement for CO responses, a reinforcement set up in one condition but not received was cleared when the schedule changed. This was true of a change from the unsignalled to signalled schedule and *vice versa.*

No tone. To determine if the tone was responsible for the preference, the tone was alternately eliminated and reintroduced. In the no-tone condition, the schedule was identical to the CO schedule, except the tone never occurred.

Results

Typical multiple schedule records for each subject are shown on the left side of Figure 1. Both birds developed typical VI performance on the unsignalled component of the multiple schedule. On the signalled schedule, subjects typically did not respond in the absence of the tone, but began to peck at tone onset and continued until reinforcement.

Under the CO procedure, both pigeons chose the signalled schedule. Changeover responses increased gradually. After extended exposure, both subjects maintained the signalled schedule over 90% of the session (see Figure 2). Subjects often introduced the signalled sched-

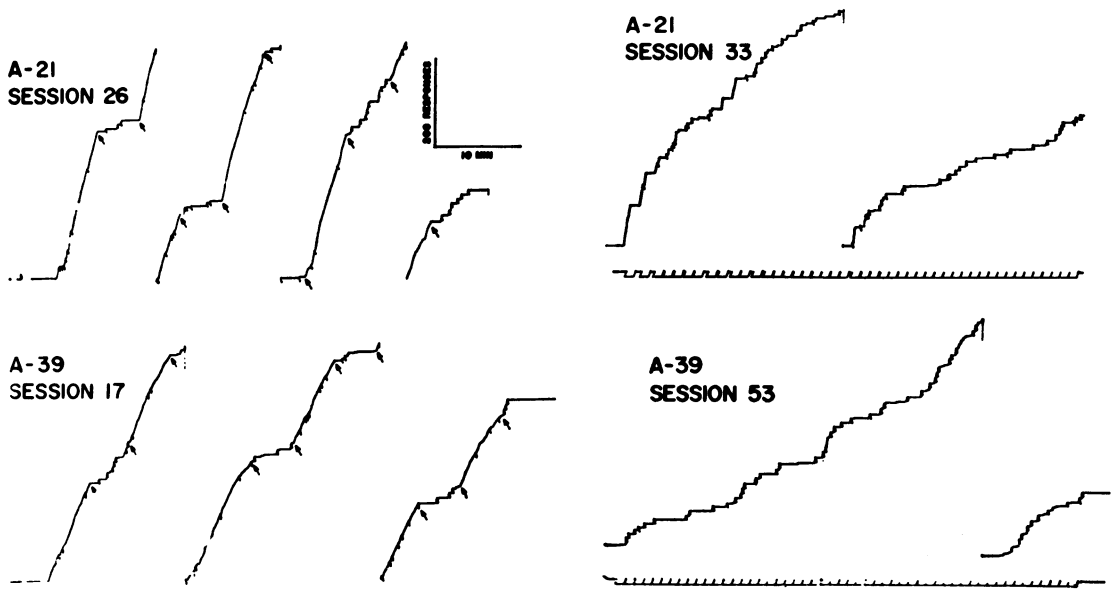

Fig. 1. The two records on the left show cumulative food-key pecks on the multiple signalled unsignalled VI 65-sec schedule for Subjects A-21 and A-39. Components alternated every 5 min, at the points indicated by the arrows below the record. The first component was unsignalled. The two records on the right show changeover schedule performances for the same subjects. Food-key pecks stepped the cumulative pen vertically and slashes indicate grain reinforcement. Downward deflections on the event pen indicate 1-min periods of the signalled VI schedule.

ule before pecking the food key at the beginning of a session. This pattern can be observed in the cumulative record of A-39, Session 53 (Figure 1). Occasionally, subjects pecked the food key at the start of a session before producing the signalled schedule. This pattern is illustrated by A-21, Session 33 (Figure 1). On the CO schedule, the red and green keys continued to control the pattern of responding that had been observed on the multiple schedule.

Figure 2 shows the effect of eliminating the tone from the CO schedule on the per cent of total session time spent in the signalled schedule. In each instance when the tone was eliminated, CO responding gradually declined over several sessions. With the tone omitted, the schedule of reinforcement in green was identical to the unsignalled schedule in red. Cumulative records revealed that within the first session after the tone was eliminated, the pausing in the absence of the pre-reinforcement tone characteristic of the signalled schedule had largely disappeared. Consequently, before reintroducing the CO schedule, it was necessary to reestablish the multiple schedule performance. The appropriate patterns developed by the end of the first multiple schedule session for A-21, but required three or four sessions for A-39.

EXPERIMENT II

In the first experiment, subjects chose a signalled over unsignalled VI schedule by emitting a response that changed the schedule in effect. The following experiment was carried out to see if subjects would *stop* responding on the CO key when responding changed the schedule from signalled VI to unsignalled VI.

Method

Subjects

Two White Carneaux pigeons, A-39 from the previous experiment and a new bird, G-60, were used. Subject G-60 had originally been hand shaped to key peck. Both birds had previous exposure to the CO schedule in which different VI schedules and small fixed-ratio CO requirements were employed.

Apparatus

Same as Experiment I.

Procedure

At the beginning of this experiment, both subjects were pecking on the changeover sched-

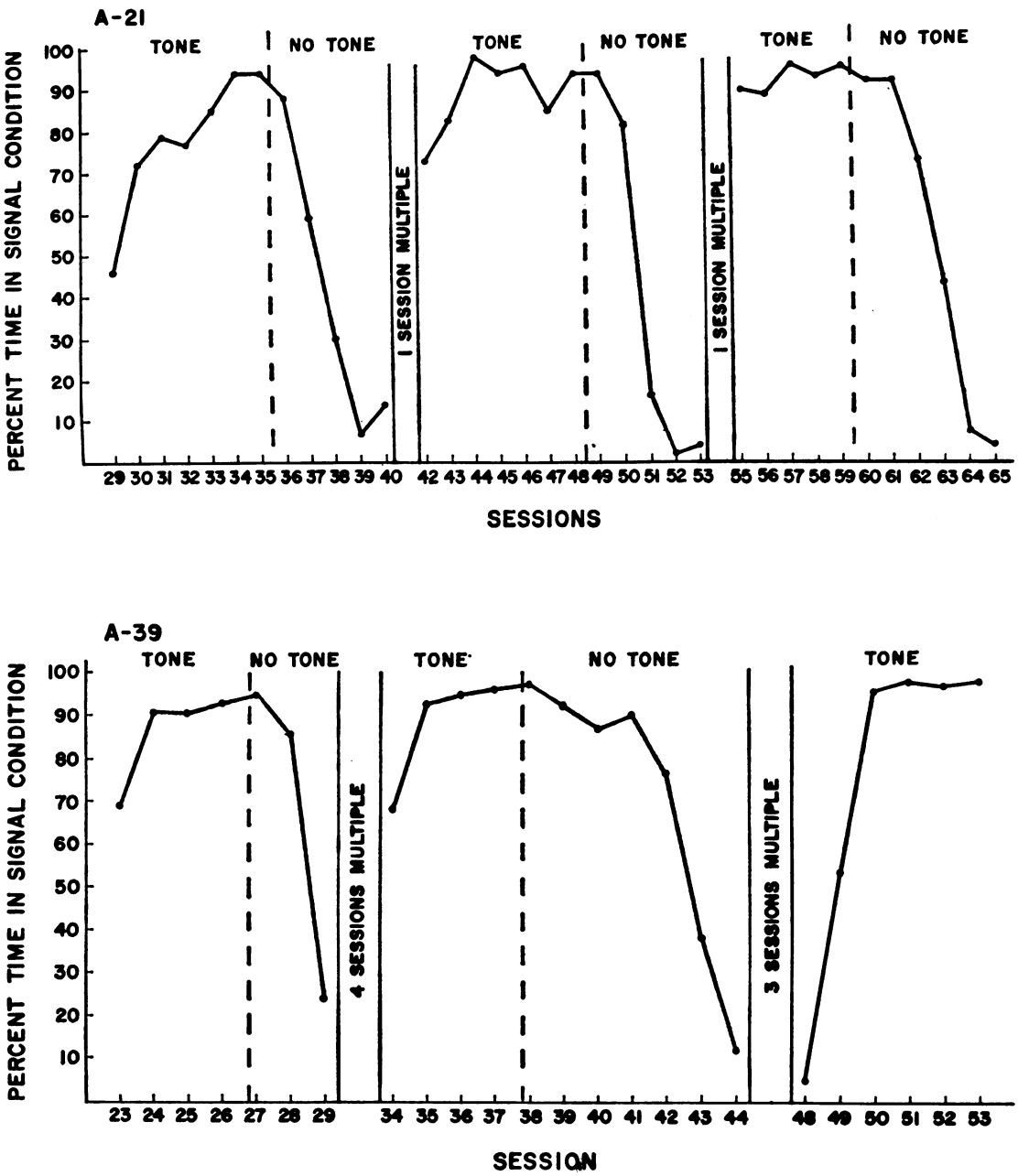

Fig. 2. Per cent of each session spent in the signalled VI 65-sec schedule during the changeover schedule. Sessions labelled "no tone" were identical to tone sessions except the tone never occurred.

ule described in Experiment I. The only differences were that now six pecks (FR 6) on the CO key were required to produce the signalled schedule and the food reinforcement schedule was now VI 125-sec. Subjects were maintained on this schedule for three sessions at the beginning of the present experiment, and were then introduced to a condition in which the *signalled* schedule was in effect on the food key and six CO responses produced the unsignalled schedule. After eight and 13 sessions (see Figure 3) on this schedule, an attempt was made to recover the original CO schedule performance.

Results

At the beginning of the experiment, subjects were pecking the CO key and producing the alternate schedule consistently. The cumulative records were very similar to those shown in Figure 1. The signalled schedule controlled the same pattern described in Experiment 1

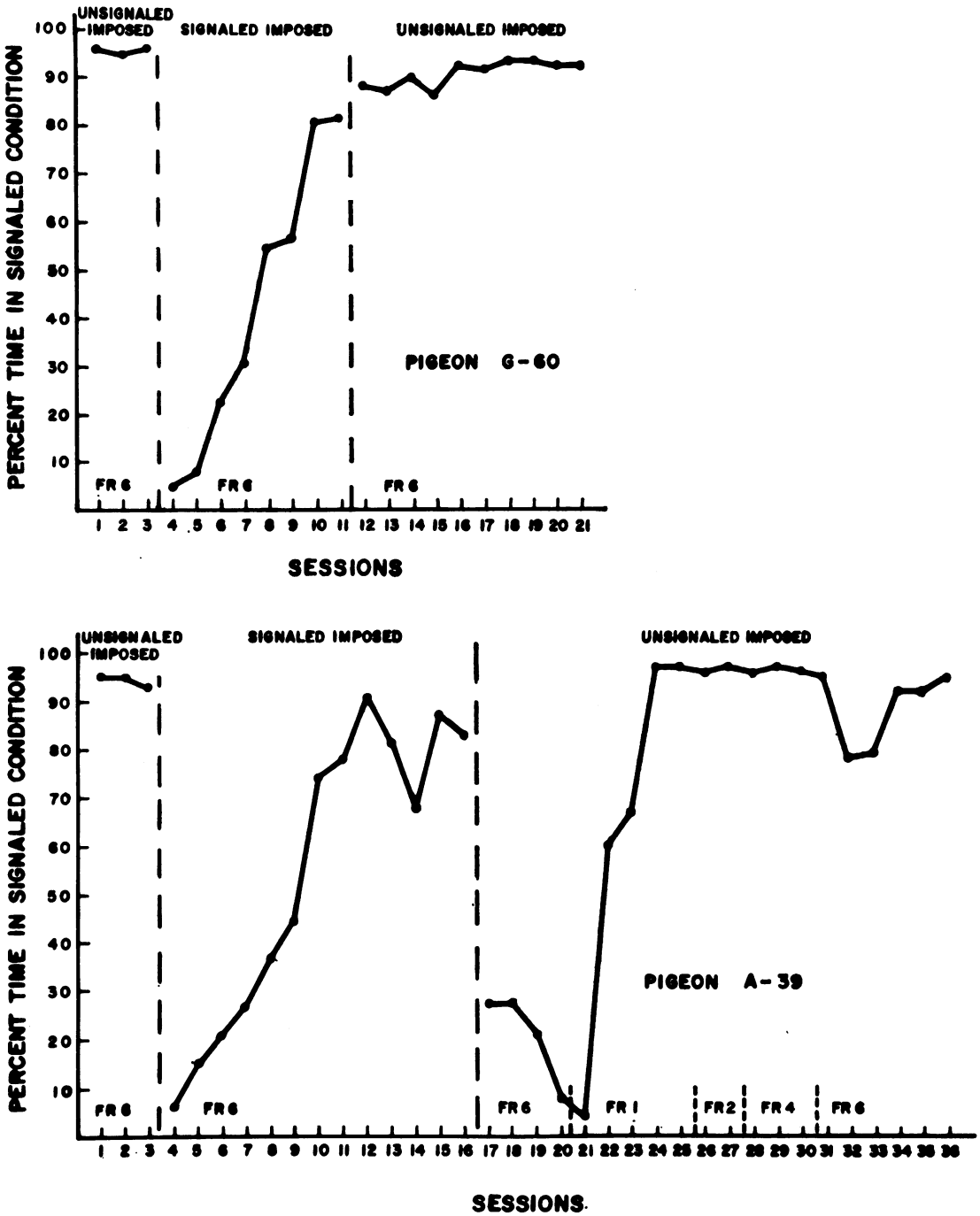

Fig. 3. Per cent time spent in the signalled condition when unsignalled VI 65-sec schedule was imposed and signalled schedule was alternate and when signalled schedule was imposed and unsignalled alternate. Fixed-ratio schedule required to produce the alternate condition is indicated along the abscissa.

and was in effect approximately 95% of each session (see Figure 3). The six responses required to produce the signalled schedule were emitted in a single run.

When the signalled schedule was placed in the imposed condition, CO responding terminated the signalled schedule and introduced the unsignalled schedule. Initially, both subjects continued to peck the CO key. However, CO key responding declined steadily until the signalled schedule was in effect for a high percentage of each session (see Figure 3). After subjects had shown clear preferences for the signalled schedule, the unsignalled schedule was again placed in the imposed condition. Subject G-60 immediately began pecking the changeover key and maintained the signalled schedule in effect for approximately 95% of each session. Subject A-39's changeover responding decreased under this condition. When the FR requirement was reduced to one and gradually increased to six, CO responding recovered.

DISCUSSION

Subjects consistently pecked throughout each pre-food stimulus in spite of the fact that pecking was never reinforced in the presence of the tone. It was anticipated before the experiments that subjects would adopt a pattern of responding in the signalled schedule which included a single peck after the tone terminated and near-zero pecking rates at other times. A number of investigators have observed pecking on a response key when a brief illumination of the key precedes food (*e.g.,* Brown and Jenkins, 1968). This phenomenon is called auto-shaping and seems to depend on the relationship between the lighted key and the delivery of grain. It may be that in the present experiment, pecking the response key during the tone was determined in part by the relationship between the tone and the grain, as in the auto-shaping procedure.

Fewer responses were emitted in the signalled VI schedule than in the unsignalled VI schedule. Subjects' preference for the signalled schedule may have been in part determined by the lower response rate controlled by the signalled schedule. This seems unlikely, however, since a number of investigators have studied the effect of response rate on preference and found preference to be largely independent of response rate (*e.g.,* Herrnstein, 1964). Indeed, Herrnstein's study, if anything, showed a very slight preference *for* stimuli controlling high rates of response (Herrnstein, 1964, Figure 8).

One point that should be considered is whether accidental conditioned reinforcement could account for the changeover behavior. The signal immediately followed a CO response if the CO response occurred within 5 sec before reinforcement was available while the unsignalled schedule was in effect. Approximately 8% of CO responses emitted at random points throughout the unsignalled schedule would initiate the signal, since the signal duration was 5 sec and reinforcement was scheduled once every 65 sec. The signal may have functioned as a conditioned reinforcer for the CO response, maintaining it on an intermittent basis. From this point of view, the changeover schedule was analogous to a procedure reported by Zimmerman (1963). He maintained responding on a concurrent schedule in which pecking on one key was followed intermittently by grain and pecking on a second key was followed intermittently by brief presentations of stimuli paired with grain. Although a conditioned reinforcement interpretation of the present experiments cannot be ruled out, two observations argue against it. One, the speed with which subjects acquired the response during each of the replications in the first experiment suggests a more frequent reinforcing event than the occasional occurrence of the signal would provide. Second, the CO response was maintained on an FR 6 schedule in Experiment 2 and the six responses were emitted together in a burst. It seems unlikely the intermittent conditioned reinforcer would have controlled responding so effectively that food-key responding would have been suppressed completely by the FR 6 schedule.

Interpretations of observed preference for signalled *versus* unsignalled reinforcers have focused on either the properties of the signal *per se* or the properties of the signalled situation when the signal is not on. Perkins' (1955) preparatory response theory and Hendry's (1969) information hypothesis emphasize the warning signal, although for different reasons, while Badia and Culbertson's (1972) shock-free time analysis, and Seligman's (1968) fear theory emphasize the presignal stimuli on the signalled schedule.

Badia and Culbertson (1972) and Seligman (1968) interpreted experiments showing a preference for signalled over unsignalled shock by noting that three discriminable stimuli exist in any situation involving signalled and unsignalled shocks: (1) stimuli correlated with unsignalled shock, (2) the warning signal, and (3) the presignal stimuli. Subjects may choose signalled shock situations, not so much because of the signal, but because the presignal stimuli identify safe periods. While this analysis works well in the case of aversive stimuli, an analogous analysis in the present experiment would predict preference for unsignalled VI schedules, a prediction opposite to the observed preference.

Preparation theory (Perkins, 1955) suggests that subjects will prefer signalled to unsignalled shock or food because the signal allows preparatory responses that either minimize the shock or maximize the food. It is difficult to see how *overt* responses preceding food could have been different, in the present experiment, for signalled and unsignalled grain delivery. The chain of behavior was the same in both cases: a key peck followed by 4-sec access to grain in the absence of the signal. Preference for signalled *versus* unsignalled brain stimulation also argues against the adequacy of a preparation analysis (Cantor and LoLordo, 1970).

Hendry's (1969) information hypothesis seems to be the only view that predicts observed preferences for signalled events in both food and shock situations. According to Hendry, stimuli that are consistently correlated with reinforcing conditions provide information that is reinforcing. The pre-food signal in the present experiments may have been preferred because of the information it provided. Of course, in the present experiments subjects chose a stimulus condition in the presence of which the informative signal occurred, rather than choosing the signal itself. In other words, preceding grain by a signal in the presence of a distinctive stimulus complex resulted in that stimulus complex acquiring reinforcing properties. This may be an extension of the information hypothesis.

One study, in contrast to the present experiments, has reported preference for unsignalled over signalled positive reinforcement (Hershiser and Trapold, 1971). Rats, implanted with permanently affixed mouth fistula, occasionally received a sucrose solution. If subjects remained on one side of a shuttlebox, sucrose was preceded by a 5-sec tone; on the other side the tone followed the sucrose. Subjects preferred the unsignalled compartment. There are so many variables that differ between Hershiser and Trapold's experiment and the present ones that it seems useless to speculate about possible reasons for the conflicting outcomes.

Notwithstanding the conflicting evidence just mentioned, one final explanation for observed preference for signalled over unsignalled food may be offered. Several investigators have shown that escape from intermittent reinforcement schedules is reinforcing. Escape from fixed-ratio (Azrin, 1961) and fixed-interval schedules (Brown and Flory, 1972) has been reported. Typically, subjects escape during the post-reinforcement period, when food-reinforced responding is at a minimum. It may be that VI schedules of reinforcement are also aversive and that changeover responding observed in the present experiment was reinforced by escape from the unsignalled VI schedule, rather than the production of the signalled VI schedule.

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