FACTORS AFFECTING CHOICE OF SIGNED OR UNSIGNED FOOD SCHEDULES

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Choice between signaled and unsigned food schedules was assessed in two experiments using a shuttlebox. Experiment 1 examined preference with both a five-second signal and a thirty-second signal. Subjects preferred the unsigned side with a five-second signal but preferred the signaled side with a thirty-second signal. Experiment 2 assessed preference using either a commitment procedure (a shuttle response resulted in exposure to the schedule for a fixed time) or a noncommitment procedure (each shuttle response changed the schedule in effect). Subjects preferred the signaled condition with the commitment procedure but the unsigned condition with the noncommitment procedure. These results indicate that the discrepant findings of earlier studies are due to procedural differences involving signal duration and choice commitment. The data are consistent with a conditioned reinforcement interpretation of choice.

Key words: choice, signaling, food, shuttle response, rats

Several investigators have reported that subjects prefer signaled food schedules over unsigned ones (e.g., Badia, Ryan, & Harsh, 1981; Lewis, Lewin, Muehleisen, & Stoyak, 1974; Ryan & Badia, 1982). Lewis et al. (1974), for example, found that pigeons acquired a key-peck changeover response that converted an unsigned variable-interval food schedule to a signaled one for 1-min periods. These findings are consistent with the literature on observing responses (e.g., Auge, 1974; Dinsmoor, Browne, & Lawrence, 1972; Wyckoff, 1952, 1969). In Wyckoff's now classic study of observing responses, pigeons stepped onto a treadle to change a mixed schedule of reinforcement, where alternating reinforcement and extinction schedules could not be separately identified, to a multiple schedule, where the two schedules were identified by correlated stimuli. Not all investigators, however, report preference for signaled schedules. Hershisier and Trapold (1971) trained and tested their subjects (rats) in a shuttlebox and found that

more time was spent on the side of the box correlated with the unsigned schedule. Additionally, Wilkie (1973) and Marcucella and Margolius (1978) reported that their subjects (pigeons), at times, spent more time on an unsigned food schedule than on a signaled one in a concurrent-schedules choice test. Unfortunately, the studies yielding different outcomes involve different apparatus and procedures, making it difficult to determine reasons for the conflicting findings.

The study by Badia et al. (1981) addressed the differences in the findings of Lewis et al. (1974) and of Hershisier and Trapold (1971). Subjects were first given forced exposure to signaled and unsigned food schedules in an operant chamber and then were tested by giving them the opportunity to change, for brief periods of time, from the unsigned to the signaled schedule (during some test sessions) or vice versa (during other test sessions). Two procedural features were varied: (1) response-reinforcer contingency (contingent vs. noncontingent) and (2) reinforcer quality (milk or pellets). Preference for the signaled schedule was obtained in all test conditions, and it was concluded that species differences, reinforcer quality, and response dependency were not the variables responsible for the earlier conflicting findings.

The present research pursues the issue further. An apparatus and a choice procedure

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similar to that used by Hershisier and Trapold (1971) was chosen. Specifically, subjects were given forced exposure in a shuttlebox to signaled and unsignaled schedules presented on different sides of the box. During testing, subjects could choose the side of the box that they preferred. Two variables were manipulated. In Experiment 1, subjects were tested with both a 5-sec and a 30-sec signal. In Experiment 2, the type of choice procedure (commitment vs. noncommitment) was varied.

EXPERIMENT 1

One of the critical differences between the experiments finding preference for signaled over unsignaled food schedules and those finding the opposite may be the duration of the food signal. In the Hershisier and Trapold (1971) study, the signal was brief, occupying only 5 sec of the 60-sec (on the average) interfood interval. Wyckoff (1952), on the other hand, used a comparable interfood interval but a 30-sec prefood signal. It may be that increasing signal duration from 5 to 30 sec in the shuttlebox test procedure will result in a change of preference from the unsignaled to the signaled schedule. Experiment 1 investigates this possibility.

METHOD

Subjects

Ten experimentally naive female Sprague-Dawley (Holtzman Co.) rats (90 to 120 days) were maintained at 80% of their free-feeding weights. Subjects were individually housed with free access to water. Two of these subjects (SO2, SO4) had previous experience in an operant lever-press apparatus.

Apparatus

The shuttlebox measured 50 by 25 by 25 cm with a clear Plexiglas top and grid floor bottom. It was housed inside a sound-attenuating box. The walls were aluminum with one side painted black and the other unpainted. The box was balanced such that standing on either side closed a switch, pulsed a counter, and started a clock. The beginning of the experimental session was identified by the illumination of a 24-V dc bulb, capped by a 2.5-cm jeweled lens and mounted in the center of the Plexiglas ceiling. This light went off at the end of the session. Two solenoids mounted on

platforms adjacent to the 50-cm wall of the shuttlebox delivered .10-cc injections of lowfat chocolate milk into brass cups through standard size drinking tubes, one on each side of the box. Both drinking tubes were shielded so that the animal could not lick the tube and drain it of milk. A tone generator (Mallory Sonalert), located midway between the food cups and on the outside of the shuttlebox, produced a 4500-Hz tone at 80 db and served as the prefood signal.

Procedure

Subjects were tested in 3-hr daily sessions. Two signal durations were examined: 5 sec and 30 sec. Six subjects received a 5-sec signal first and then were switched to a 30-sec signal (ascending order). Four others received the reverse order (descending order). Reinforcers were delivered on a variable-time (VT) 60-sec schedule generated by the Fleshler and Hoffman (1962) tables modified to accommodate a minimum interfood interval of 6 sec for the 5-sec signal and 31 sec for the 30-sec signal. Food was delivered only to the side of the box on which the subject was located. Subjects could collect all reinforcers by remaining on one side of the box. Signals were delivered only when the subject was on the side correlated with the signaled schedule.

Adaptation-baseline. Subjects received 3-hr adaptation sessions in which neither signals nor reinforcers were presented. The percentage of time spent on one side as opposed to the other was used to determine whether a side preference existed and also served as baseline data. Adaptation sessions terminated when the relative time spent on one side did not vary by more than 10% for three consecutive sessions.

Initial training. Subjects were given four training sessions, two with the signaled and two with the unsignaled schedule. An aluminum barrier separated the sides and forced the subjects to remain on one side throughout the entire session.

Choice and reversal. Following initial training, the barrier was removed and choice sessions began. These sessions were continued until the stability criterion had been met (see next page). Next, the sides of the shuttlebox correlated with the two schedules were reversed and testing was continued. After reversal, subjects were given four additional train-

ing sessions, two on each schedule, with the other signal duration. Following this training, the barrier was removed and choice sessions were given with the new signal duration. Shuttling did not affect the timing of food delivery or the number of scheduled food deliveries. When shuttling to the signal side occurred during the signal interval, the signal was presented only for the remainder of the interval.

Criterion for change. Choice testing terminated when the percentage of time spent on one side varied no more than 10% for five consecutive sessions. Minor exceptions to this criterion occurred occasionally.

RESULTS AND DISCUSSION

Adaptation-baseline. During baseline sessions, five of the six subjects B3, B4, B5, S02, S04) to be tested with the 5-sec signal first spent more time on the black side of the chamber. Therefore, to avoid a bias in favor of the expected outcome (i.e., preference for the unsignaled side), the unsignaled schedule was associated with the less-preferred side of the chamber. Subject B2 spent an average of 72.3% of the time on the unpainted side during adaptation; consequently, the unsignaled schedule for this subject was associated with the black side. All four subjects to be tested with the 30-sec signal first showed a bias for the black side. Therefore, the outcome was again biased against the expected outcome (preference for the signaled schedule) by correlating the signaled schedule with the less-preferred side.

Choice. Figures 1 and 2 present the percentage of time spent in the signaled schedule during adaptation-baseline, choice, and reversal sessions. Figure 1 shows data for subjects given the ascending order and Figure 2 shows data for subjects given the descending order.

As seen in Figure 1, subjects preferred the unsignaled side of the chamber when the signal duration was 5 sec. When the side on which the signal occurred was reversed, side preference also reversed. When these subjects had the signal extended to 30 sec, five of the six subjects changed their preference in favor of the signaled condition. With the exception of Subject B3, subjects now strongly preferred the signaled side even though the side for which they had showed a strong bias in baseline was now associated with unsignaled presentations. For Subject B3, it is possible that

a combination of side preference (black side) and carry over from the previous choice test interfered with the control exerted by the 30-sec signal condition.

Of the four subjects given the 30-sec signal duration first (Figure 2), three (Subjects B9, B10, B11) averaged from 70% to more than 90% of the session on the signaled side. These subjects maintained their preference when the side receiving the signal was reversed. When the signal duration was reduced from 30 sec to 5 sec, a change in preference occurred for each of the three subjects. Subjects with the 5-sec signal spent more time on the unsignaled side even though the side for which they had shown a strong bias during baseline was associated with the signaled presentations. As Figure 2 shows, Subject B8 performed in a different manner from the other subjects. It is apparent that this subject's strong initial side preference (black side) was maintained throughout the experiment regardless of the imposed condition. This subject died before completing the test with the 5-sec signal.

The findings of this experiment indicate that the direction of choice when using a shuttlebox procedure is related to signal duration. With a 5-sec signal, subjects generally spent more time on the unsignaled side—an outcome consistent with Hershisier and Trapold (1971). With a 30-sec signal, subjects generally spent more time on the signaled side—an outcome consistent with Wyckoff (1952). Thus, it would appear that the conflicting findings of the Hershisier and Trapold and Wyckoff studies were due to differences related to signal duration and not to other procedural factors.

It should be noted that as the absolute duration of the signal changed from 5 sec to 30 sec and vice versa, there were two additional variables that changed at the same time. That is, the duration of the signal relative to the duration of the stimulus in its absence varied, as did the minimum interfood interval (6 sec with the 5-sec signal and 31 sec with the 30-sec signal). The data obtained here do not permit emphasizing one more than the other variables.

EXPERIMENT 2

Experiment 1 leads to the conclusion that with shuttlebox test procedures, the direction of preference between signaled and unsignaled

Fig. 1. The percentage of time spent in the signaled schedule during the final three sessions of adaptation-base-line and the final five sessions of choice and reversal for subjects given the ascending order.

sides is related to the duration of prefood signals. It is apparent from the choice literature, however, that factors in addition to signal duration are important. Marcucella and Margolius (1978), for example, found that whether subjects spent more time on an unsignaled schedule was related to reinforcement frequency and to the manner in which the signaled schedule was introduced. More important in the present context are the findings of

Lewis et al. (1974) and Badia et al. (1981). These investigators, using signaled and unsignaled schedules comparable to those in Experiment 1, reported strong preference for the signaled rather than the unsignaled schedule. Experiment 2 is concerned with these conflicting reports.

An examination of the different procedures used in choice studies suggests that the conflicting outcomes reported may be related to

Fig. 2. The percentage of time spent in the signaled schedule during the final three sessions of adaptation-base-line and the final five sessions of choice and reversal for subjects given the descending order.

whether subjects are permitted to change freely between schedules. That is, in each of the studies in which subjects spent more time on an unsignaled schedule (Hershiser & Trapold, 1971; Marcucella & Margolius, 1978; Wilkie, 1973, Experiment 1), the procedure permitted changing from one to the other schedule at any time (noncommitment procedures). Studies with schedule and signal parameters comparable to those of Hershiser and Trapold (or of Experiment 1 here), but using a commitment procedure, found preference for the signaled schedule. With a commitment procedure a response changes the schedule in effect for a fixed period of time (e.g., 1 min) and additional responses are nonfunctional (e.g., Badia et al., 1981; Lewis et al., 1974; Ryan & Badia, 1982).

Experiment 2 assessed whether differences in preference are due to a commitment or non-commitment procedure, or to other factors re-

lated to the apparatus, response, and stimuli selected. In the Badia et al. (1981) study the apparatus was an operant chamber, the response was a lever press, and the stimuli identifying the signaled and unsignaled schedules were light and darkness. In contrast, the present study and the Hershiser and Trapold (1971) study used a shuttlebox and required a shuttle response; the stimuli were also different. These latter differences, rather than the commitment vs. noncommitment differences, may have been important in determining preference.

METHOD

Subjects

Five experimentally naive female Sprague-Dawley (Holtzman Co.) rats (90 to 120 days) were maintained at 80% of their free-feeding weights. Subjects were individually housed with free access to water.

Apparatus

The shuttlebox used in this experiment was identical to that used in Experiment 1 except that the inside walls on both sides were painted black. The beginning of the experimental session was identified by the termination of the flashing (one-half second on, one-half second off) of a 24-V dc bulb, capped by a 2.5-cm jeweled lens and mounted in the center of the Plexiglas ceiling. The flashing of this light identified the end of the session. Discriminative stimuli identifying the two schedules were either light or darkness, provided by the onset or termination of a 24-V dc bulb also mounted in the ceiling.

Procedure

Subjects were trained and tested in 3-hr daily sessions. Reinforcers were delivered on a VT 60-sec schedule generated by the Fleshler and Hoffman (1962) tables modified to accommodate a minimum interfood interval of 6 sec. A 5-sec tone preceded food in the signaled schedule. No prefood signal was available during the unsignaled schedule. Three subjects were tested using a commitment procedure (see below) identical to that used in Badia et al. (1981) with the exception that the response initiating the changeover condition was a shuttle response and not a lever-press response. Two additional subjects were tested using a noncommitment procedure similar to Experiment 1.

Commitment procedure. For Subjects CS1 and CS3, the signaled schedule was associated with light and one side of the box (side B), while the unsignaled schedule was associated with darkness and the other side of the box (side A). For Subject CS2, darkness and side A identified the signaled schedule and light and side B identified the unsignaled schedule. All subjects received a minimum of six training-baseline sessions with three exposures to each food schedule. The schedules alternated daily. During the baseline condition, a shuttle response did not produce a stimulus change, but responses and the time that would have been spent in changeover condition had the responses been effective were recorded and served as baseline data. The requirement for stability for baseline and other test conditions described below (except where otherwise

noted) was three consecutive sessions in which the percentage of time in the changeover condition varied no more than 10% between sessions.

Changeover-choice sessions followed the training-baseline sessions. During some sessions subjects could change from the unsignaled to the signaled schedule and during other sessions subjects could change from the signaled to the unsignaled schedule. The order in which subjects received these tests varied, with two of the subjects (CS2, CS3) given the opportunity to change to the unsignaled schedule first and one subject (CS1) given the reverse order. At the beginning of a session, one of the schedules (signaled or unsignaled) was in effect and food was delivered to the side associated with that schedule. A shuttle response from one side to the other terminated the existing schedule and produced the alternate schedule for 1 min. Food delivery then occurred on the side associated with the alternate schedule. Further shuttles from one side to the other during the 1-min period had no effect. At the end of the 1-min changeover period, the alternate schedule and the stimulus associated with that schedule terminated and the initial schedule was reinstated. Food delivery likewise reverted back to the original side. Reinstating the alternate schedule at that time required a further shuttle response. The measure of preference was the percentage of session time spent in the changeover condition. Two replications were given of each changeover condition.

Noncommitment procedure. Two subjects (NCS1, NCS2) were given a choice between the two schedules using a noncommitment procedure identical to that used in Experiment 1. Discriminative stimuli identifying each schedule were light or darkness. For Subject NCS1, side B and darkness identified the signaled schedule, and side A and light identified the unsignaled schedule. For Subject NCS2, side A and light identified the signaled schedule, and side B and darkness identified the unsignaled schedule. Choice sessions were terminated when the percentage of time spent on one side varied by no more than 10% for five consecutive sessions. Following the choice sessions, the discriminative stimuli identifying each schedule were reversed and choice was reexamined.

RESULTS AND DISCUSSION

Table 2

Percentage of time spent in the unsignaled schedule for the last five sessions of choice and reversal in the non-commitment procedure.

Subject	Choice	Reversal
NCS1	80, 80, 74, 83, 82	83, 73, 80, 81, 78
Session Number	3, 4, 5, 6, 7	11, 12, 13, 14, 15
NCS2	69, 75, 72, 75, 77	72, 80, 76, 73, 75
Session Number	3, 4, 5, 6, 7	14, 15, 16, 17, 18

Commitment Procedure. Table 1 shows the percentage of time spent in the changeover condition for the final three sessions of the training-baseline and choice conditions for subjects in the commitment procedure. Rows beginning "CO to Sig" represent the percentage of time subjects spent in the changeover condition when the shuttle response produced the signaled condition. Subjects CS1, CS2, and CS3 spent an average of 63%, 73%, and 75%, respectively, in the signaled schedule, which was 14.5%, 29.3%, and 28% over the previous baseline performance.

As shown in the row beginning "CO to Unsig," subjects did not change to the unsignaled condition. Subjects CS1, CS2, and CS3 responded for the unsignaled schedule either at or below baseline, spending an average of 46.0%, 44.7%, and 43.7% of the session in the unsignaled schedule, respectively.

Noncommitment procedure. Table 2 shows the percentage of time spent in the unsignaled schedule for the last five days of choice and reversal for Subjects NCS1 and NCS2 in the non-commitment procedure. Both preferred the unsignaled condition. These subjects spent an average of 79.8% and 73.6%, respectively, during the last five sessions of reversal in the unsignaled schedule. These results were similar to those observed in Experiment 1 in which subjects spent most of each choice session in the unsignaled schedule.

These findings show that preference for one condition over another is affected by the procedure used. Clearly, commitment and non-

commitment procedures result in different outcomes. These data strongly suggest that the discrepant outcomes of earlier choice studies (e.g., Hershisier & Trapold, 1971; Lewis et al., 1974) can be attributed to differences in the choice procedures used and not to other procedural factors (cf. Badia et al., 1981). Further studies are needed, however, to assess the generality of the effect demonstrated here. Whether the direction of preference is affected by commitment/noncommitment procedures in an operant chamber using a lever-press response should be determined.

GENERAL DISCUSSION

The results of the present study can be summarized as follows. In Experiment 1, it was shown that preference could be reversed by extending signal duration from 5 sec to 30 sec. That is, subjects preferred the unsignaled side of the box when the signal was 5 sec in duration, but they preferred the signaled side of the box when the signal was 30 sec in duration. Experiment 2 showed that preference could also be reversed by modifying the choice test. That is, when subjects could move freely between schedules, more time was spent on the unsignaled side, but when a shuttle response produced a schedule change for a fixed (60-sec) period of time, subjects generally spent more time in the signaled side of the box.

The results of the present experiments provide strong support for the conclusion that the discrepant findings among earlier studies involving choice between signaled and unsignaled food schedules (e.g., Hershisier & Trapold, 1971; Lewis et al., 1974; Wyckoff, 1952) can be attributed to differences in signal parameters and test procedures and not to other factors (cf. Badia et al., 1981). Further tests are now needed with different signal durations

Table 1

Percentage of time spent in the changeover condition for the final three sessions of the training-baseline and changeover-choice conditions for subjects in the commitment procedure.

Condition	Subjects		
	CS1	CS2	CS3
Baseline	48, 48, 50	42, 40, 49	43, 53, 45
Session Number	20, 21, 22	40, 41, 42	40, 41, 42
CO to Sig	64, 63, 62	73, 73, 73	75, 76, 74
Session Number	24, 25, 26	44, 45, 46	48, 49, 50
Baseline	53, 44, 44	46, 51, 48	49, 44, 47
Session Number	36, 37, 38	18, 19, 20	19, 20, 21
CO to Unsig	49, 45, 44	43, 47, 44	47, 40, 44
Session Number	40, 41, 42	22, 23, 24	23, 24, 25

(Experiment 1) and with longer and shorter commitment periods (Experiment 2) to provide a greater understanding of the importance of these variables.

Theoretical accounts of choice behavior based on the information provided by food-related stimuli (e.g., Hendry, 1969) or on hypothetical preparatory responses during pre-food signals (Perkins, 1971) are insufficient to account for the reversal of choice observed in Experiments 1 and 2. Both views predict a general preference for signaled conditions. These views also have difficulty accounting for the factors controlling choice between signaled and unsignaled aversive situations (see Badia, Harsh, & Abbott, 1979).

An alternative view is based on conditioned reinforcement and emphasizes the differences in the density of primary reinforcement correlated with the stimulus components of choice-test situations (see Bowe & Dinsmoor, 1983; Browne & Dinsmoor, 1974; see also Fantino, 1977). Three stimulus components can be identified in the present experiments: (1) the signal that is associated with the highest food density; (2) the side cues, in the absence of the signal on the signaled side, that are associated with the absence of food (zero food density); and (3) the cues of the unsignaled side that are associated with intermediate food density. From a conditioned-reinforcement view, responses are reinforced when they produce a stimulus correlated with a higher reinforcement density and punished when they produce a stimulus correlated with a lower food density.

The pattern of shuttling behavior observed was consistent with a conditioned-reinforcement interpretation. A study of event records revealed that although subjects tested with a 5-sec signal spent most of the available time on the unsignaled side of the box, they often shuttled to the signaled side. Once on the signaled side, further shuttling was determined by the signal. The subjects remained on the signaled side when the signal was encountered, but, when the signal was absent, they tended to return quickly to the unsignaled side. The same pattern of responding has also been described by Dinsmoor, Browne, Lawrence, & Wasserman (1971) in their replication of Wyckoff's study and by Marcucella and Margolius (1978) in their study of the role of signaling in choice

between concurrent variable-interval schedules.

It follows from the analysis offered here that increasing signal duration (as in Experiment 1) should increase time spent in the signaled side. As signal duration increases, shuttling from the unsignaled to the signaled side should be more likely since the signal component (reinforcement) would be more likely to occur and the signal-absent component less likely. Additionally, shuttling from the signaled to the unsignaled side should decrease because time spent in the signal-absent component decreases.

With regard to Experiment 2, it may be the extent of control of the duration of the signal-absent component of the signaled schedule that separates (behaviorally) commitment and noncommitment procedures. That is, when shuttling to the signaled side under the noncommitment procedure, subjects may return to the unsignaled side when the signal does not occur. This behavior limits exposure to the signal-absent component and, when signals are brief as in Experiment 2, subjects may prefer the signal but spend most of the session time in the unsignaled side of the box. This option is not available with the commitment procedure where exposure to the signal-absent component can not be as readily controlled. During the "CO-SIG" test, production of the signaled schedule suggests that, even though the unsignaled side may be preferred to the signal-absent component, the positive effect of signal production is greater than the negative effect of uncontrollable and extended exposure to the signal-absent component.

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