SIGNAL MODALITY AND CHOICE BETWEEN SIGNALLED AND UNSIGNALLED FOOD

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Choice between signaled and unsignaled response-independent food schedules was assessed in three experiments using a commitment procedure. In Experiment 1, subjects tested with a 5-s visual signal consistently changed from the signaled to the unsignaled schedule. Changing from the unsignaled to the signaled schedule was observed only occasionally and only at low levels. The same outcome was observed in Experiment 2 with different types of visual signals and with different stimulus combinations identifying the signal period, the signal-absent period, and the unsignaled schedule. In Experiment 3 the visual signal was replaced with an auditory signal for four of the subjects tested in Experiment 2. The subjects then changed from the unsignaled to the signaled schedule or showed a substantial reduction in choice for the unsignaled schedule. The data were assessed using a conditioned-reinforcement interpretation of choice.

Key words: choice, signal modality, food, lever press, rats

Several studies have investigated choice between signaled and unsignaled food schedules. In some, choice of the signaled schedule occurred (Badia, Ryan, & Harsh, 1981; Lewis, Lewin, Muehleisen, & Stoyak, 1974; Ryan & Badia, 1982); but in others, choice for the unsignaled schedule occurred (Hershiser & Trapold, 1971; Marcucella & Margolius, 1978; Wilkie, 1973). A recent report by Harsh, Badia, and Ryan (1983) provides information helpful in understanding these mixed findings. These investigators found that the direction of choice was dependent on an interaction between the duration of the signal and the choice contingencies. That is, when subjects (rats) could move freely between the unsignaled and signaled conditions (a noncommitment choice procedure), they chose the unsignaled schedule when signals were brief, but chose

the signaled schedule when the signals were long. In contrast, when responses produced a fixed time period of exposure to the signaled or to the unsignaled schedule (a commitment choice procedure), subjects chose the signaled schedule even with brief signals.

The present study investigated additional factors controlling choice between signaled and unsignaled food schedules. Effects of signal modality were explored in three experiments. A visual signal was used in Experiments 1 and 2 and the findings were contrasted with those of earlier experiments (Badia et al., 1981) in which auditory signals were used. In Experiment 3, subjects that had been tested earlier with a visual signal were tested with an auditory signal to assess signal-modality effects using a within-subjects procedure.

EXPERIMENT 1

Previous research using a commitment choice procedure and a 5-s auditory signal (e.g., Badia et al., 1981; Lewis et al., 1974; Ryan & Badia, 1982) found predominant choice of the signaled food schedule. The present experiment involved the same choice procedure as in the earlier studies but used a

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visual signal instead of an auditory one. Both hooded and albino rats were used as subjects and chocolate milk and food pellets served as reinforcers.

METHOD

Subjects

Nine experimentally naive female albino rats (90 to 120 days) of the Sprague-Dawley strain (Holtzman Co.) and three experimentally naive female hooded rats (90 to 120 days) were maintained at 80% of their free-feeding weights. Subjects H1, H2, and H3 were the hooded rats. The subjects were individually housed with free access to water.

Apparatus

Subjects were tested in two standard Foringer operant conditioning chambers (25 by 23 by 25 cm) housed in sound-attenuating boxes. Two levers were mounted on the 25-cm wall, 7 cm above the floor and 4 cm from either side. Both levers required a force of 0.19 N to depress and were operative for changeover responding (see below). Each chamber was fitted with a Plexiglas ceiling 12 cm above the grid floor. The beginning of the experimental session was identified by the termination of light provided by a 24-V dc bulb, capped by a 1.27-cm jeweled lens and mounted 6 cm above the right lever. The onset of this light identified the end of the session. The correlated stimulus was the onset of a steady light provided by two 24-V dc bulbs mounted 16 cm above the grid floor. The prefood signal was the flashing (0.5 s on, 0.5 s off) of the correlated stimulus for 5 s. Noyes food pellets (45 mg) were delivered from a Davis feeder (Model PD 104) into a food cup situated midway between the two response levers. The feeder was located outside the sound-attenuating chamber. Water was available throughout the session for subjects receiving food pellets. Milk delivery consisted of 0.10 cc injections of commercially available lowfat (one-half percent milkfat) chocolate milk. A solenoid mounted on the outside of the sound-attenuating box delivered the chocolate milk into a brass cup

through a tube located between the two levers. The tube was shielded so that subjects could not lick the tip and drain the tube of the liquid. Throughout the experimental session white noise (72 dB) was presented through a speaker mounted on the ceiling of the operant chamber.

Procedure

Subjects were tested in daily 3-hr sessions. Food delivery was arranged using a single variable-time (VT) 60-s schedule generated by the Fleshler and Hoffman (1962) progression modified to accommodate a minimum interfood interval of 6 s. Subjects FP1, FP3, and FP4 received food pellets; the remaining subjects received chocolate milk.

Training-Baseline. Prior to the changeover test (see below), subjects received a minimum of four training-baseline sessions. During half the sessions, food delivery was always preceded by a signal. These signaled sessions alternated with unsignaled ones during which the signal was not presented. For Subjects CO7, CO13, CO21, H3, and FP3, darkness identified the signaled schedule and light (the correlated stimulus) identified the unsignaled schedule. For Subjects CO8, CO9, CO20, H1, H2, FP1, and FP4, this was reversed.

During training-baseline, lever responses did not produce a stimulus change, but responses and the time that would have been spent in changeover had the responses been effective were recorded and served as baseline data. The requirement for stability for training-baseline and the changeover test described below was three consecutive sessions in which the percentage of time in changeover varied no more than 10%. Relaxation of this criterion (to 20%) occurred when, in the experimenter's judgment, continued testing would not have yielded useful information. This occurred on less than 5% of the occasions.

Changeover. Following the training-baseline sessions, subjects were given the opportunity to change from the signaled schedule to the unsignaled one and vice versa. Half the subjects were given the opportunity

to change to the unsignaled schedule first and half were first given the opportunity to change to the signaled schedule. During the changeover test, a lever press terminated the existing schedule and produced the alternate schedule for 1 min. Further responding during this period had no effect. At the end of the changeover period, the alternate schedule was terminated and the initial schedule was reinstated. Subjects could then remain under the initial schedule or reinstate the alternate one. Preference was measured as the percentage of session time spent in the alternate condition (percentage of time in changeover). Changeover responding had no effect on food delivery. At least two exposures to each changeover condition were given.

RESULTS AND DISCUSSION

Figure 1 shows the data from six albino rats tested with a visual signal and with chocolate milk as the reinforcer. The data obtained with the hooded rats and with the subjects given food pellets are presented in Table 1. Although some subjects did change to the signaled schedule at levels that were discernibly above baseline (see for example, Subject CO7 in Figure 1), none of the subjects showed the strong and consistent choice for the signaled schedule that was observed by Badia et al. (1981).

As can be seen in Figure 1 and Table 1, all subjects responded in a manner that produced the unsignaled schedule during two exposures to the "CO to unsig" condition. Subjects CO8, CO20, and CO21 (see Columns 6 through 10, Fig. 1) were tested during a third exposure because of ambiguous performance during one of their first two exposures. That is, CO8 and CO20 changed over during the second exposure but not the first, and CO21 was inadvertently removed from the second exposure while the level of changeover was in a clear downward trend. The order in which the test conditions were given did not affect performance because subjects given the option to change to the signaled condition first (Subjects CO7, CO9, CO20) did not differ from those given

the reverse order. The choice of an unsignaled over a signaled schedule described here with a visual signal is opposite to that reported by Badia et al. (1981), who used an auditory signal. Choice, then, appears to be related to signal modality.

EXPERIMENT 2

One possible basis for the discrepancy between the findings of Experiment 1 and previous experiments (e.g., Badia et al., 1981) is that the flashing light used in Experiment 1 may have been aversive. In addition, the use of visual stimuli for all three stimulus conditions (signal, signal-absent period, unsignaled condition) in Experiment 1 may have had unknown effects. This latter consideration is relevant because in previous work with auditory signals (e.g., Badia et al., 1981), the three stimulus conditions were composed of two dimensions, tone and light, rather than light alone. Experiment 2 assessed the relevance of these considerations to the findings obtained in Experiment 1.

METHOD

Subjects

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

Apparatus

The apparatus was the same as that used in Experiment 1. Chocolate milk was used as the reinforcer for all subjects.

Procedure

The procedure was the same as that in Experiment 1. Choice was between a signaled and an unsignaled schedule; however, the stimuli identifying the signal and signal-absent periods of the signaled schedule and the stimulus identifying the unsignaled schedule varied between subjects. Table 2 lists the stimuli used to identify the three conditions for each subject. Note that for

Table 1

Percentage of session time spent in the changeover condition for the last three sessions of training-baseline and changeover conditions. Corresponding sessions numbers are in parentheses. The data were derived from hooded rats (H1, H2, H3) with chocolate milk as the reinforcer and from albino rats (FP1, FP3, FP4) with food pellets as the reinforcer.

Subject	Exposure		Changeover to Signaled Condition		Changeover to Unsignaled Condition	
			Baseline	Baseline	Baseline	Baseline
H1	1st	% Time Session	4, 20, 8 (30, 31, 32)	6, 8, 10 (33, 34, 35)	0, 0, 1 (2, 3, 4)	61, 53, 61 (12, 13, 14)
	2nd	% Time Session	6, 8, 6 (37, 38, 39)	26, 20, 16 (41, 42, 43)	38, 31, 31 (17, 18, 19)	61, 53, 61 (26, 27, 28)
H2	1st	% Time Session	11, 7, 11 (29, 30, 31)	13, 7, 7 (32, 33, 34)	4, 2, 4 (2, 3, 4)	41, 37, 39 (12, 13, 14)
	2nd	% Time Session	3, 13, 8 (36, 37, 38)	10, 15, 13 (39, 40, 41)	6, 19, 8 (18, 19, 20)	50, 53, 50 (23, 24, 25)
H3	1st	% Time Session	3, 3, 2 (2, 3, 4)	0, 3, 2 (5, 6, 7)	6, 1, 5 (16, 17, 18)	45, 55, 51 (23, 24, 25)
	2nd	% Time Session	0, 5, 3 (9, 10, 11)	1, 3, 0 (12, 13, 14)	4, 6, 5 (27, 28, 29)	58, 58, 55 (32, 33, 34)
FP1	1st	% Time Session	4, 6, 2 (6, 7, 8)	11, 12, 15 (12, 13, 14)	17, 22, 28 (26, 27, 28)	45, 55, 54 (33, 34, 35)
	2nd	% Time Session	8, 10, 5 (16, 17, 18)	22, 20, 22 (20, 21, 22)	7, 7, 5 (41, 42, 43)	60, 62, 62 (47, 48, 49)
FP3	1st	% Time Session	15, 25, 15 (2, 3, 4)	32, 25, 27 (8, 9, 10)	8, 2, 0 (23, 24, 25)	75, 73, 71 (31, 32, 33)
	2nd	% Time Session	4, 2, 4 (14, 15, 16)	11, 10, 2 (17, 18, 19)	2, 4, 1 (35, 36, 37)	72, 78, 77 (39, 40, 41)
FP4	1st	% Time Session	10, 22, 14 (26, 27, 28)	27, 30, 33 (33, 34, 35)	16, 23, 32 (4, 5, 6)	71, 73, 72 (9, 10, 11)
	2nd	% Time Session	25, 25, 26 (39, 40, 41)	33, 31, 33 (43, 44, 45)	13, 24, 17 (15, 16, 17)	67, 71, 73 (18, 19, 20)

Subjects COL2, COL3, COL4, and COL5, the flashing light occurred equally often in both the signaled and unsignaled schedules. That is, a 5-s flashing light served as the signal but also was presented in the unsignaled schedule on a VT 60-s schedule (with the modification that no presentation of the randomized light occur simultaneously or overlap with the presentation of food). Note also that for Subjects CP1, CP2, CP3, and CP4, a continuously flashing light identified the unsignaled schedule. The stimulus conditions for these eight subjects (COL2 through CP4) permitted a test of the hypothesis that the subjects' responding in Experiment 1 was maintained by prevention of the

flashing light. That is, if the flashing light was aversive, Subjects 1-4 would be expected to change to the signaled schedule and Subjects COL 2-5 would not be expected to change to either the signaled schedule or the unsignaled one.

For subjects in Experiment 1 and Subjects COL2 through CP4 in the present experiment, a visual stimulus was used to identify all three stimulus conditions (signal period, signal-absent period, and the unsignaled condition). For Subjects WN1, WN2, WN3, and WN4, however, white noise identified either the signal-absent period or the unsignaled condition (See Table 2). Thus, for these four subjects, there were two critical

Table 2

Stimuli used to identify signal, signal-absent period, and unsignaled condition.
fl. light = flashing light, w. noise = 70 dB white noise.

<i>Subject</i>	<i>Signal</i>	<i>Signal-Absent Period</i>	<i>Unsignaled Condition</i>
COL2	fl. light	dark	light + randomized fl. light
COL3	fl. light	light	dark + randomized fl. light
COL4	fl. light	dark	light + randomized fl. light
COL5	fl. light	light	dark + randomized fl. light
CP1	dark	light	fl. light
CP2	light	dark	fl. light
CP3	dark	light	fl. light
CP4	light	dark	fl. light
WN1	light	dark + w. noise	dark
WN2	light	dark + w. noise	dark
WN3	light	dark	dark + w. noise
WN4	light	dark	dark + w. noise

stimulus dimensions (auditory and visual), as in the Badia et al. (1981) study, rather than just one (visual), as in Experiment 1. Tests of these subjects permitted assessing the importance of this difference. It should also be noted that for Subjects WN1, WN2, WN3, and WN4, the onset of the signal was the only time during the experimental session that a change in illumination occurred. For Experiment 1, the production of the unsignaled condition also was accompanied by a change in illumination (from darkness to light, or vice versa).

RESULTS AND DISCUSSION

The percentage of time spent in change-over for the last three sessions of training-baseline and the percentage of time spent in changeover during testing are shown in Tables 3, 4, and 5. Table 3 presents the data obtained when a 5-s flashing light served as a signal and a randomly distributed flashing light was presented during the unsignaled schedule. All subjects changed over to the unsignaled schedule at a level comparable to that observed in Experiment 1. No subjects responded in a way that consistently produced the signaled schedule. Table 4 presents the data obtained when a flashing light accompanied the unsignaled schedule and the signal was either a continuous light or

darkness. Subjects again changed over to the unsignaled schedule at levels comparable to those observed for previous subjects. No subjects responded in a way that produced the signaled schedule at levels consistently above baseline during both exposures. The data from Tables 3 and 4 showing that subjects produced the unsignaled schedule even when it was accompanied by the flashing light rule out explanations of the results of Experiment 1 based on the aversiveness of the flashing light. The data from the test in which white noise identified either the unsignaled schedule or the signal-absent period of the signaled schedule are presented in Table 5. Again, all subjects changed over to the unsignaled schedule, but responding that produced the signaled schedule was inconsistent. These findings show that the unsignaled schedule is chosen when a visual signal is used whether one (visual) or two (visual and auditory) stimulus dimensions are used to identify schedule components.

EXPERIMENT 3

Comparisons of the results of the first two experiments and those of Badia et al. (1981) indicate that a visual signal prior to food results in choice of the unsignaled schedule, whereas the auditory signal prior to food results in choice of the signaled schedule.

Table 3

Percentage of session time spent in changeover for the last three sessions of training-baseline and changeover conditions. Corresponding session numbers are in parentheses. A 5-s flashing light served as a signal during the signaled schedule and also was randomly presented during the unsignaled schedule. Darkness identified the signal-absent period and a light identified the unsignaled schedule for Subjects COL2 and COL4. This was reversed for Subjects COL3 and COL5.

Subject	Exposure		Changeover to Signaled Condition		Changeover to Unsignaled Condition	
			Baseline	Baseline	Baseline	Baseline
COL2	1st	% Time	7, 9, 6	7, 10, 8	13, 7, 2	78, 74, 72
		Session	(6, 7, 8)	(9, 10, 11)	(20, 21, 22)	(23, 24, 25)
	2nd	% Time	5, 12, 2	5, 6, 5	3, 11, 2	73, 70, 75
		Session	(13, 14, 15)	(16, 17, 18)	(27, 28, 29)	(30, 31, 32)
COL3	1st	% Time	10, 11, 8	11, 12, 11	1, 10, 10	59, 57, 51
		Session	(31, 32, 33)	(34, 35, 36)	(6, 7, 8)	(12, 13, 14)
	2nd	% Time	5, 5, 6	14, 5, 12	4, 5, 13	52, 56, 54
		Session	(42, 43, 44)	(47, 48, 49)	(20, 21, 22)	(25, 26, 27)
COL4	1st	% Time	8, 8, 13	24, 21, 17	21, 20, 16	70, 78, 72
		Session	(8, 9, 10)	(12, 13, 14)	(25, 26, 27)	(31, 32, 33)
	2nd	% Time	23, 15, 24	23, 23, 26	18, 17, 26	56, 53, 52
		Session	(16, 17, 18)	(20, 21, 22)	(39, 40, 41)	(42, 43, 44)
COL5	1st	% Time	1, 0, 0	0, 2, 0	3, 3, 0	62, 56, 61
		Session	(4, 5, 6)	(7, 8, 9)	(19, 20, 21)	(27, 28, 29)
	2nd	% Time	0, 1, 1	0, 4, 1	3, 5, 6	61, 58, 66
		Session	(11, 12, 13)	(15, 16, 17)	(35, 36, 37)	(40, 41, 42)

Table 4

Percentage of session time spent in changeover for the last three sessions of training-baseline and changeover conditions. Corresponding session numbers are in parentheses. A continuously flashing light identified the unsignaled schedule. For Subjects CP2 and CP4 the signal was a 5-s steady light and the signal-absent period was darkness. For Subjects CP1 and CP3 the signal was 5 s of darkness and the signal-absent period was identified by light.

Subject	Exposure		Changeover to Signaled Condition		Changeover to Unsignaled Condition	
			Baseline	Baseline	Baseline	Baseline
CP1	1st	% Time	4, 14, 16	25, 27, 27	4, 13, 0	50, 43, 49
		Session	(4, 5, 6)	(7, 8, 9)	(27, 28, 29)	(34, 35, 36)
	2nd	% Time	22, 26, 26	12, 15, 18	5, 15, 6	58, 53, 61
		Session	(15, 16, 17)	(21, 22, 23)	(40, 41, 42)	(46, 47, 48)
CP2	1st	% Time	11, 18, 16	16, 6, 7	12, 8, 5	48, 51, 49
		Session	(2, 3, 4)	(10, 11, 12)	(28, 29, 30)	(32, 33, 34)
	2nd	% Time	8, 8, 4	2, 6, 3	20, 13, 19	45, 45, 42
		Session	(14, 15, 16)	(17, 18, 19)	(36, 37, 38)	(39, 40, 41)
CP3	1st	% Time	22, 25, 16	13, 11, 8	12, 23, 17	53, 58, 60
		Session	(42, 43, 44)	(45, 46, 47)	(16, 17, 18)	(23, 24, 25)
	2nd	% Time	21, 29, 17	5, 13, 8	6, 13, 11	67, 70, 61
		Session	(49, 50, 51)	(53, 54, 55)	(29, 30, 31)	(34, 35, 36)
CP4	1st	% Time	15, 6, 12	25, 25, 32	2, 3, 7	55, 62, 62
		Session	(27, 28, 29)	(31, 32, 33)	(2, 3, 4)	(12, 13, 14)
	2nd	% Time	25, 25, 20	10, 19, 18	8, 14, 5	58, 50, 55
		Session	(35, 36, 37)	(39, 40, 41)	(20, 21, 22)	(23, 24, 25)

Table 5

Percentage of session time spent in changeover for the last three sessions of training-baseline and changeover conditions. Corresponding session numbers are in parentheses. A 5-s steady light served as the signal. For Subjects WN1 and WN2, darkness and a 70-dB white noise identified the signal-absent period and darkness identified the unsignaled schedule. For Subjects WN3 and WN4, darkness alone identified the signal-absent period and darkness and white noise identified the unsignaled schedule.

Subject	Exposure		Changeover to		Changeover to	
			Baseline	Signaled Condition	Baseline	Unsignaled Condition
WN1	1st	% Time	8, 4, 4	13, 5, 4	9, 10, 15	53, 59, 51
		Session	(2, 3, 4)	(5, 6, 7)	(27, 28, 29)	(33, 34, 35)
	2nd	% Time	5, 18, 6	3, 7, 11	13, 23, 16	61, 56, 58
		Session	(9, 10, 11)	(12, 13, 14)	(37, 38, 39)	(40, 41, 42)
WN2	1st	% Time	18, 27, 17	15, 24, 22	6, 11, 5	72, 79, 82
		Session	(26, 27, 28)	(29, 30, 31)	(2, 3, 4)	(7, 8, 9)
	2nd	% Time	19, 25, 16	21, 11, 12	24, 19, 16	63, 73, 63
		Session	(37, 38, 39)	(40, 41, 42)	(15, 16, 17)	(22, 23, 24)
WN3	1st	% Time	17, 20, 11	5, 13, 10	12, 11, 1	54, 59, 60
		Session	(31, 32, 33)	(34, 35, 36)	(13, 14, 15)	(19, 20, 21)
	2nd	% Time	7, 13, 5	6, 8, 5	12, 22, 11	61, 53, 50
		Session	(38, 39, 40)	(41, 42, 43)	(23, 24, 25)	(27, 28, 29)
WN4	1st	% Time	5, 13, 4	5, 5, 6	16, 18, 7	41, 47, 44
		Session	(4, 5, 6)	(7, 8, 9)	(27, 28, 29)	(32, 33, 34)
	2nd	% Time	7, 13, 3	18, 15, 13	14, 24, 27	40, 48, 50
		Session	(11, 12, 13)	(16, 17, 18)	(36, 37, 38)	(39, 40, 41)

Table 6

Mean percentage of time spent in changeover for the last three sessions of baseline and changeover conditions for Subjects CP1, CP2, CP3, and CP4. In parentheses is the session number of the last session of the condition. Both a visual and auditory signal were used but at different times.

Subject	Exposure		Changeover to		Changeover to	
			Baseline	Signaled Condition	Baseline	Unsignaled Condition
CP1 Dark	1st	% Time	11 (6)	26 (9)	6 (29)	47 (36)
		% Time	25 (17)	15 (23)	9 (42)	57 (48)
	Tone	% Time	10 (56)	8 (59)	10 (76)	32 (80)
		% Time	7 (65)	5 (68)	11 (88)	31 (95)
CP2 Light	1st	% Time	15 (4)	10 (12)	8 (30)	49 (34)
		% Time	7 (16)	4 (19)	17 (38)	44 (41)
	Tone	% Time	48 (105)	89 (109)	15 (63)	36 (71)
		% Time	48 (115)	90 (118)	20 (75)	48 (83)
CP3 Dark	1st	% Time	21 (44)	11 (47)	17 (18)	57 (25)
		% Time	23 (51)	9 (55)	10 (31)	66 (36)
	Tone	% Time	5 (86)	5 (89)	11 (61)	39 (69)
		% Time	13 (93)	10 (98)	31 (76)	32 (80)
CP4 Light	1st	% Time	11 (29)	27 (33)	4 (4)	60 (14)
		% Time	23 (37)	16 (41)	9 (22)	54 (25)
	Tone	% Time	24 (68)	65 (84)	11 (47)	33 (55)
		% Time	27 (92)	80 (95)	14 (59)	43 (64)

These signal-modality comparisons have been between-subject comparisons. Experiment 3 examined the effect of signal modality on choice using within-subject comparisons. Four of the subjects from Experiment 2 were tested with an auditory signal.

METHOD

Subjects

Four subjects (CP1, CP2, CP3, CP4) from Experiment 2 were maintained at 80% of their free-feeding weights.

Apparatus

The apparatus was the same as that used in Experiment 1 with the exception of a tone generator (Mallory Sonalert), which was mounted 10 cm above the right lever and which produced an 80-dB 4500-Hz pure tone. Chocolate milk served as the reinforcer.

Procedure

The procedure was the same as in Experiment 2. However, subjects were given training-baseline sessions with a tone as the signal. The stimulus identifying the signal-absent period in the signaled schedule and the stimulus identifying the unsignaled schedule corresponded to those used for these subjects in Experiment 2 (see Table 2). The tone signal during the signaled schedule was superimposed upon the stimulus identifying the signaled schedule. Subject CP1 was tested in the "Changeover to Signaled" condition first. Subjects CP2, CP3, and CP4 were first tested in the "Changeover to Unsignaled" condition.

RESULTS AND DISCUSSION

Table 6 shows the mean percentage of time spent in the changeover condition for the last three sessions of training-baseline and changeover conditions. Each subject's performance with both a visual signal (from Experiment 2) and an auditory signal (Experiment 3) is shown. Mean values rather than individual session values (see Table 4 for session values obtained with a visual

signal) are given to facilitate comparison across signal modalities. With a visual signal, the pattern of responding was consistent across subjects and within subjects across exposures. That is, the subjects consistently produced the unsignaled schedule during the "Changeover to Unsignaled" condition, but did not consistently produce the signaled schedule during the "Changeover to Signaled" condition. When the signal was changed to a tone, however, the amount of time spent in the unsignaled schedule was reduced for each subject, indicating an effect of signal modality. In addition, two of the four subjects (CP2 and CP4) began to respond during the "Changeover to Signaled" condition at levels sufficient to spend 65 to 90% of the sessions in the signaled schedule. Preference for signaling when an auditory signal is used is consistent with the report by Badia et al. (1981). It must be pointed out, however, that responding of Subjects CP1 and CP3 was not maintained above baseline levels when it could produce the signaled schedule. Further, although the prior levels of responding were reduced, the time spent in changeover during the "Changeover to Unsignaled" condition responding remained above baseline for all four subjects. This ambiguous pattern of responding is considered to be a "carry-over" effect from prior testing with a visual signal. This conclusion is based on the observation that none of the thirteen subjects tested by Badia et al. (1981) failed to show a strong and consistent preference for the signaled schedule. Further, none of those subjects showed a strong tendency to change from the signaled schedule to the unsignaled one.

GENERAL DISCUSSION

The results indicate that signal modality is an important determinant of choice between signaled and unsignaled food presentations. In Experiment 1, subjects chose an unsignaled over a signaled response-independent food schedule when the signal was visual. This outcome is opposite to that reported by Badia et al. (1981), who used an auditory signal but otherwise identical test condi-

tions. Experiment 2 showed that the results of Experiment 1 were not due to the aversive properties of the flashing light or to other aspects related to visual stimuli. Finally, the third experiment demonstrated that switching from a visual to an auditory signal reversed or attenuated choice between the unsignaled and signaled schedules. It is apparent from the present findings and those of Harsh et al. (1983) that direction of choice between signaled and unsignaled appetitive schedules is complexly related to a number of factors. These factors include: (a) signal modality, (b) signal length, (c) response-dependent versus response-independent delivery of reinforcers, and (d) commitment versus noncommitment choice. Theoretical views of choice that predict a general preference for signaling (e.g., Berlyne, 1960; Perkins, 1971) cannot account for this complexity.

A conditioned reinforcement/punishment hypothesis may account for a reversal of choice as signal modality is varied. This view focuses on the stimulus components of test situations rather than on the general properties of predictable environments (Bowe & Dinsmoor, 1983; Browne & Dinsmoor, 1974; Fantino 1977). According to this view, changeover from an unsignaled food schedule to a signaled one occurs when the conditioned reinforcement resulting from production of the signal (food) component is greater than the conditioned punishment resulting from production of the signal-absent (no food) component. When the conditioned punishment is greater, changeover in the opposite direction is expected. Harsh et al. (1983) used the conditioned reinforcement/punishment hypothesis to account for their findings showing that the direction of choice may vary with choice contingencies and signal durations.

From a conditioned reinforcement/punishment view, the present data and those of Badia et al. (1981) indicate that with rats as subjects and with the described test conditions, an auditory signal provides sufficient conditioned reinforcement to override the conditioned punishment produced by the

no-food stimulus, and responding for the signaled schedule is maintained. With a visual signal, however, there is considerably less conditioned reinforcement, and choice for the unsignaled schedule develops (Experiments 1 and 2) or responding for the signaled schedule is at least considerably reduced (Experiment 3).

There are at least two possible explanations of why greater conditioned reinforcement may result from use of auditory signals. First, auditory signals may simply be more salient. The importance of stimulus salience is suggested by the findings of Dinsmoor, Sears, and Dout (1976), who found that the rate of observing responses depended on the difference between the physical characteristics of the positive discriminative stimulus (correlated with a relative high frequency of primary reinforcement) and those of the mixed-schedule stimulus (correlated with an intermediate frequency of food). Larger differences between the positive discriminative stimulus and the mixed schedule led to higher rates of observing responses.

An alternative explanation is that with food as a reinforcer, auditory stimuli become more powerful conditioned reinforcers for rats than do visual stimuli. Holland (1977) reported that the form of the Pavlovian conditioned response to a stimulus paired with an appetitive reinforcer was determined by whether the conditioned stimulus was auditory or visual. Additionally, research by LoLordo and his colleagues (Foree & LoLordo, 1973, 1975; LoLordo & Furrow, 1976) has shown that for a different species (pigeons), visual stimuli more readily acquire control than auditory stimuli in situations in which appetitive events are involved (auditory stimuli more readily acquired control in aversive settings). The data obtained in the present investigation are consistent with the view that, for rats in appetitive situations, auditory signals acquire greater control than visual signals.

In sum, the present data, along with those from similar studies (Badia et al., 1981; Harsh et al., 1983, Ryan & Badia, 1982), in-

dicates that the direction of choice between signaled and unsignaled food schedules is influenced by a number of complexly related factors. It is clear that general theories of choice based upon processes such as uncertainty reduction and/or preparation are insufficient to account for these findings. The findings are more consistent with the notion that responding is governed by conditioned reinforcement/punishment resulting from presentation of stimuli correlated with food and no-food periods.

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