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STIMULUS CHANGE AS A FACTOR IN RESPONSE MAINTENANCE WITH FREE FOOD AVAILABLE

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Rats bar pressed for food on a reinforcement schedule in which every response was reinforced, even though a dish of pellets was present. Initially, auditory and visual stimuli accompanied response-produced food presentation. With stimulus feedback as an added consequence of bar pressing, responding was maintained in the presence of free food; without stimulus feedback, responding decreased to a low level. Auditory feedback maintained slightly more responding than did visual feedback, and both together maintained more responding than did either separately. Almost no responding occurred when the only consequence of bar pressing was stimulus feedback. The data indicated conditioned and sensory reinforcement effects of response-produced stimulus feedback.

Animals will respond to obtain food when "free food" is concurrently available. Jensen (1963) trained rats to lever press for food pellets. After 40, 80, 160, 320, 640, or 1280 continuously reinforced responses, a cup of pellets was placed in the rear of the chamber. Jensen found that the proportion of pellets obtained by bar pressing increased as a logarithmic function of the number of the previously reinforced responses. Neuringer (1969) showed that pigeons would learn, without prior shaping, to peck a response key or push a foot treadle for a grain reinforcer when identical grain was freely available. That animals respond for reinforcers when equivalent free reinforcers are concurrently available has been shown with other species (Lambe and Guy, 1973; Koffer and Coulson, 1971; Powell, 1974), different schedules of reinforcement (Carder and Berkowitz, 1970; Neuringer, 1970), and with reinforcers other than food (Tarte, Townsend, Vernon, and Rovner, 1974).

Two recent experiments have attempted to qualify the variables that control response maintenance in free-food experiments. Wallace, Osborne, Norborg, and Fantino (1973) found that when pigeons' key pecks produced both food and the stimulus change ordinarily paired with food presentation, over 100 responses were emitted per session. When identical stimulus change was presented contemporaneous with free food and responses produced food with no concomitant stimulus change, responding decreased to nearly zero. Alferink, Crossman, and Cheney (1973) obtained similar data with pigeons. They pointed out that stimuli associated with food presentation acquire reinforcing properties themselves, *i.e.*, they become conditioned reinforcers. Conditioned reinforcers, in turn, increase the reinforcing effectiveness of response-produced food.

The above studies suggest the importance of investigating the effects of specific stimulus-food pairings in the context of free food. The present experiment was designed to elucidate the role of response-produced stimulus change as a factor influencing response maintenance in a free-food situation, and to assess the generality of the Alferink *et al.* and Wallace *et al.* findings with a nonavian species. Rats' lever presses for food were initially accompanied by a compound auditory and visual stimulus. Subsequently, varying stimulus feedback conditions were associated with response-produced food. If stimulus change paired with food presentation abets responding for food when free food is available, then variations in response-produced stimulus change should result in concomitant changes in amount of maintained responding.

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METHOD

Subjects

Five experimentally naive male albino rats, 90 to 120 days old, served.

Apparatus

All training and testing was completed in a 30 by 25 by 28 cm clear Plexiglas operant-conditioning chamber enclosed in a Lehigh Valley Electronics sound-attenuating shell. A food cup mounted 2 cm above the grid floor was centered on each end wall of the chamber. The response lever was positioned on the front wall 5 cm to the side of the food dish and 2 cm above the floor and was operable by a minimum force of 0.15 N. Three 1.25-cm diameter jewelled lights (red, white, and blue) were mounted 5 cm above the lever. Chamber illumination consisted of a miniature lamp mounted in the ceiling directly above each food dish. When present, white noise (107 dB, 0.0002 dynes/cm^2) was presented through a speaker centered in the ceiling. A Davis Model PD 109 feeder, positioned on a 5-cm pad of foam rubber atop the shell, dispensed 0.045-g Noyes pellets. Standard electromechanical scheduling and recording equipment was located in an adjoining room.

Procedure

All animals were maintained on 23-hr food deprivation; water was always available in the home cage. For 12 days immediately preceding training, each rat had 1-hr access to food in the home cage at approximately the same time of day at which subsequent experimental sessions would occur. Two 1-hr sessions followed during which each rat was placed in the experimental chamber with 500 pellets in the food dish opposite the front wall. The next two sessions involved magazine and lever-press training. Each press produced a pellet. The next six conditions remained in effect for 12 sessions each and Condition 7 lasted nine sessions. The 60-min sessions were conducted six days per week.

Condition 1. Free-food sessions alternated with response-produced food sessions. During free-food sessions, the response lever was removed and 500 pellets placed in the food dish opposite the front wall. Both chamber lights and the red stimulus light remained lit. During response-produced food sessions, the response lever was re-inserted, the free-food dish removed, and each lever press produced a pellet. Responses also extinguished chamber and red stimulus lights and illuminated the blue stimulus light for 0.5 sec (visual feedback), and produced a loud click from the feeder (auditory feedback).

During Conditions 2 to 6, both free and response-produced food were available. Stimulus conditions (feedback) attendant upon response-produced food were varied.

Condition 2. Responses produced both auditory and visual feedback.

Condition 3. Responses affected neither the stimulus light nor chamber illumination and continuous white noise masked the sound of the pellet dispenser. To control for the possibility that the sound of feeder operation was still correlated with lever presses, an identical feeder was placed atop the experimental enclosure and operated once every 2 sec. The second feeder was operated in all subsequent conditions of the experiment.

Condition 4. Response-dependent stimulus feedback was re-instated. For R1 and R2, responses produced the visual feedback of Condition 1; white noise was continuously present. For R3, R4, and R5, responses interrupted white noise for 0.5 sec. Since response rate for four of the rats had decreased to a low level, a single session without free food preceded Condition 4; no scheduled stimulus change accompanied responding.

Condition 5. Response-dependent stimulus feedback conditions were reversed. For R1 and R2, responses interrupted white noise for 0.5 sec; for R3, R4, and R5, responses resulted in visual feedback with white noise continuously present. Because response rate had decreased to zero, R2 had one session without free food before Condition 5; no scheduled stimulus change accompanied responding.

Condition 6. Responses produced both visual and auditory foodback (a 0.5-sec interruption of white noise).

Condition 7. Responses produced both auditory and visual feedback as in Condition 6, but no longer produced pellets. This condition served to control for the reinforcing properties of stimulus feedback alone.

RESULTS

Table 1 shows the average number of pellets obtained per session by bar pressing and

Table 1

Mean number of pellets obtained per session by bar pressing and from the free-food source. A_1 = auditory feedback provided by the operation of the feeder; A_2 = auditory feedback provided by a 0.5-sec interruption of white noise; V = visual feedback resulting from a change in stimulus light illumination from red to blue and a dimming of chamber illumination, both for 0.5 sec. See text for details.

			Subjects					
Cond.	*Food Source*	*Stimulus Feedback*	*R1*	*R2*	*R3*	*R4*	*R5*	*Mean*
1	Resp-Food	A_1 and V	385	307	239	431	389	350
	Free-Food		329	261	316	367	285	311
2	Resp-Food	A_1 and V	97	195	33	268	34	125
	Free-Food		335	240	372	172	393	302
3	Resp-Food	none	4	6	1	214	7	46
	Free-Food		479	435	473	235	460	416
4 and 5	Resp-Food	V	64	0	79	212	16	74
	Free-Food		377	388	399	268	459	378
4 and 5	Resp-Food	A_2	43	27	131	224	51	95
	Free-Food		415	444	250	192	376	335
6	Resp-Food	A_2 and V	79	32	184	332	62	138
	Free-Food		395	422	306	150	412	337
7	Extinction	A_2 and V	5	4	3	8	2	4
	Free-Food		442	401	465	475	416	438

from the free-food source. Means were calculated from the last five sessions of Conditions 2 to 7. For Condition 1, means were calculated from the last three free-food and response-produced food sessions.

During Condition 1, an average of 39 more pellets were obtained in response-produced than in free-food sessions, out of an average of approximately 330 pellets per session. With a choice between free and response-produced food (Condition 2), bar pressing was maintained, but at a lower level than that maintained in the absence of free food. Overall, 29% of total session food intake was obtained by responding. In .Condition 3, when stimulus feedback no longer accompanied response-produced food presentation, responding decreased ($t = 2.65$; $df = 4$; $p < 0.05$). Four of the five animals emitted fewer than seven responses per session. Re-instatement of stimulus feedback associated with response-produced food (Condition 4 and 5) increased responding. Comparing the effect of different stimulus feedback conditions shows that for four of five animals, response-produced auditory feedback maintained slightly more (not significant) responding than did response-produced visual feedback. Combined auditory and visual feedback in Condition 6 increased responding above the level maintained by either auditory ($t = 2.30$; $df = 4$; $p < 0.05$) or visual ($t = 3.07$; $df = 4$; $p < 0.025$) feedback alone. Finally, in Condition 7, responding decreased ($t = 2.46$; $df = 4$; $p < 0.05$) to a low level when the only scheduled effect of bar pressing was the presentation of auditory and visual feedback. For all but one animal, the amount of responding maintained by stimulus feedback alone was comparable to that maintained by food alone. (Statistical tests were one-tailed t-tests for correlated measures; Winer, 1971).

Mean differences in responding across conditions tended to be overshadowed by large between-subject variability. Statistical significance was obtained, albeit with multiple t-tests. However, the most important aspect of the data was the consistent within-subject change in responding as a function of response-produced stimulus feedback.

DISCUSSION

Response-produced stimulus feedback reinforced responding for food in the presence of free food. Responding was maintained when stimulus feedback was an added consequence of bar pressing, but was greatly reduced when stimulus feedback no longer accompanied responses. Stimulus feedback alone or food presentation alone maintained little responding. Response maintenance depended on stimulus feedback *and* response-produced food presentation. That auditory feedback maintained slightly more responding than did visual feedback may be due to the poor visual acuity of albino rats, although a similar effect occurred with pigeons in the Wallace *et al.* study. In that study, when stimulus change previously paired with response-produced food was shifted to free food, responding decreased to nearly zero. The operation of the grain hopper continued to provide auditory feedback, which accompanied food presentation, but apparently had little effect on response maintenance. Thus, it may be important to consider modality of stimulus feedback when making comparisons across species.

Alferink *et al.* suggested a conditioned reinforcement analysis of the free-food phenomenon. Due to the large number of stimulus feedback-food pairings during training, stimulus feedback could have acquired conditioned reinforcing properties. Thus, response maintenance might be attributed to the combined reinforcing effectiveness of response-produced food and conditioned reinforcement provided by stimulus feedback. The present failure and those of Neuringer (1969) and Davidson (1971) to maintain responding with stimulus feedback alone are all consistent with the finding that stimuli that serve as conditioned reinforcers often lose their effectiveness once primary reinforcement is withheld (Kelleher and Gollub, 1962).

Stimulus change alone has previously been shown to maintain some responding with free food available (Davidson, 1971; Neuringer, 1969). Stubbs (1971) suggested that nearly any stimulus will serve as a reinforcer under appropriate scheduling conditions, and Herrnstein and Loveland (1972) suggested that the presence of food in a procedure enhances the reinforcing effectiveness of stimulus change. Perhaps animals in free-food experiments respond for food *plus* stimulus change, not because stimulus change serves as a conditioned reinforcer, but because the reinforcing value of stimulus change increases in the context of other, more potent primary reinforcers.

Response-dependent stimuli unrelated to appetitive primary reinforcers are reinforcing (see Kish, 1966 for a review). The sensory reinforcing properties of response-produced stimulus feedback may help to explain the changes in responding that occurred across conditions in the present experiment. The observation that the compound stimulus in Conditions 2 and 6 maintained more responding than did either of the individual components can perhaps be attributed to differences in stimulus complexity or novelty (*cf.* Barnes and Baron, 1961; Welker and King, 1962). Furthermore, sensory reinforcement effects may interact with the primary reinforcement effects of response-produced food such that the total reinforcement obtained by bar pressing is sufficient to maintain responding when free food is available.

Considerable interexperimental variability has occurred in studies of preference between free and response-produced food. Typically, stimulus feedback has been uncontrolled and has varied across experiments because of methodological, and perhaps apparatus differences. As shown in the present experiment, the amount of responding maintained in the presence of free food varies as a function of stimulus feedback. Tarte and Synder (1973) showed that food training procedures also affect response maintenance. They found that when amount of time or number of obtained pellets was equalized for both free and response-produced food during training, rats bar pressed for only 15 to 20% of their food when later provided a choice between the two. When three sessions of free-food training and six sessions of bar-press training were given, animals responded for 70% of their food. Together, these findings suggest that interexperimental variability in preference for response-produced food may be largely attributed to differences in the food training procedures and stimulus feedback conditions associated with response-produced food.

Experiments that have varied stimulus conditions attendant upon response-produced food have used food-paired stimuli. This makes it difficult to distinguish between conditioned and sensory reinforcement effects of stimulus change. However, if conditioned reinforcers acquire their reinforcing properties through repeated association with primary reinforcers (Kelleher and Gollub, 1962; Wike, 1966), then acquisition of a food-obtaining response in the presence of free food (Neuringer, 1969) is difficult to explain by conditioned reinforcing effects of stimulus change. The same argument holds for responding maintained by auditory feedback in Conditions 4 and 5 in the present experiment, since this stimulus had not previously been associated with food.

In sum, the present changes in responding were due to variations in stimulus feedback associated with response-produced food. Whether this effect can be exclusively attributed to sensory or conditioned reinforcing effects of stimulus feedback is indeterminable on the basis of extant data. Additionally, it is possible that stimulus feedback serves both a conditioned *and* a sensory reinforcement function.

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