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TESTING THE REINFORCING PROPERTIES OF S−: A REPLICATION OF LIEBERMAN'S PROCEDURE

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A critical issue in testing theories of observing is whether the stimulus associated with extinction (the S−) reinforces observing responses. In previous experiments, subjects have been trained to make observing responses that produce both the S− and the stimulus correlated with reinforcement (the S+). Then, either the S+ or the S− has been withheld. Conflicting results have been attributed to differences among species. In the present experiments, pecking one key by master pigeons was reinforced with grain on a variable-ratio extinction schedule. Yoked pigeons received the grain on a variable-interval, extinction schedule controlled by the variable-ratio performances of the master birds. For both groups, concurrent pecking on a second key was reinforced on a variable-interval schedule with displays of discriminative stimuli. Subsequently, either the S+ or the S− was eliminated from the procedure. Omission of S+ produced a large decrease, as predicted by traditional conditioned reinforcement accounts of observing. By itself, S− did not maintain observing. A smaller and less reliable decrease, comparable to that obtained by Lieberman (1972) with rhesus monkeys, occurred when S− was eliminated. This replication with pigeons of Lieberman's results indicates that they are not species-specific, and the fact that observing was not maintained by S− alone suggests that the decrease obtained when S− was omitted is not attributable to the reinforcing power of S−.

Key words: observing, conditioned reinforcement, information, key peck, pigeons

In most experiments employing an artificial observing response, the subject does not gain additional primary reinforcement by performing that response. In E-maze studies, for example, the frequency of food reward is the same whether the rat chooses the side of the maze on which stimuli are correlated with the receipt or nonreceipt of food or the side on which they are uncorrelated (e.g., Prokasy, 1956). In free operant studies in which a mixed schedule can be transformed into a multiple schedule by the observing response, the food-reinforcement schedules typically used in one component are interval-based (e.g., Dinsmoor, Browne, & Lawrence, 1972; Wyckoff, 1969), with extinction in the second component. Usually the pigeon pecks the food key often enough, even in the presence of the mixed-schedule stimulus, to obtain virtually all scheduled reinforcers.

Thus, in operant observing-response procedures, the average density of reinforcement in the presence of the S+ and S− (the stimuli accompanied by reinforcement and extinction, respectively) should be equal to the density of reinforcement in their absence. In terms of traditional theories of conditioned reinforcement (Kelleher & Gollub, 1962), it is difficult to see why S+ and S− should be preferred to the mixed stimulus. This observation has led various writers to postulate other sources of reinforcement for observing responses. Perkins (1955, 1968, 1971), for example, has suggested that the discriminative stimuli produced by observing allow the animal to make preparatory responses that heighten the value of the primary reinforcer. Others (e.g., Berlyne, 1957, 1960; Bloomfield, 1972; Hendry, 1969) have proposed the information hypothesis, which states that information concerning biologically important events is the source of reinforcement for observing responses.

Relatively few convincing data have been assembled to support the information hypothesis. The major issue is whether S− is rein-

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forcing. Perhaps the strongest evidence was provided by Experiment III of a doctoral dissertation conducted by Lieberman (1972), which has been described as "the only truly provocative support of the notion that bad news is reinforcing" (Fantino, 1977, p. 32). Using rhesus monkeys as subjects, Lieberman reinforced responses on one lever with food delivered on a variable-ratio (VR) 50 schedule which alternated with periods of extinction. Each response on a second lever produced a brief exposure to a visual stimulus that indicated whether the VR or the extinction component was in effect. After training in which both S+ and S− were produced, the S− was eliminated; during VR components observing responses produced the S+, and during extinction components observing responses had no effect. Following the removal of the S−, observing responses decreased. Lieberman attributed the decrease to loss of the reinforcement provided by the information carried by S−.

However, if the information hypothesis is correct, and S− is reinforcing, then S− should be sufficient to maintain observing responses when S+ is omitted from the procedure. Dinsmoor et al. (1972) tested this prediction with unequivocal results. In that experiment, pigeons were used as subjects. Pecking one key produced food on a variable-interval (VI) schedule that alternated with periods of extinction, while pecking a second key produced discriminative stimuli, also on a VI schedule. When the S+ was omitted and only S− could be produced, observing rates dropped precipitously to near-zero levels. Subsequent experiments have reported that animals fail to observe a stimulus associated with a smaller magnitude of reinforcement (Auge, 1973) or a less preferred schedule of reinforcement (Auge, 1974). Further, Mulvaney, Dinsmoor, Jwaideh, and Hughes (1974) showed that the failure of the S− to maintain observing was not a matter of the birds' indifference to S−. In a concurrent observing procedure, pigeons pecked a key that produced only the S+ at higher rates than a key that produced both S+ and S− (see also Jwaideh & Mulvaney, 1976).

In addition to the S− -Only test, Dinsmoor et al. (1972) also conducted an S+ -Only test. Their results showed, for most birds, a slight increase in observing when S− was omitted. This result, of course, conflicts with the decrease obtained by Lieberman. However, the magnitude of the increase obtained by Dinsmoor et al. with S+ only was far less than the magnitude of the decrease in observing obtained in the S− -Only test.

Recently, attempts have been made to resolve these conflicting results by attributing them to species differences. Perone and Baron (1980) and Schrier, Thompson, and Spector (1980) have pointed out that support for the conditioned-reinforcement hypothesis has come from experiments using pigeons, whereas support for the information hypothesis has been obtained in experiments with primates. These investigators suggest that negative information is reinforcing only for primates. However, another possible critical factor in Lieberman's (1972) results was his use of a variable-ratio schedule of food reinforcement. A number of experiments have shown that animals responding on fixed-ratio schedules will make responses that switch the schedule into extinction and also produce the accompanying S− (e.g., Appel, 1963; Thompson, 1964). Perhaps extinction periods are more valuable relative to food-reinforced responding on VR than on VI schedules. In addition, more effort can be saved by observing S− with ratio, as opposed to interval, food schedules (Branch, 1973). Accordingly, the initial purpose of the experiments reported below was to investigate, using pigeons, the effect of food schedule on the ability of the S− to reinforce observing responses.

EXPERIMENT 1

In Experiment 1 the effects of omitting either the S+ or the S− were studied using two variable-ratio food schedules. In addition, the reinforcers obtained by a second bird were yoked to those produced by each of the birds maintained on a VR schedule. The yoked birds' responding, then, produced food on a VI schedule with density and timing of reinforcement approximately matched to reinforcement received by master birds.

METHOD

Subjects

Subjects were White Carneaux pigeons, retired female breeders. Two of the six birds (M1, Y1) had been trained to press a pedal; four were experimentally naive (M2, Y2, M3, Y3). Subjects were maintained at 75% of free-feeding weights by postsession feeding.

Apparatus

Two Lehigh Valley pigeon chambers were used; work panels were 35 cm square. In Box 1, the work panel was a standard Lehigh Valley three-key panel with the keys arranged in a row 25 cm from the floor. The right-hand key was masked by a piece of tape. The left-hand key, used for observing responses, was 9.5 cm from the rear wall. The center key, used to produce food, was 8 cm to its right, center-to-center. A hopper opening 5.7 wide and 5 cm high was directly below the center key, 10 cm from floor to bottom edge. A shielded houselight, 7 cm above the center key, remained on at all times.

In Box 2, three keys were arranged in a triangle. The key at the apex was masked; the left-hand, observing key was 14 cm from the rear wall, and the food key was 7 cm to its right, center-to-center. The hopper opening was centered between the keys 10 cm from the floor. Two shielded houselights were located at the upper right and left corners of the panel. To control for possible differences between boxes, Pair 1 was run with the master bird working in Box 1 and the yoked bird in Box 2. For Pairs 2 and 3 the boxes were reversed. No systematic effect of experimental chamber was noted.

Stimuli were provided by in-line projectors. The stimulus displayed during the mixed schedule (the "mixed stimulus") was a yellow keylight (Roscolene filter No. 908), the S+ was a blue keylight (No. 854), and the S− was a red keylight (No. 819). All keys required pecks of .2 N for switch closure. Sound masking was provided by speech noise of approximately 95 dB, SPL, measured 5 cm from a speaker on the left-hand side of each panel. The keylights and houselights of the two boxes were electrically isolated from each other and from the programming circuit. Events were controlled and data recorded by electromechanical equipment located in an adjacent room. Both boxes were located in the same room, but rested on separate supports.

Procedure

When necessary, successive approximations to pecking the food key were reinforced to establish key pecking. The mixed stimulus was displayed on the key and a patch of tape covered the observing key. Birds were then randomly assigned to master versus yoked status, with the exception of Bird Y1, which appeared hopper shy and was assigned to the yoked condition to avoid the possibility of losing data from two birds. All birds were then exposed to discrimination training on a multiple schedule in which periods of reinforcement alternated with periods of extinction. During reinforcement components, the master birds received 3-s access to grain on a VR schedule contingent upon pecking the food key. Reinforcement of key pecking by the yoked birds was made available when reinforcement became available to the corresponding master birds. Thus, during reinforcement components, the master birds produced food on a VR schedule and the yoked birds on a VI schedule with density and timing of reinforcement approximately matched. During reinforcement components, the key was continuously lit with the S+ and during extinction with the S−. A variable-interval 45-s tape controlled the transitions between reinforcement and extinction components. Sessions were conducted daily and ended when 40 reinforcers had been collected or after a maximum of 90 min. The discriminative performance was evaluated by dividing the rate of responding during S+ by the sum of the rates during S+ and S−. Training was continued until this index was .95 or better for both birds for two consecutive days.

The behavior necessary for observing was established by covering the center (food) key with tape for three sessions and continuing the discrimination training procedure with reinforcement of pecks on the left-hand (observing) key. The tape was then removed and responding on the food key was again reinforced on a VR schedule that alternated with periods of extinction. Responding on the observing key was reinforced with a stimulus display, first after every response, then on a VI 15-s, then on a VI 30-s schedule. The reinforcement of observing consisted of a 30-s display of the appropriate S+ or S− on both keys. If the schedule component changed during the display, the color on the keys also changed. In the absence of discriminative stimuli, the mixed stimulus was displayed on both keys. During observing training, the VR parameter for food reinforcement was 30.

Three changeover delays (COD) were used. Beginning with discrimination training, one COD delayed any transition from the extinction to the reinforcement component for 3 s following a food-key response by either bird. Observing responses, after their addition, similarly delayed component transitions. These CODs were disconnected during S+ -Only sessions, when the S− was not available. Otherwise, considerable responding would have occurred during extinction and little session time would have been spent in the reinforcement component. A third delay prevented food reinforcement within 5 s of an observing response.

Twelve sessions were originally planned for each treatment condition, but apparatus malfunctions made necessary the lengthening of some of these conditions to approximately sixteen sessions. The birds were tested under three conditions: S+S−, in which observing responses produced both stimuli; S+ Only, in which S− was discontinued; and S− Only, in which S+ was discontinued. All conditions were studied with the VR parameter set at 50 and again with it set at 100. An S+S− treatment block preceded each test with S+ Only or S− Only.

During the S+ -Only and S− -Only conditions, the programming apparatus functioned in the same way as in the S+S− condition, except that certain stimulus displays were omitted. Thus, for example, in the S+ -Only condition, observing responses that would have produced S− initiated instead a pseudostimulus display. If, however, the food-key schedule switched back to the reinforcement component before the pseudodisplay was terminated, the S+ was displayed on the key for the remainder of that period. This procedure equated the amount of S+ produced in the S+S− and S+ -Only procedures. The pseudostimulus display was timed by the same device that timed real displays and the current opportunity to produce a display was canceled when a pseudodisplay occurred.

RESULTS

Figure 1 shows the effect of omitting S+. Observing rates (key pecks per minute) are shown for the four S+S− sessions that preceded introduction of S− Only, for the four sessions immediately following introduction of S− Only, and for the last four sessions in the S− -Only condition. Rates are shown separately for each bird and for VR 50 and VR 100 tests. Following removal of S+, observing rates of both the VR and the yoked birds quickly and uniformly dropped to zero levels. By itself, the S− failed to maintain observing. This result is predicted by the traditional conditioned reinforcement interpretation of learning.

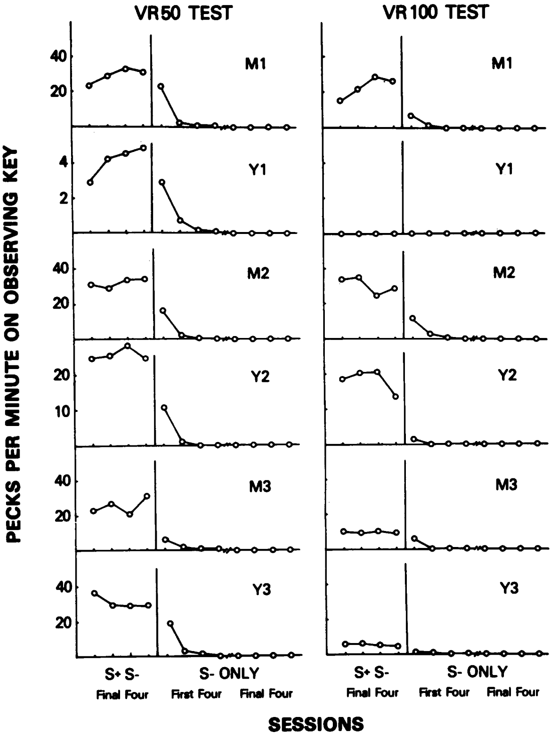

Fig. 1. Pecks per minute on the observing key for the final four sessions of the S+S− condition that immediately preceded removal of S+ and for the first and final four sessions of the S− -Only condition. Rates are shown separately for each subject in Experiment 1 and for tests conducted with VR 50 and VR 100 or their yoked food schedules.

Figure 2 shows in similar format the effect of omitting S−. Data that were possibly contaminated by apparatus malfunctions are omitted. The information hypothesis predicts a decrease in observing. The conditioned-reinforcement hypothesis predicts a consistent increase in observing. Clearly, neither result was obtained. The effect of omitting S− varied both between and within birds. The predominant tendency was for observing rates to decline, although even the largest decreases (e.g., Y2 at VR 100) left observing rates substantially higher than those obtained in the S− -Only condition. There appeared to be no consistent effect of differing reinforcement schedule.

The effect of omitting S− on responding on the food key during the mixed stimulus is

Table 1

Individual means of pecks per minute on the food key for the four sessions immediately prior to the S– -Only test and for the first four and last four sessions of that test. Data were collected both for master (M) and for yoked (Y) birds and under both the VR 50 and the VR 100 schedules of reinforcement. Periods when either S+ or S– was present have been excluded. Also shown are the product-moment correlations (*r*) with corresponding rates on the observing key. (Experiment 1)

			VR 50 Tests		*VR 100 Tests*	
Birds	*Sessions*		*Food Key Rates*	*Correlation with Obs.*	*Food Key Rates*	*Correlation with Obs.*
	Final	S+S–	1.01		9.96	
M1	Initial	S+ Only	.67		4.36	
	Final	S+ Only	.83	+.53	15.66	–.54
	Final	S+S–	16.70		12.30	
Y1	Initial	S+ Only	16.02	–.26	13.33	
	Final	S+ Only	–		7.71	–.55
	Final	S+S–	–		21.50	
M2	Initial	S+ Only	–		13.90	
	Final	S+ Only	–		14.90	+.01
	Final	S+S–	–		.50	
Y2	Initial	S+ Only	–		8.94	
	Final	S+ Only	–		.27	–.60
	Final	S+S–	39.03		32.58	
M3	Initial	S+ Only	20.45		41.18	–.58
	Final	S+ Only	3.53	–.70	–	
	Final	S+S–	30.28		21.28	
Y3	Initial	S+ Only	27.24		34.19	–.87
	Final	S+ Only	6.31	–.70	–	

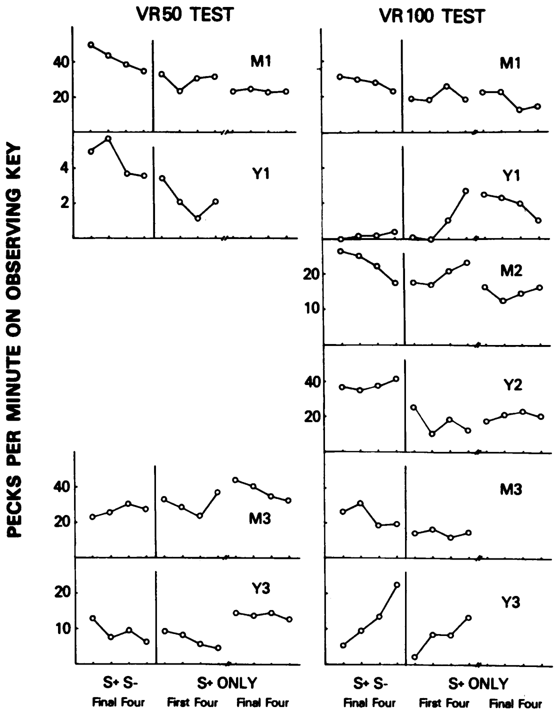

Fig. 2. Pecks per minute on the observing key for the final four sessions of the S+S– condition that immediately preceded removal of S– and for the first and final four sessions of the S+ -Only condition. Rates are shown separately for each subject in Experiment 1 and for tests conducted with VR 50 and VR 100 or their yoked food schedules. Some data were omitted because of possible contamination by apparatus malfunctions.

shown in Table 1. As in the case of observing responses, individual means are presented for the final four sessions of the S+S– condition, the first four sessions of S+ Only, and the final four sessions of S+ Only. The effect of omitting S– on food responding was inconsistent, as was its effect on observing response rates. However, a negative relationship did exist, for most subjects, between food- and observing-response rates during the mixed stimulus. To examine this relationship, separate correlation coefficients were computed for each subject at the VR 50 and VR 100 tests, using the session-by-session data from the twelve sessions used to compute the means presented above. Table 1 shows these correlation coefficients. Although exceptions occurred, the correlations were typically negative, and many were quite strong.

Discussion

Clearly the decline in rate of observing obtained by Dinsmoor et al. (1972), when they omitted S+, is replicable when pigeons are responding on variable-ratio, as opposed to variable-interval, food schedules. By itself, the S– does not maintain observing. This finding strongly contradicts the information hypothesis, which predicts that S– will be as effective as S+ in maintaining observing; it supports the traditional conditioned-reinforcement interpretation, which characterizes S– as aversive, rather than reinforcing. It is noteworthy that the decrease in rate was obtained even under a procedure in which substantial effort could be saved by observing the S–.

Considered in isolation, the results obtained with the S+ -Only condition offer more support to the information than to the conditioned-reinforcement hypothesis. The information hypothesis predicts a decrease in observing when S– is omitted and a decrease was obtained in some subjects. According to the conditioned reinforcement hypothesis, omission of the negatively valued S− should produce an increase in observing.

Consider, however, the fact that declines in observing with S+ Only were obtained in the same experiment and with the same subjects that unequivocally showed, when S+ was eliminated, that S− did not maintain observing behavior. Therefore, the declines in observing obtained in S+ Only cannot be attributed to the elimination of S− as a reinforcing event. In light of these results, the fact that Lieberman obtained a relatively small decline in observing when he omitted S− is by no means conclusive evidence that S− is reinforcing. If Lieberman had conducted the S− -Only test, he too might have obtained the profound decline in observing obtained in the present experiment.

The effect of omission of S− on food-response rates was inconsistent, as was its effect on observing. A substantial negative correlation existed, in some subjects, between observing and food responding. Rate of food responding is unlikely to affect directly the rate of observing. Previous work (e.g., Catania, 1963; Rachlin & Baum, 1969) has shown that concurrent response rates are affected by the rate of reinforcement of a second response, but not by the rate of the response itself. However, the negative correlation suggests sources of variance in rate of observing in this design that are not related to reinforcing properties of S−.

EXPERIMENT 2

In Experiment 2, the comparison between the S+S− and the S+ -Only conditions was replicated to determine whether some artifact of apparatus or subjects was responsible for the inconsistent results. Since the results obtained in Experiment 1 when S+ was omitted were so clear-cut, that manipulation was not replicated.

Method

Subjects

Four White Carneaux pigeons, retired female breeders, had previously been trained to peck a green key and had been tested for generalization along the wavelength dimension, The feeding regimen was as in Experiment 1.

Apparatus

Both boxes were Lehigh Valley pigeon chambers with standard three-key panels. The dimensions were as described for Box 1 of Experiment 1. Green, red, and white jewel lamps provided the S+, S−, and mixed stimulus, respectively. In Box 2, the food key required pecks of .13 N and the observing key, .16 N for operation. The physical arrangement of the boxes and programming apparatus was as in Experiment 1. However, the electromechanical programming circuit was reconstructed.

Procedure

Training procedures and details of the S+S− and S+ -Only procedures were as in Experiment 1, with the following exceptions: During observing training the VR parameter was 50 (vs. 30); observing produced stimulus displays of varying (vs. fixed) lengths with a mean of 30 s; and CODs that delayed transitions from extinction to reinforcement were 5 (vs. 3) s. The master bird of Pair 5 was randomly assigned to Box 1, with the assignment reversed for Pair 6. Only the comparison between S+S− and S+ Only was studied and only at VR 100. Each condition was conducted for 15 sessions.

Results

Figure 3 presents rates on the observing key for the four sessions of S+S− that immediately preceded S+ Only, and for the first and last four sessions of S+ Only. As in Experiment 1, the results were inconsistent. They included a decline (M5), a decline followed by an increase (Y5), and little change followed by a decline (M4, Y4).

Figure 4 shows grouped data from both experiments for comparison with the grouped data presented by Lieberman. From the present experiments, mean daily rates are shown for the eight birds for which complete data were available at VR 100 tests (M3 and Y3 are omitted due to lack of data from final sessions). Also shown for comparison is a redrawing of the rates presented in Figure 6 of Lieberman (1972).

Although differences in species, response, and schedule make the scales on the ordinate only very roughly comparable, a mean decrease

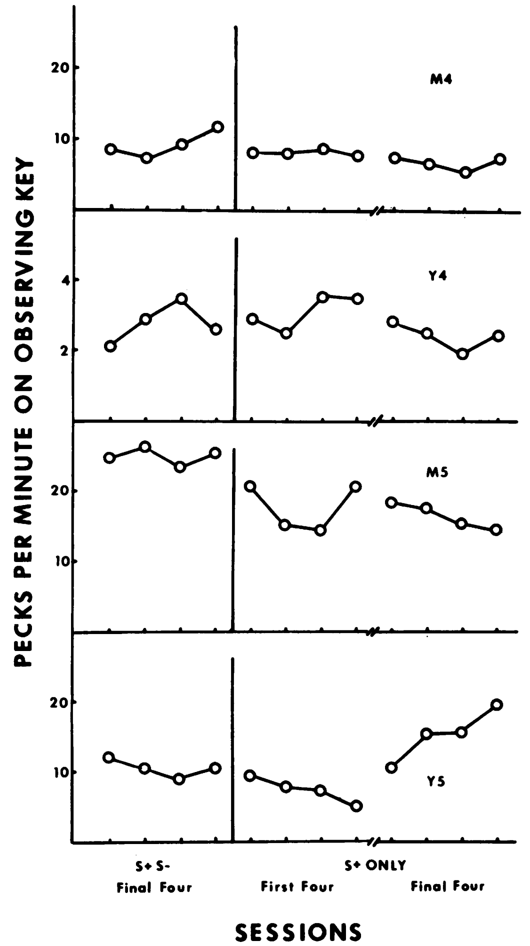

Fig. 3. Pecks per minute on the observing key for the final four sessions of the S+S– condition that immediately preceded removal of S– and for the first and final four sessions of the S+ -Only condition. Rates are shown separately for each subject in Experiment 2.

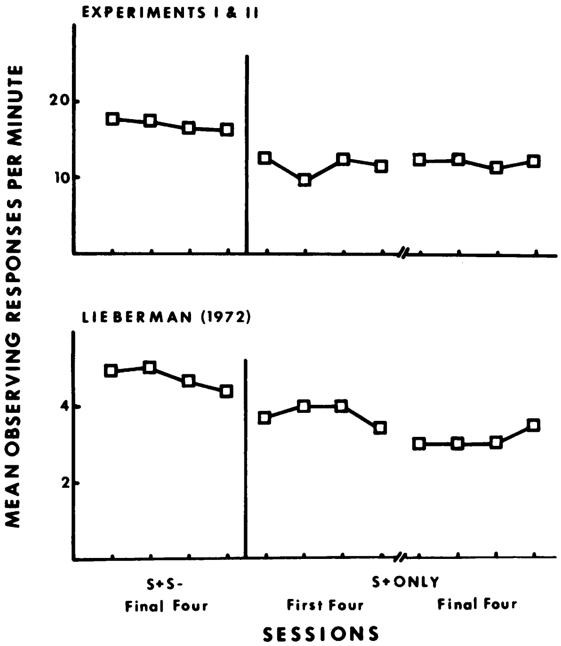

Fig. 4. Mean observing rates across subjects for the final four sessions of the S+S– condition that immediately preceded removal of S– and for the first and final sessions of the S+ -Only condition. Mean rates are shown for eight subjects from the present experiment (top) and for five subjects from Lieberman (1972, redrawn from his Figure 6).

of similar magnitude may be seen in both graphs. The decline obtained by Lieberman, using five subjects, was statistically significant. A correlated *t* test applied to the data from the present experiments using means of final sessions from S+S– and S+ Only yielded results that approached, but did not achieve, significance [$t(7) = 1.90$, $p < .10$]. A correlated *t* test applied to means of all ten subjects for the final sessions of S+S– and initial sessions of S+ Only yielded a significant effect [$t(9) = 2.70$, $p < .05$].

As in Experiment 1, the effect of omitting S– on food responding during the mixed stimulus displays was inconsistent. These food-response rates are shown in Table 2. For completeness, *t* tests analogous to those performed for observing response rates were calculated for food-response rates. All *t* ratios were less than 1. Again, however, substantial negative correlations, also shown in Table 2, were found between food- and observing-response rates during the mixed stimulus.

GENERAL DISCUSSION

Inspection of individual data from Experiment 2, as from Experiment 1, suggests that removal of S–, unlike removal of S+, has mixed and unreliable effects on observing. Grouped data and statistical analysis suggest that, if anything, observing rates declined following removal of S–, much as they did in Lieberman's experiment. The fact that a decrease in observing can be obtained when S– is omitted presents difficulties for the conditioned-reinforcement approach. However, we have already concluded that declines obtained in observing were not due to removal of a rein-

Table 2

Individual means of pecks per minute on the food key for the four sessions immediately prior to the S− -Only test and for the first four and last four sessions of that test. Data were collected both for master (M) and for yoked (Y) birds, but periods when either S+ or S− was present have been excluded. Also shown are the product-moment correlations (*r*) with corresponding rates on the observing key. (Experiment 2)

Birds	*Sessions*	*Food Key Rates*	*Correlation with Obs.*
	Final S+S−	35.76	
M4	Initial S+ Only	25.78	
	Final S+ Only	40.76	−.53
	Final S+S−	63.78	
Y4	Initial S+ Only	47.19	
	Final S+ Only	52.11	−.37
	Final S+S−	6.13	
M5	Initial S+ Only	19.61	
	Final S+ Only	20.02	−.91
	Final S+S−	13.60	
Y5	Initial S+ Only	15.50	
	Final S+ Only	3.57	−.93

forcing S−: In Experiment 1, S− alone clearly was not reinforcing, as it failed to maintain observing. The fact that some animals show a decline in observing in S+ Only must be related to unknown processes extraneous to the conditioned reinforcing value of S−.

It is possible that S− has a punishing effect on observing responses but that this effect is weak and easily overcome by extraneous factors. Such a speculation fits well with the finding of Dinsmoor, Browne, Lawrence, and Wasserman (1971) and Dinsmoor, Mueller, Martin, and Bowe (1982) that animals free to terminate as well as to produce stimuli spend relatively little time observing S−. If, as suggested by recent work (Dinsmoor, Mulvaney, & Jwaideh, 1981), the effect of a stimulus is related to the duration of exposure to that stimulus, one would expect the omission of S− to produce only weak effects, easily obscured by other sources of variability.

The existence of some potential sources of variability is suggested by the negative correlations between observing rates and food-response rates during the mixed stimulus. Furthermore, omission of S− reduces the density of reinforcement during the mixed stimulus, both for observing and for food responding. This reduction occurs because, after omission of S−, periods of extinction that would have been signaled by S− occur during mixed-stimulus displays. On the one hand, the effect of this reduction in density of food reinforcement during the mixed stimulus should be to raise concurrent observing-response rates. On the other hand, density of reinforcement of observing responses with an S+ display also would decrease, thereby decreasing observing rates. The net outcome could vary from subject to subject.

Furthermore, it is possible that the declines obtained in the present experiment were related to the use of variable-ratio food reinforcement schedules. The ratio requirement per se cannot be responsible, since yoked as well as master birds showed a decline in observing following removal of S−. However, some other aspect of the ratio schedule, such as the temporal patterning of reinforcement, could be responsible. For example, in some sessions, the master birds may have exhibited long pauses in food responding. The effect of an irregular distribution of food reinforcement on observing behavior is unclear.

Finally, it is important to note that in the present experiments results similar to those obtained previously with primates were obtained with pigeons. If the S− -Only test had not been conducted, as it was not by Lieberman (1972), the present data would have indicated that the S− is reinforcing for pigeons as well as for primates. Only the inclusion of the S− -Only test precluded attribution of the decline in observing obtained in S+ -Only tests to the omission of reinforcement by S−. Relatively small declines in observing can occur in pigeons as well as in primates when S− is eliminated. However, these declines can occur, as in the present experiments, even when other evidence indicates that S− is not reinforcing. Declines in observing following elimination of S− do not demonstrate that S− is reinforcing.

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