THE DELAY-REDUCTION HYPOTHESIS OF CONDITIONED REINFORCEMENT AND PUNISHMENT: OBSERVING BEHAVIOR

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Pigeons responded in an observing-response procedure in which three fixed-interval components alternated. Pecking one response key produced food reinforcement according to a mixed schedule. Pecking the second (observing) key occasionally replaced the mixed-schedule stimulus with the stimulus correlated with the fixed-interval component then in effect. In Experiment 1, observing was best maintained by stimuli correlated with a reduction in mean time to reinforcement. That finding was consistent with the conditioned-reinforcement hypothesis of observing behavior. However, low rates of observing were also maintained by stimuli not representing delay reduction. Experiment 2 assessed the role of sensory reinforcement. It showed that response rate was higher when maintained by stimuli uncorrelated with reinforcement delay than when the stimuli were correlated with a delay increase. This latter result supports a symmetrical version of the conditioned-reinforcement hypothesis that requires suppression by stimuli correlated with an increase in time to reinforcement. The results were inconsistent with hypotheses stressing the reinforcing potency of uncertainty reduction.

Key words: conditioned reinforcement, conditioned punishment, delay-reduction hypothesis, observing behavior, multiple schedules, mixed schedules, sensory reinforcement, key peck, pigeons

An observing response is one which produces stimuli correlated with the availability or non-availability of reinforcement. Typically the stimuli are correlated with the particular schedule of reinforcement in effect. Thus, an observing response converts a mixed schedule into an equivalent multiple schedule.[1] Observing responses do not have any effect upon the rate or distribution of scheduled primary reinforcers.

Experiments on observing have addressed the question of why the contingent stimuli are reinforcing. One hypothesis is that they reduce uncertainty (the "uncertainty-reduction hypothesis"); another suggests they have a positive association with primary reinforcement

[1]A mixed schedule is one in which reinforcement occurs on alternating schedules, and in which no exteroceptive stimulus indicates which component is in effect. In a multiple schedule, however, distinctive stimuli are correlated with each of the components. In either case, in the present experiments, the alternation was random and occurred at the completion of a component.

(the "conditioned-reinforcement hypothesis"). A large body of research has supported the conditioned-reinforcement interpretation (e.g., Dinsmoor, Browne, & Lawrence, 1972; cf. Fantino, 1977, for a review). The role of conditioned reinforcement in observing behavior may be explained by the delay-reduction hypothesis, which states that the strength of a stimulus as a conditioned reinforcer is a function of the reduction in time to reinforcement correlated with the onset of that stimulus (Fantino, 1977). The delay-reduction hypothesis was developed with choice procedures in which the production of stimuli affect the occurrence of reinforcement. Fantino (1977) extended the hypothesis by predicting that "a stimulus correlated with a reduction in time to primary reinforcement should be a conditioned reinforcer, i.e., it should maintain responses (such as observing or choice responses) whether or not these responses affect the temporal distribution of reinforcement" (p. 315). Thus, the generality of that hypothesis will be enhanced by its extension to procedures in which the produced stimuli do not affect the temporal distribution of reinforcement.

When two schedules alternate in an observing-response procedure, only the stimulus as-

sociated with the more positive schedule (i.e., the schedule providing the more immediate reinforcement) is correlated with a reduction in time to reinforcement. Since the average time to reinforcement associated with the mixed schedule is intermediate to that associated with the two schedules comprising the mixed schedule, it follows that the less positive schedule is correlated with an increase, not a reduction, in time to reinforcement. Thus, according to the delay-reduction hypothesis, only the more positive stimulus should maintain observing, a prediction consistent with the results of many studies of observing (cf. Fantino, 1977 and the present Discussion).

It should be noted that another version of the conditioned-reinforcement interpretation of observing, the reinforcement-density hypothesis (Fantino, 1977), makes predictions that are equivalent to those of the delay-reduction hypothesis. The reinforcement-density hypothesis states that a stimulus should maintain observing if the rate of reinforcement in its presence is higher than that in the presence of the mixed-schedule stimulus. The present experiments are not designed to permit a relative assessment of these two versions of the conditioned-reinforcement hypothesis. Research on choice behavior, however, clearly favors delay reduction over reinforcement density (e.g., Fantino, 1969b, 1977; Squires & Fantino, 1971). For example, Fantino (1969b) assessed whether choice measured in a concurrent-chains procedure was better described by the relative reinforcement density or by the relative delay reduction associated with each of two outcomes. Only the delay-reduction hypothesis provided an adequate description of choice. For this reason and for simplicity of presentation, we discuss the experiments in terms of the delay-reduction hypothesis.

The present studies assess the delay-reduction hypothesis when the mixed schedule consists of three components, instead of the usual two. Production of the most positive stimulus, always signaling a fixed-interval 20-sec (FI 20-sec) schedule in the present studies, is correlated with a decrease in time to reinforcement and should maintain observing. The stimulus associated with the least positive schedule, always an FI 180-sec, is correlated with an increase in time to reinforcement and should not maintain observing. The critical question concerns the extent to which the stimulus as-

sociated with the intermediate schedule maintains observing. Two intermediate schedules were selected in different conditions. One, FI 40-sec, represents a reduction in time to reinforcement (relative to the mixed schedule) and should maintain observing; the other, FI 120-sec, represents an increase in time to reinforcement and should not maintain observing.[2]

Results from these conditions should provide a more stringent test of the delay-reduction hypothesis (and of the reinforcement-density hypothesis) than those based on observing with two-component mixed schedules. In two-component procedures the delay-reduction hypothesis simply requires that the stimulus correlated with the more positive schedule maintain more observing than that correlated with the less positive schedule. The data are minimally constrained. In three-component procedures on the other hand, the delay-reduction hypothesis requires this pattern for each pairwise comparison of the stimuli and a monotonic ordering when comparing all three. The data are thus considerably more constrained in three-component procedures. Manipulation of the intermediate schedule imposes still further constraint on results which are compatible with the delay-reduction hypothesis.

The three-component procedure also provides a test of the uncertainty-reduction hypothesis in a context that may increase the likelihood of its confirmation. Specifically, uncertainty-reduction may be more reinforcing the more complex the situation. The reasoning is intuitive but has been quantified by mathematical information theorists (Shannon & Weaver, 1949). More events about which there is uncertainty implies that each event is relatively more informative. The informativeness of an event has been manipulated in two-component observing studies by varying component probability. However, the results have

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[2] Since efforts have failed to discover a general rule for transforming mixed or variable schedules into fixed-schedule equivalents (Hursh & Fantino, 1973), the choice of averaging rule is somewhat arbitrary. The conceptually simplest rule, and the one employed here, is arithmetic averaging. This is also the rule that is typically assumed, especially for predictions based upon the delay-reduction hypothesis (Fantino, 1977). Identical predictions would be made assuming geometric averaging for the particular values used here. However harmonic averaging would predict different results for FI 40-sec in Part A, and root-mean-square averaging would predict different results for FI 120-sec in Part B.

failed to support the uncertainty-reduction hypothesis (McMillan, 1974; Wilton & Clements, 1971; but see Green & Rachlin, 1977). Perhaps the hypothesis may find some support when observing is measured in a three-component procedure.

EXPERIMENT 1

The first experiment assessed the effects on observing behavior of signaled delay to reinforcement using three FI schedules of differing duration. In Part A, the durations were selected so that two of them represented delay reductions relative to the mean of all three fixed-interval schedules. The delay-reduction hypothesis predicts that the stimuli correlated with short and intermediate FI schedules will maintain observing. The third FI stimulus represented a delay increase and therefore should not maintain observing. In Part B the shortest and longest FIs were the same as in Part A, but the intermediate FI was correlated with an increase in time to reinforcement and the associated stimulus should not maintain observing.

In addition to varying the duration of the intermediate FI, Part B added two control conditions. In principle, effects might reflect color preferences. Thus, in one condition ("uncorrelated baseline"), the correlation between the multiple stimuli and the FI schedules was eliminated. Since the colors were the same as those used throughout Parts A and B, a color-preference account would predict that data from this condition should match the results of the (correlated) baseline condition. In a final condition, observing responses were completely ineffective in producing stimulus change. By comparing this "extinction-of-observing" condition with the uncorrelated baseline condition, an estimate may be made of the degree that stimulus change maintains behavior in the (correlated) baseline condition irrespective of the delay-signaling properties of the produced stimuli (Kish, 1966).

METHOD

Subjects

Five male White Carneaux pigeons served. One additional pigeon died, and the incomplete data for this subject are not presented. All subjects had extensive histories of key pecking for food reinforcement. The pigeons were maintained at 80% of their free-feeding weights.

Apparatus

Three conventional two-key chambers, constructed in our shop, were used to conduct the experiments. The chambers were 30 cm long, 30 cm wide, and 40 cm high, and were enclosed in wooden boxes. The response keys, translucent plastic disks 2 cm in diameter, were located on one wall. The centers of the keys were 24 cm from the floor and the keys were 10.5 cm apart, center-to-center. A solenoid-operated food magazine was accessible through a 5-cm square hole in the wall, centered beneath the keys and located 11 cm from the floor. The keys were illuminated by Industrial Electronics Engineers #1820 stimulus projectors and required a minimum force of .15 N to operate. Two 6-W houselights were located in the top corners of the wall opposite the keys. White background noise was used. The chambers were controlled and monitored by standard relay equipment located in an adjacent room.

Procedure

Throughout the experiment responses on the observing key had no effect on the occurrence of primary reinforcement (except for the use of a changeover delay, described below). Depending upon the conditions, responses on the observing key either had no effect, produced a stimulus correlated with the schedule of reinforcement in effect on that trial, or produced a stimulus uncorrelated with the schedule of reinforcement in effect on that trial. A particular schedule of reinforcement remained in effect on the food key until a reinforcement was dispensed.

The daily sessions were composed of two phases, training and testing. The testing phase began a few minutes after the end of the training phase (described below); the chamber was dark and inoperative during the interim. Two types of testing phase procedures were used, one for the baseline and one for the experimental conditions. Each part of the experiment began with a baseline condition, and the baseline was also interposed between experimental conditions (see Table 1). In a baseline condition, responses on the left key (observing key) changed the schedule on the right key (food key) from mixed to the corresponding

Table 1

Order of Presentation of Conditions and Number of Sessions in Each, for Experiments 1 and 2

Subject	Condition	Sessions	Subject	Condition	Sessions
	EXPERIMENT 1			PART B continued	
	PART A			Baseline	18
S1	Baseline	30		FI 120-sec	15
	FI 180-sec	15		Baseline	10
	Baseline	13		Uncorrelated Baseline	18
	FI 40-sec	19		Extinction	15
	Baseline	14		Uncorrelated Baseline	15
	FI 20-sec	17	S4	Baseline	20
S2	Baseline	19		FI 20-sec	17
	FI 40-sec	15		Baseline	10
	Baseline	13		FI 180-sec	15
	FI 180-sec	15		Baseline	13
	Baseline	20		FI 120-sec	15
	FI 20-sec	20		Uncorrelated Baseline	15
S3	Baseline	14		Extinction	15
	FI 180-sec	15		Uncorrelated Baseline	15
	Baseline	11	S5	Baseline	10
	FI 40-sec	18		FI 20-sec	20
	Baseline	12		Baseline	19
	FI 20-sec	15		FI 120-sec	15
S4	Baseline	37		Baseline	13
	FI 20-sec	15		FI 180-sec	15
	Baseline	14		Baseline	13
	FI 180-sec	15		FI 120-sec	15
	Baseline	14		Baseline	12
	FI 40-sec	15		Uncorrelated Baseline	16
	Baseline	12		Extinction	15
	FI 40-sec	15		Uncorrelated Baseline	15
S5	Baseline	25			
	FI 20-sec	18		EXPERIMENT 2	
	Baseline	11	S6	Baseline	15
	FI 40-sec	15		FI 120-sec	13
	Baseline	12		Baseline	15
	FI 180-sec	15		Uncorrelated	15
				Baseline	15
	PART B		S7	Baseline	15
S1	Baseline	11		FI 120-sec	14
	FI 180-sec	15		Baseline	15
	Baseline	11		Uncorrelated	15
	FI 120-sec	16		Baseline	15
	Baseline	18	S8	Baseline	15
	FI 20-sec	15		FI 120-sec	15
	Baseline	10		Baseline	15
	Uncorrelated Baseline	18		Uncorrelated	15
	Extinction	15		Baseline	15
	Uncorrelated Baseline	15	S9	Baseline	16
S2	Baseline	20		FI 120-sec	15
	FI 120-sec	15		Baseline	15
	Baseline	14		Uncorrelated	15
	FI 180-sec	15		Baseline	15
	Baseline	16	S10	Baseline	15
	FI 20-sec	16		FI 120-sec	15
	Baseline	14		Baseline	15
	Uncorrelated Baseline	16		Uncorrelated	15
	Extinction	15		Baseline	15
	Uncorrelated Baseline	15	S11	Baseline	15
S3	Baseline	15		FI 120-sec	15
	FI 180-sec	15		Baseline	15
	Baseline	10		Uncorrelated	15
	FI 20-sec	16		Baseline	15

multiple schedule. The mixed schedule consisted of three FI-schedule components, alternating on a pseudo-random basis. Pecking the lighted observing key produced the following transition from the mixed schedule to the multiple according to a variable-interval 10-sec schedule (VI 10-sec): the observing key and the chamber light were both darkened, and the observing key became inoperative; the mixed stimulus, a white food key, was replaced by the appropriate multiple-schedule stimulus (see below). The subject was exposed to the multiple-schedule stimulus for 10 sec whereupon the mixed-schedule stimulus replaced it, the observing key and chamber lights were reilluminated, and the variable-interval programmer associated with the observing key restarted. More than one brief exposure to the multiple-schedule stimulus was thus possible before the component ended. If a reinforcer was obtained in the presence of a multiple-schedule stimulus, exposure to the multiple-schedule stimulus was terminated at that point. Thus, each new component remained unsignaled prior to additional responding on the observing key. A changeover delay was in effect at all times, preventing reinforcement of a food-key peck from occurring within 2 sec of an observing-key peck. During reinforcement, which consisted of a 3-sec access to mixed grain, the key-lights and the chamber light darkened and a magazine light illuminated the food. The food-schedule component changed after each reinforcement and each component was tested 10 times.

The experimental conditions were identical to the baseline conditions with the following exception: In an experimental condition only one of the multiple stimuli was available as a consequence of observing. That is, if either of the other two components happened to be in effect, then pecking the observing key could not produce the transition from the mixed to the multiple schedule. This procedure contrasts with the baseline conditions, in which all three stimuli were available for observing. The data were collected identically in the baseline and experimental conditions, and consist of the rate of observing summed over components. Because the data were collected identically in both conditions, observing responses were not counted in the experimental conditions during some of the time that the observing key was illuminated. During components

where the multiple-schedule stimulus was unavailable, observing responses nonetheless caused the 10-sec exposure timer to start as usual. Responses during this time were not counted. Thus, rate of observing was measured over strictly comparable temporal distributions.

In the training phase of each session, food was presented for pecking the right key (food key) according to a four-component multiple schedule. The four components consisted of the mixed schedule used in the testing phase and the three FI schedules that made up the corresponding multiple schedule. The four components were correlated with the same colored lights projected onto the food key as used in the testing phase. The other key remained dark and inoperative during the training phase. In addition to the keylight, the chamber light was illuminated during the mixed schedule and darkened at other times. The components alternated pseudo-randomly after each reinforcement such that each training phase contained two exposures to each FI schedule and six exposures to the stimulus associated with the mixed schedule. The components of the mixed schedule were arranged so that they occurred equally often. Each training phase therefore provided 12 reinforcers. The total number of reinforcers in both phases was 42, not quite enough to maintain the subjects at their 80% weights. Supplemental feeding was given in the home cages following the session.

The following criteria were used in determining the number of sessions per condition: The subjects were exposed to the initial baseline condition until the data appeared stable over the last 5 sessions, using a visual criterion. All subsequent baselines included a minimum of 10 sessions. If the initial baseline observing level had not recovered by this time (again using a visual criterion) then 5 additional sessions were conducted. If the stability criterion was satisfied after these sessions, the condition was ended. If not, then X more sessions were conducted, where X is a number randomly drawn from the set [1,2,3,4,5]. The condition was then ended irrespective of the apparent stability at that point. The experimental conditions included a minimum of 15 sessions. If the stability criterion had not been met, X sessions were added as in baseline. This criterion was adopted because pilot data suggested that subjects occasionally did not meet

our visual stability criterion even after an extended number of sessions.

The three components used in Part A were FI 20-sec, FI 40-sec, and FI 180-sec. The mean of these values is 80 sec and the shorter components represent delay-reduction of 60 and 40 sec, respectively. The keylights correlated with the components were green, blue, and red, respectively, and were the same for all subjects. The mixed schedule stimulus on the food-key and the observing-key stimulus were white keylights and were accompanied by the illumination of the chamber light.

Procedural details in Part B were identical to those in Part A except that the intermediate schedule was now FI 120-sec (the mean of the three FIs was now 107 sec), and that the uncorrelated baseline and extinction-of-observing conditions were added. In the uncorrelated baseline condition each multiple-schedule stimulus was associated equally often with each FI schedule. Subject S5 displayed unusually high rates in the FI 120-sec condition. The condition was repeated for this subject prior to the final four conditions of Part B. The results failed to replicate the earlier ones, confirming a suspicion that unusually high baseline responding just prior to the first test of this condition elevated the rates. The results from the two replications were averaged prior to the statistical analysis and no further mention will be made of this replication. Table 1 lists the order of exposure to each condition for each subject.

Two measures of observing were collected and are reported. The first is the pre-exposure observing rate or the number of observing responses per minute measured over the interval from the beginning of a component until the first transition from the mixed to multiple schedule in that component. The second measure is the overall rate of observing, which includes both pre-exposure and postexposure observing responses. No observing could occur during the exposure to the multiple-schedule stimuli. The pre-exposure rate has the advantage of approximately equating duration of opportunity for observing between components since the components differed in duration. It also restricts the measurement of observing to periods prior to the initial production of a multiple-schedule stimulus on a given trial. Following production of a multiple-schedule stimulus on a given trial effective observing

responses produce redundant cues; hence, a lower rate of observing might be expected in these periods. The pre-exposure rate measure has the disadvantage of sampling only a small portion of the session. The overall rate measure has the advantage of sampling over a larger portion of the session and of greater comparability to previous studies that have used brief-exposure techniques.
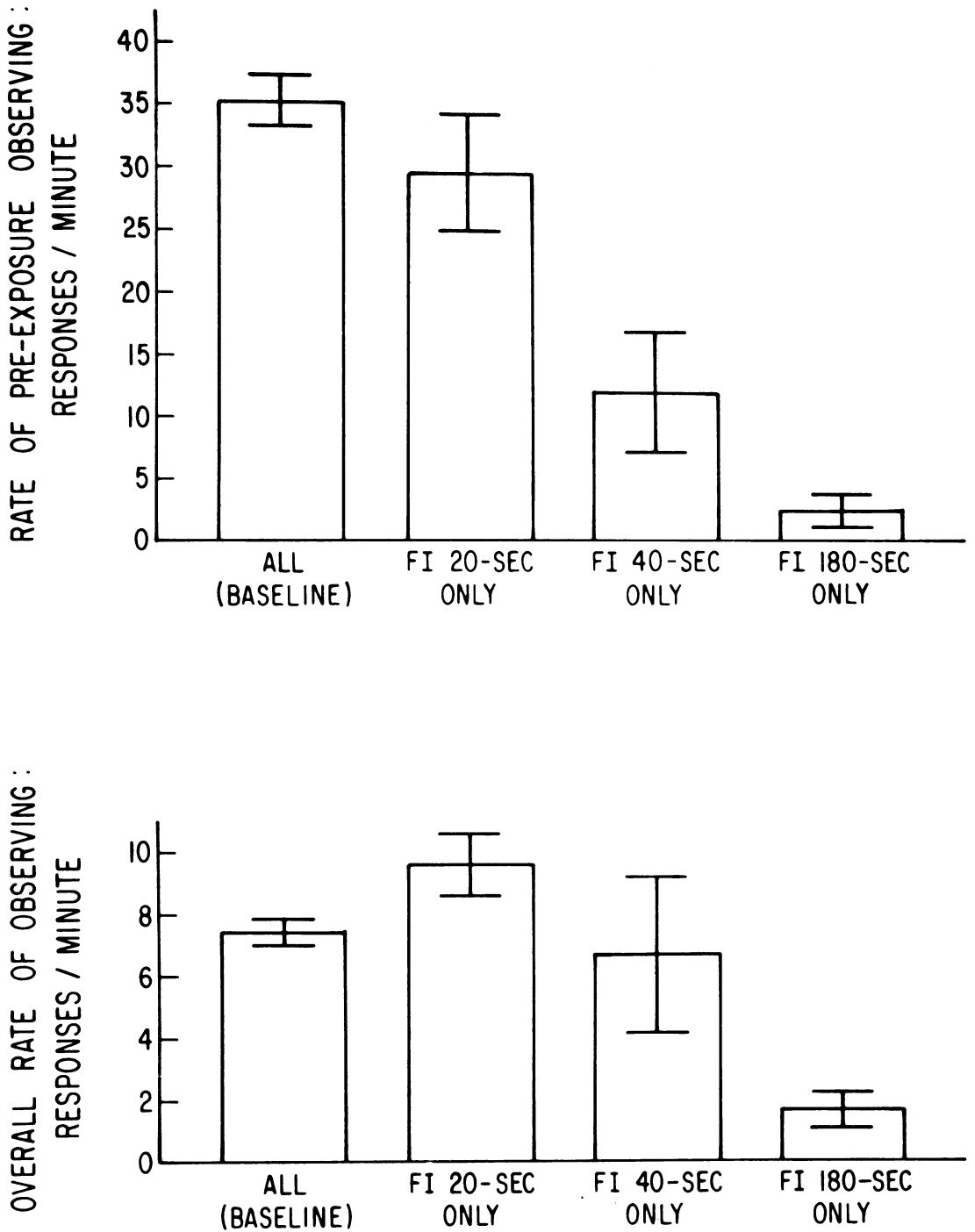
RESULTS

Responding on the food key showed typical FI and mixed-schedule patterning during training. Observation of the subjects while responding suggested typical FI and mixed-schedule stimulus control during testing as well, but the rates and patterns of responding on the food key during testing were not recorded in a manner that permitted rigorous assessment of stimulus control. Hence, responding on the food key will not be discussed.

Figure 1 plots both measures of observing for Part A. Note the different scales for the two dependent variables. The data are based upon the average over the last five sessions of a condition for each subject. Because of the unusually low rates displayed by Subject S4 in the FI 40-sec condition, the condition was repeated for this subject at the end of the experiment. The results replicated the earlier ones, and the data were averaged prior to the statistical analysis summarized below. No further mention will be made of this replication. Figures 2 and 3 contain the individual subject results.

The plot of the baseline results in Figure 1 is the mean of the three baseline conditions, and the accompanying thin vertical line indicates the standard deviation. Within-subjects analyses of variance comparing the replications yield nonsignificant differences for both dependent variables with $F(2,8) = 1.4$ (p > .1) for the pre-exposure rates and $F(2,8) = .8$ for the overall rates. The fact that observing levels were successfully recovered across the experiment in the baseline conditions strengthens the findings of the experimental conditions.

The results of the experimental conditions show that the bulk of the responding maintained in the baseline conditions was due to the contribution of the FI 20-sec and FI 40-sec stimuli. The FI 180-sec stimulus maintained only low amounts of observing, less than three responses per minute, as indicated by either

Fig. 1. Rate of overall and pre-exposure observing found in Part A of Experiment 1, measured in responses per minute. The baseline results are the mean and standard deviation of the three replications of this condition after first averaging over subjects. The other results are the mean and standard deviation across subjects for each condition.
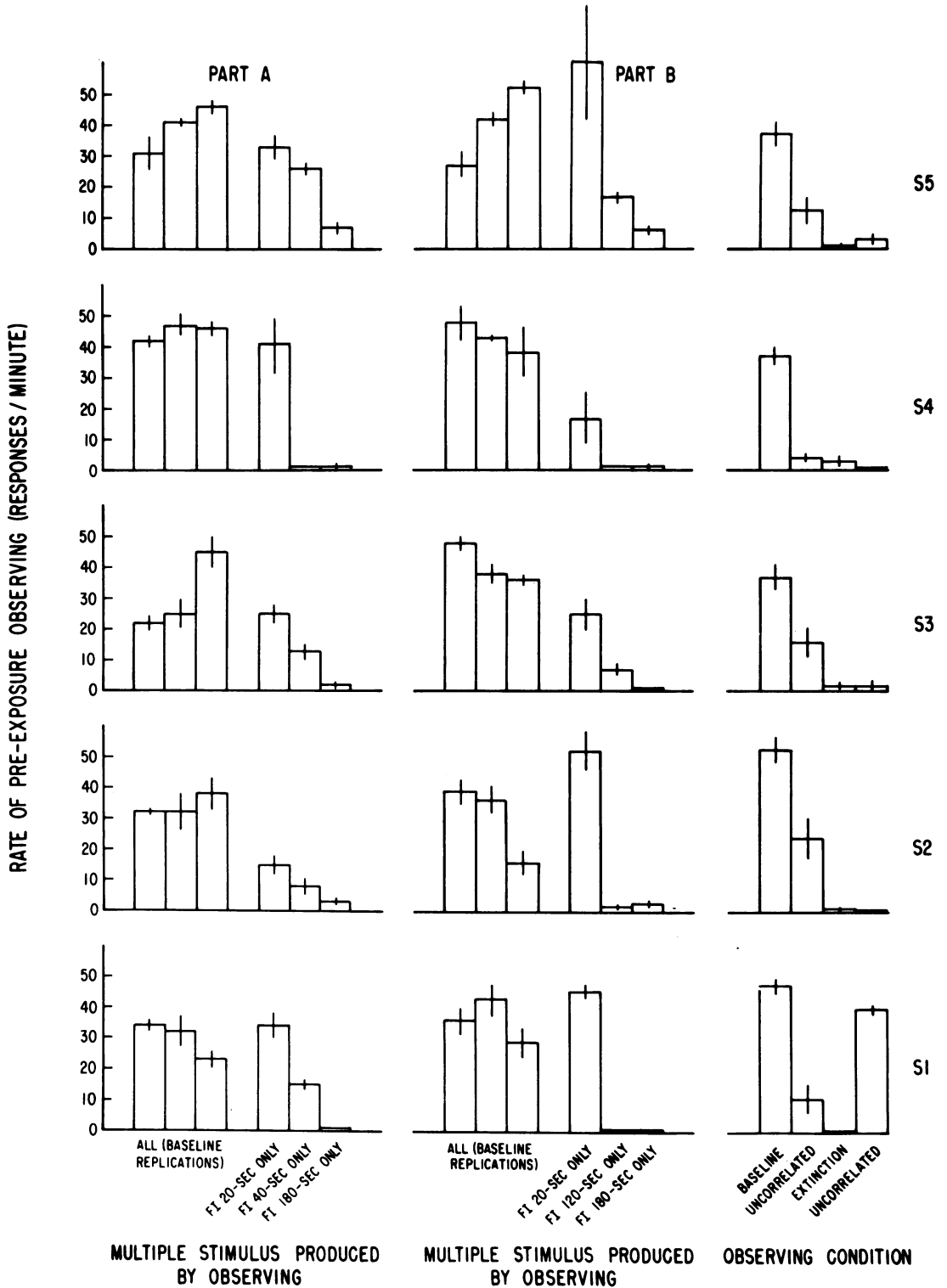
Fig. 2. Rate of pre-exposure observing for each subject in Experiment 1. Plotted are the mean and standard deviation of the last five sessions of each condition. Bars lacking deviation lines have deviations too small to illustrate clearly in the figure. The bars designated "uncorrelated" and "extinction" are the results for the uncorrelated baseline and extinction of observing conditions, respectively, from Part B.
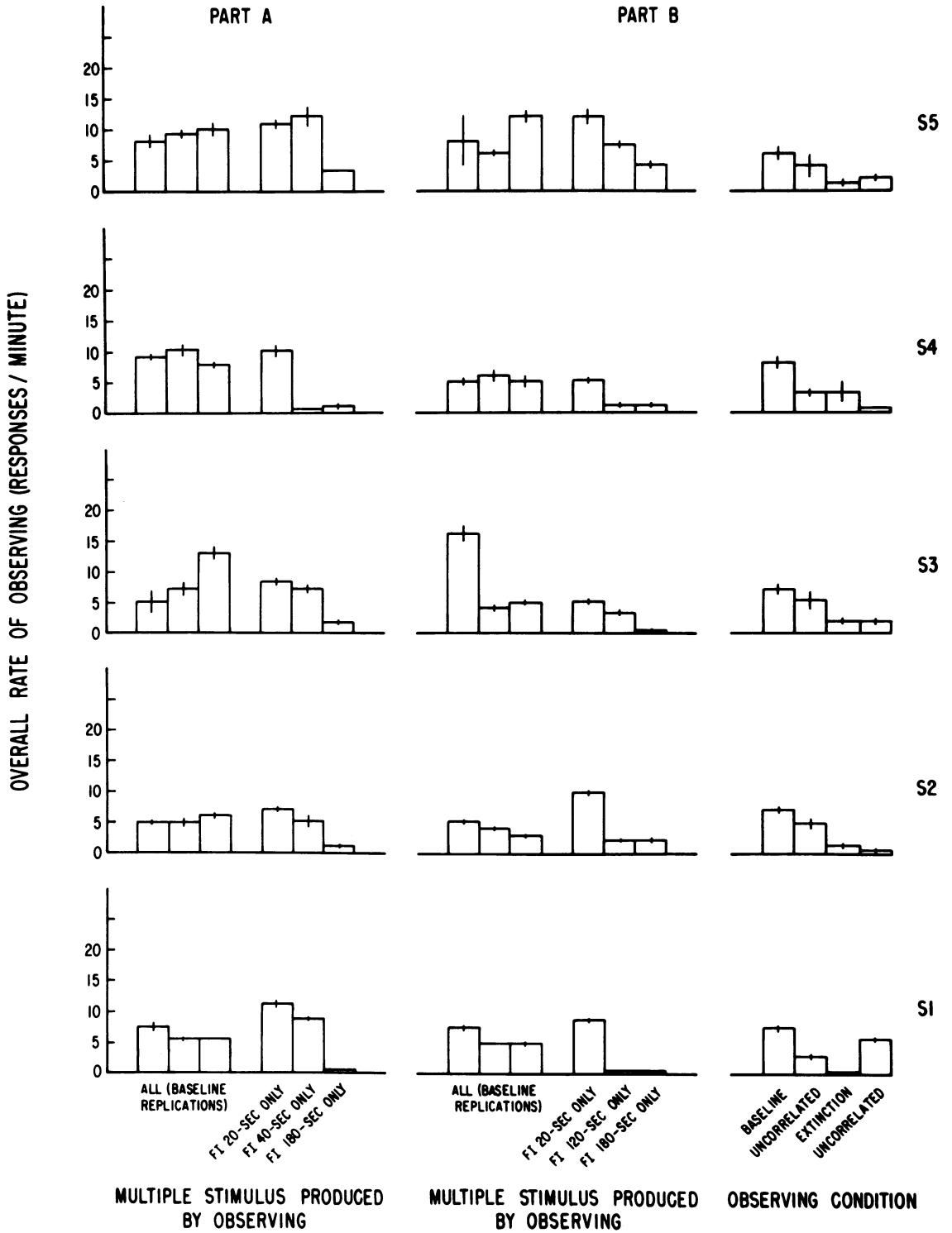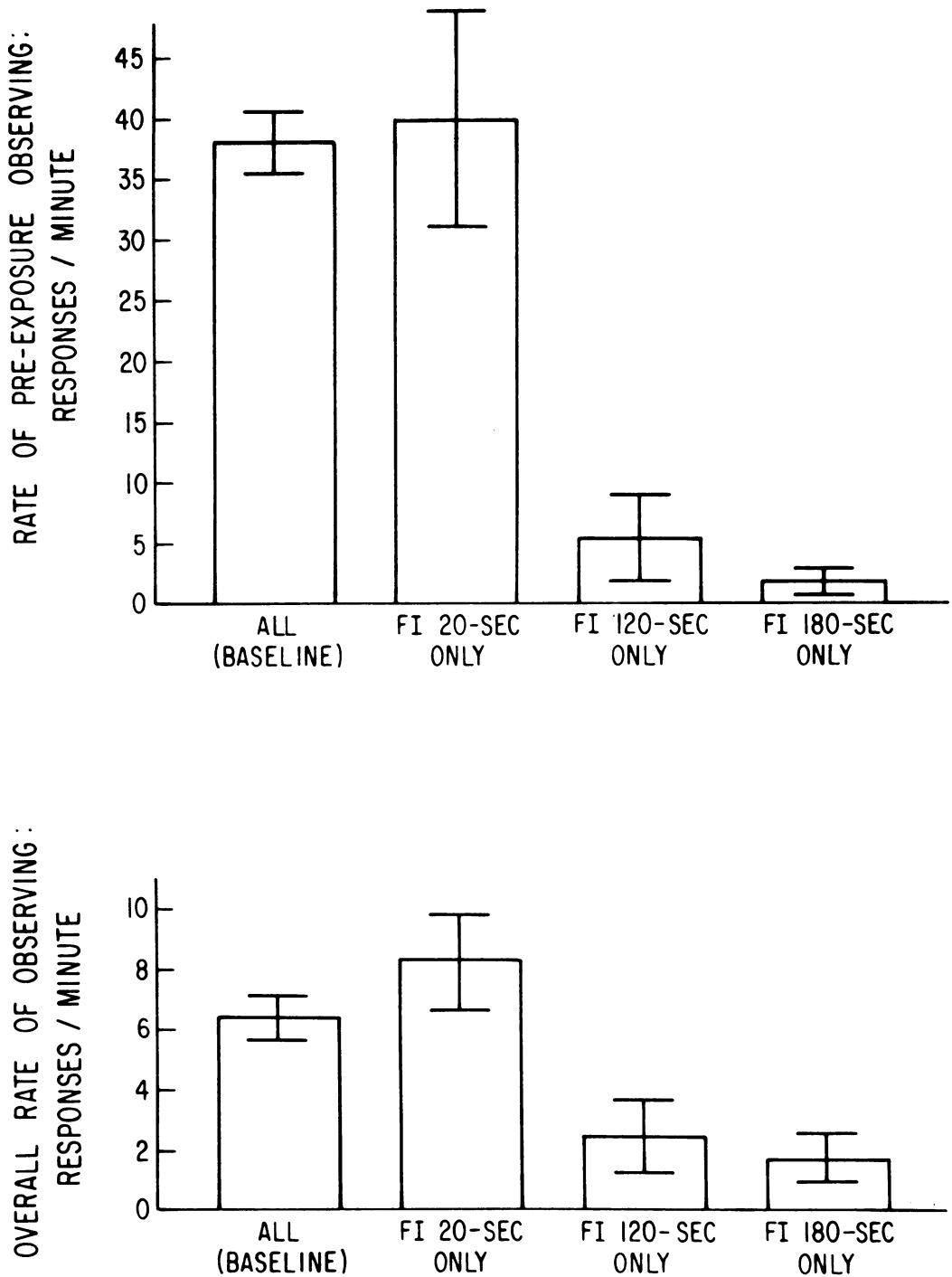
Fig. 3. Rate of overall observing for each subject in Experiment 1. See Figure 2 for details.

Fig. 4. Rate of overall and pre-exposure observing found in Part B of Experiment 1, measured in responses per minute. The baseline results are the mean and standard deviation of the three replications of this condition after first averaging over subjects. The other results are the mean and standard deviation across subjects for each condition.

dependent variable. More responding occurred in the FI 20-sec condition in baseline conditions for overall rate of observing. For both measures, the amount of observing was an inverse function of the delay signaled by the associated stimulus, as predicted. Within-subjects analyses of variance comparing these conditions yield significant effects for both dependent variables, $F(2,8) = 15$, $p < .01$, for the pre-exposure rates and $F(2,8) = 12$, $p < .01$ for the overall rates.

Figure 4 displays the results of the principal experimental conditions of Part B and the mean of the results of the baseline conditions that just preceded them. The baseline data were more variable across replications than in Part A; however, the differences across conditions are nonsignificant. The F-ratios from testing these replications are equal to .6 for pre-exposure observing and 1.3 ($p > .1$) for overall observing.

A comparison of the baseline and experimental conditions reveals that the baseline responding was due mostly to the effect of the

FI 20-sec stimulus: only this stimulus maintained substantial amounts of observing. The fixed-interval 20-sec condition maintained more observing than baseline for some subjects. Within-subjects analyses of variance indicated that the effects of experimental conditions were significant for both dependent variables. Specifically, the effect on pre-exposure rates was significant ($F(2,8) = 23$, $p < .01$), and the effect on overall rates was significant ($F(2,8) = 27$, $p < .01$).

The rates of observing maintained by the intermediate-delay stimuli of Parts A and B are plotted in Figure 5 for each subject. Although in 4 out of 5 subjects less observing was maintained by the stimulus associated with FI 120-sec, the difference between the means of the two conditions is not significant, $.05 < p < .10$. The F-ratios are $F(1,4) = 7.1$ for the pre-exposure rates and $F(1,4) = 6.6$ for the overall rates.

Figure 6 displays the results of the remaining conditions of Part B. The uncorrelated baseline condition was repeated following the extinction-of-observing condition. The results (Figures 2 and 3) indicate that the uncorrelated baseline maintains more observing behavior when following a correlated baseline (Replication 1) than when following the extinction of observing (Replication 2). However, the two replications were averaged prior to the statistical analysis that compared the correlated baseline, uncorrelated baseline, and extinction of observing conditions (Figure 6). The difference between the baseline and the uncorrelated baseline conditions is significant, $p < .01$, for both overall rates and pre-exposure rates. The difference between the uncorrelated baseline and the extinction of observing conditions is not significant for pre-exposure rates, $F(1,4) = 5.6$ and $p < .10$, and is also nonsignificant for overall rates, $F(1,4) = 4.5$ and $p > .10$.

DISCUSSION

In this study experimental control was repeatedly demonstrated by frequent returns to baseline. The large difference found between baseline and uncorrelated baseline conditions in Part B eliminates color preference as a possible alternate explanation of the data. The results provide general support for the delay-reduction hypothesis in that, according to either measure, rate of observing maintained by a stimulus was an increasing function of the
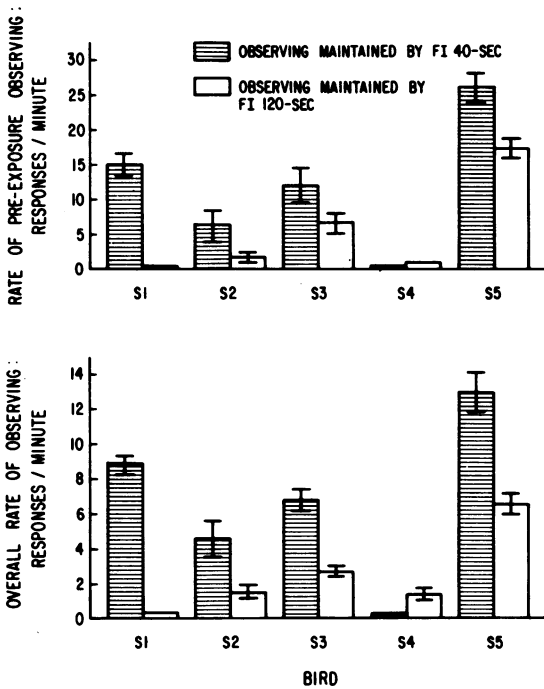
Fig. 5. Rate of overall and pre-exposure observing found in the FI 40-sec (Part A) and the FI 120-sec (Part B) conditions. The results are presented for each subject and represent the mean and standard deviation of the last five sessions of each condition. Bars lacking deviation lines have deviations too small to illustrate clearly in the figure.
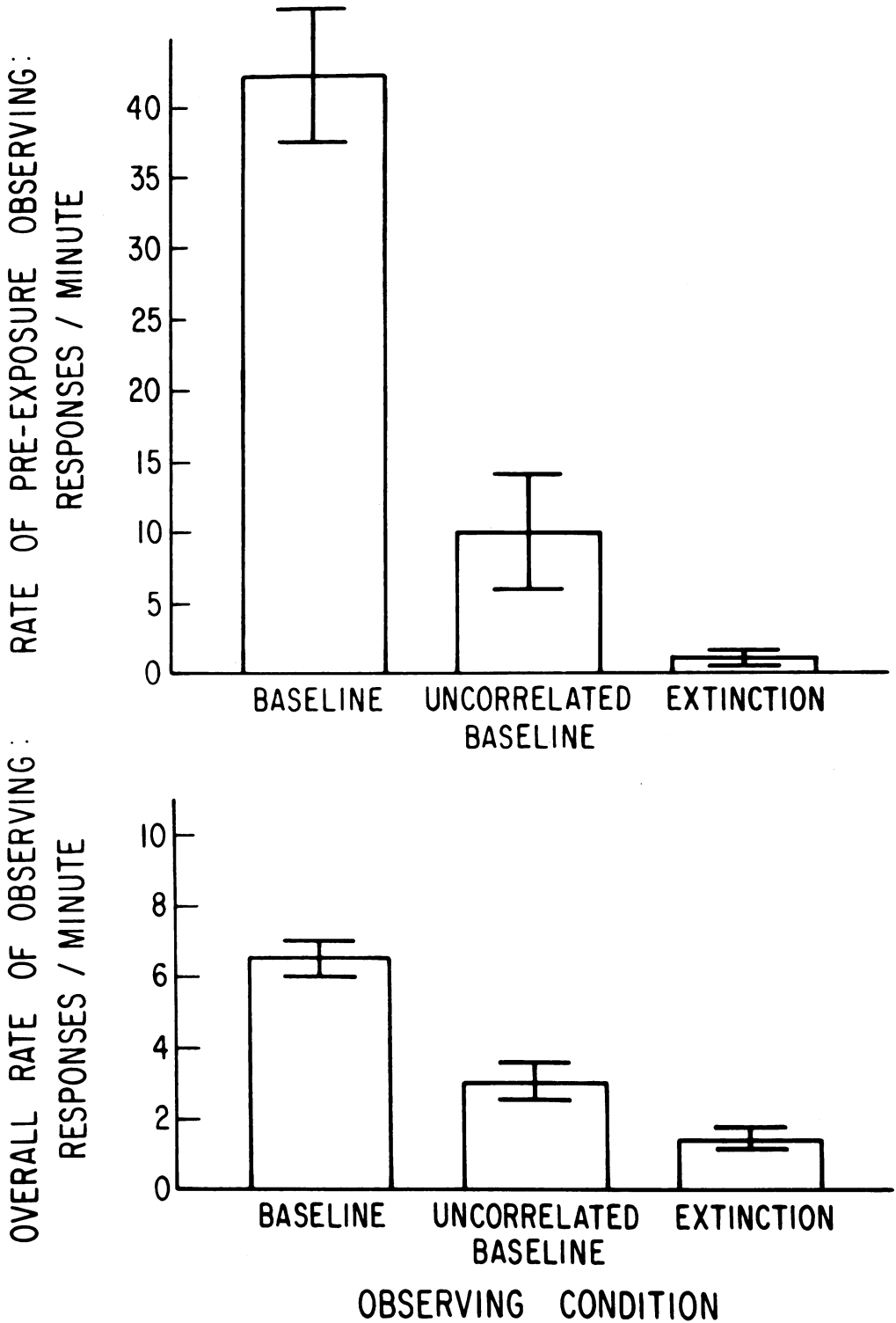
Fig. 6. Rate of overall and pre-exposure observing found in the second part of Experiment 1, Part B in responses per minute. The results represent the mean and standard deviation across subjects for each condition. The uncorrelated baseline results are based on the average of two replications, one following baseline and the other following extinction.

degree of delay reduction associated with that stimulus.

The FI 20-sec condition frequently maintained more responding than baseline, especially in Part B. Since during baseline conditions all three stimuli could be produced, this result suggests that the stimuli correlated with the intermediate and long FIs function in combination to suppress responding maintained by the FI 20-sec stimulus.

The results did not support all specific predictions of the delay-reduction hypothesis. The stimulus correlated with FI 40-sec and a relatively small degree of delay-reduction should have maintained observing, and the stimulus correlated with FI 120-sec or FI 180-sec and an *increase* in time-to-reinforcement should not have. As seen in Figures 1 and 4, the occurrence of some observing in all conditions was inconsistent with the latter prediction. Experiment 2 addresses this point.

The results are generally inconsistent with the uncertainty-reduction hypothesis. The three multiple-schedule stimuli were equally informative, yet one (correlated with FI 20-sec) maintained more than tenfold the rate of pre-exposure observing as another (correlated with FI 180-sec).

EXPERIMENT 2

In both parts of Experiment 1 the stimuli correlated with an increase in time to reinforcement maintained low rates of observing. This finding is inconsistent with the delay-reduction hypothesis, which predicts that these stimuli lack conditioned-reinforcement strength. One possibility is that delay-reduction is both necessary and sufficient to account for observing per se, but that sensory reinforcement accounts for some responding maintained on the observing key. Examination of Figure 6 shows that sensory change alone (uncorrelated baseline) cannot account for all baseline responding. However, sensory reinforcement maintained at least as much responding as maintained by the stimuli associated with the FI 120-sec and FI 180-sec schedules (Figure 4; also Figure 1 for FI 180-sec).

The role of sensory reinforcement needs further evaluation. The uncorrelated baseline condition of Experiment 1 provided three times as much opportunity to obtain stimulus change in the experimental conditions as in the uncorrelated baseline condition (since only one multiple-schedule stimulus may be produced in the experimental conditions). In order to equate for the amount of sensory reinforcement potentially available Experiment 2 replicated the FI 120-sec condition of Experiment 1 and compared it with an uncorrelated condition in which access to the uncorrelated "multiple"-schedule stimuli was restricted to one-third of the components. If the rates are equivalent in the correlated and uncorrelated conditions, sensory reinforcement can account for all of the "observing" responding maintained by the stimulus correlated with the FI 120-sec schedule. If the uncorrelated condition maintains more responding, the stimulus correlated with the FI 120-sec may be a conditioned punisher rather than a conditioned reinforcer. On the other hand if the correlated stimulus maintains more responding, a conditioned reinforcing effect inconsistent with the delay-reduction hypothesis would be demonstrated.

METHOD

Subjects

Six male White Carneaux pigeons served. All subjects had extensive histories of key pecking for food. The pigeons were maintained at 80% of their free-feeding weights.

Apparatus

The apparatus was the same as used in Experiment 1.

Procedure

The basic procedure was the same as used in Experiment 1 except for the number of trials per session of training (18) and of testing (27, or 9 per FI). The total number of reinforcements per session (45) was insufficient to maintain 80% weight. Supplemental feeding was provided in the home cage following the session.

The components used in this experiment were FI 20-sec, FI 120-sec, and FI 180-sec, as in Part B of Experiment 1. The baseline and the FI 120-sec experimental conditions were also the same as before. In the uncorrelated condition, however, observing was effective in producing the transition from mixed to "multiple" schedules during only one-third of the components, as in experimental conditions,

and the stimuli which were produced were uncorrelated with the delays to reinforcement, as in the uncorrelated baseline condition of Experiment 1. Table 1 contains a list of the conditions and the number of sessions in each.

RESULTS

Table 2 contains the results for Experiment 2. The baseline conditions, which were conducted before, after, and between the experimental conditions, showed replication of response levels across the experiment. The comparison of these conditions yields nonsignificant differences for both dependent variables with $F(2,5) = 3.5$, $p > .1$, for the pre-exposure rates and $F(2,5) = 2.6$, $p > .1$, for the overall rates.

The results of the FI 120-sec condition replicates those of Experiment 1 in that this condition again produced a low but nonzero rate of observing. Between-subjects analyses of variance comparing the FI 120-sec conditions in the two experiments yield nonsignificant differences for both dependent variables. The F-ratios are $F(1,9) = 2.2$, $p > .1$, for the pre-exposure rates and $F(1,9) = 2.7$, $p > .1$, for overall rates.

Low rates were also maintained in the uncorrelated condition. In fact, the critical result is that, for all six subjects, the uncorrelated condition maintained *more* responding than

the FI 120-sec condition. The within-subjects analysis of variance of the means shows that this difference was significant: The statistic for the pre-exposure measure is $F(1,5) = 6.8$, $p < .05$, while for the overall rate it is $F(1,5) = 14$, $p < .05$.

Finally, the between-experiments analyses of variance comparison of the FI 40-sec condition of Experiment 1 and the uncorrelated experimental condition of Experiment 2 shows that the latter condition maintained significantly less observing in the case of the pre-exposure measure ($F(1,9) = 6.0$, $p < .05$), but not in the case of the overall rates ($F(1,9) = 5.0$, $p < .1$).

GENERAL DISCUSSION

According to the delay-reduction hypothesis, the strength of a stimulus as a conditioned reinforcer is a function of the reduction in time to reinforcement correlated with the onset of that stimulus. This hypothesis has been successful in describing the strength of conditioned reinforcers as measured in a choice situation and is also consistent with results from studies of observing involving two alternating schedules. With two schedules, since only one stimulus is correlated with delay reduction, only that stimulus should reinforce observing. This result, obtained in many studies (e.g., Auge, 1973; Dinsmoor, Browne, & Lawrence, 1972; cf. Fantino, 1977, for a review) is inconsistent

Table 2

Rate of overall and pre-exposure observing for each subject in Experiment 2 (in responses per minute).

Subject	Baseline			FI 120-sec	Uncorrelated
	Replication 1	*Replication 2*	*Replication 3*		
	Overall Rate of Observing				
S6	3.6 ± .8[a]	2.3 ± .6	2.3 ± .6	.3 ± .3	.7 ± .2
S7	3.4 ± .8	3.0 ± .7	2.4 ± 1.1	.4 ± .4	1.1 ± .9
S8	11 ± 2	5.2 ± 3.5	8.9 ± 1.6	2.1 ± 2.2	4.0 ± .8
S9	9.5 ± 3.3	5.2 ± 1.0	1.0 ± .9	.2 ± .3	.6 ± .4
S10	1.8 ± 1.1	1.2 ± .6	1.9 ± 2.0	.2 ± .2	.9 ± 1.1
S11	4.0 ± .5	3.4 ± 1.0	3.5 ± 1.0	.1 ± .02	1.2 ± 1.0
mean	5.5	3.4	3.3	.6	1.4
	Rate of Pre-exposure Observing				
S6	28 ± 3	9 ± 1.5	11 ± 9	.3 ± .5	.5 ± .1
S7	20 ± 5	28 ± 10	8.7 ± 9.0	.3 ± .3	.5 ± .2
S8	36 ± 24	47 ± 7	37 ± 12	3.7 ± 4.4	4.7 ± 2.0
S9	38 ± 17	24 ± 17	1.3 ± 1.2	.2 ± .3	.4 ± .2
S10	11 ± 8	5.9 ± 8.6	9.5 ± 9.4	.2 ± .2	.9 ± 1.5
S11	32 ± 9	20 ± 15	18 ± 8	.1 ± .03	1.9 ± 2.4
mean	28	22	14	.8	1.5

[a]Each entry consists of the mean and standard deviation (m ± s.d.) of the last five sessions of each condition.

with uncertainty-reduction views of observing which require that the stimulus correlated with no delay reduction also maintain observing (since it also reduces uncertainty). Moreover, some of these studies have shown that stimuli correlated with an increase in time to reinforcement may actually suppress observing (e.g., Blanchard, 1975; Jwaideh & Mulvaney, 1976; Mulvaney, Dinsmoor, Jwaideh, & Hughes, 1974).

The present study provided more stringent tests of the delay-reduction hypothesis by assessing the extent of observing maintained by stimuli correlated with each of three alternating schedules. The rate of observing maintained by a stimulus was a function of the degree of delay-reduction correlated with its production (Experiment 1). Stimuli correlated with an increase in time to reinforcement maintained less observing than those uncorrelated with any particular outcome (Experiment 2). Thus, in reference to the appropriate control for sensory reinforcement, the stimulus correlated with the intermediate schedule maintained more responding when it was associated with a delay reduction and less responding when associated with a delay increase. The results thus extend the applicability of the delay-reduction hypothesis to observing-response procedures. Moreover, they support the extension of the hypothesis from choice situations to procedures in which the production of stimuli does not affect the temporal distribution of reinforcement. Finally, the results are also consistent with a symmetrical version of the delay-reduction hypothesis: stimuli correlated with an *increase* in time to reinforcement may be conditioned punishers (Jwaideh & Mulvaney, 1976).

Although the present results are inconsistent with the uncertainty-reduction hypothesis, one aspect of the present data ostensibly supports the possibility that observing is partially maintained by uncertainty reduction. Response rates were higher when only pre-exposure responding was considered than they were for overall responding. This difference reflects the fact that the observing rates declined following the first exposure to the multiple-schedule stimulus for that component. The uncertainty-reduction hypothesis would predict this result since postexposure observing responses produce only redundant signals. An alternative analysis recognizes that the overall rate measure (e.g., Figure 1, bottom) differentially weights the contribution of the respective components according to their duration. The longer components contribute more because of the greater period over which response rates are calculated. The evidence from the preexposure measure (e.g., Figure 1, top), which weights the components equally indicates that the greater the delay to reinforcement, the less likely observing responses will occur. Hence, the lower rates of observing reflected in the overall measure may have simply resulted from the greater weighting of the components which maintain less observing. A second alternative to an uncertainty-reduction interpretation derives from consideration of the potential effects of reinforcement upon food-key responding. Competition between observing and instrumental food responding may exist following the multiple-schedule stimulus exposure, especially in the FI 20-sec component where reinforcement for a food-key response is imminent. Consistent with this view, the largest absolute and relative decline in observing following exposure to a multiple-schedule stimulus occurs in the FI 20-sec component. Finally, observing rates may be elevated at the beginning of a component because this period is associated with a low probability of reinforcement for food-key responses. The higher rate of observing responses during this time might be functionally related to adjunctive activities that are known to occur in similar circumstances (Staddon, 1977).

Although the present results are consistent with the delay-reduction hypothesis it is possible to explain them in terms of reinforcement density as well (Fantino, 1977). As noted in the introduction, research on choice clearly favors the delay-reduction hypothesis (e.g., Fantino, 1969b, 1977; Squires & Fantino, 1971). Thus, it would be simpler conceptually to retain the same hypothesis to account for observing.

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