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THE GENERALITY OF SELECTIVE OBSERVING

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Four rats obtained food pellets by poking a key and 5-s presentations of the discriminative stimuli by pressing a lever. Every 1 or 2 min, the prevailing schedule of reinforcement for key poking alternated between rich (either variable-interval [VI] 30 s or VI 60 s) and lean (either VI 240 s, VI 480 s, or extinction) components. While the key was dark (mixed-schedule stimulus), no exteroceptive stimulus indicated the prevailing schedule. A lever press (i.e., an observing response), however, illuminated the key for 5 s with either a steady light (S+), signaling the rich reinforcement schedule, or a blinking light (S−), signaling the lean reinforcement schedule. One goal was to determine whether rats would engage in selective observing (i.e., a pattern of responding that maintains contact with S+ and decreases contact with S−). Such a pattern was found, in that a 5-s presentation of S+ was followed relatively quickly by another observing response (which likely produced another 5-s period of S+), whereas exposure to S− resulted in extended breaks from observing. Additional conditions demonstrated that the rate of observing remained high when lever presses were effective only when the rich reinforcement schedule was in effect (S+ only condition), but decreased to a low level when lever presses were effective only during the lean reinforcement component (S− only condition) or when lever presses had no effect (in removing the mixed stimulus or presenting the multiple-schedule stimuli). These findings are consistent with relativistic conceptualizations of conditioned reinforcement and extend the generality of selective observing to procedures in which the experimenter controls the duration of stimulus presentations, the schedule components both offer intermittent food reinforcement, and rats serve as subjects.

Key words: observing behavior, selective observing, conditioned reinforcement, key poke, rats

Observing responses bring sensory receptors into contact with stimuli that signal the availability of primary reinforcement, but do not alter that availability (Wycoff, 1952, 1969). It appears, then, that such responding is maintained by production of the discriminative stimuli rather than by production of primary reinforcement. As such, observing behavior has been important in the study of stimulus control (Dinsmoor, 1985, 1995; Wycoff, 1952, 1969) and conditioned reinforcement (Dinsmoor, 1983; Fantino, 1977, 2001; Hendry, 1969).

A typical method for studying observing behavior consists first of training on a multiple schedule. For example, a pigeon can obtain food by key pecking in the presence of two alternating discriminative stimuli—a green light that signals a variable-interval (VI) 60-s schedule of food reinforcement and a red light that signals extinction. The rate of primary (food) reinforcement is 60 per hour and 0 per hour in the presence of the green and red lights, respectively. Following this training, the components continue to alternate, but the discriminative stimuli no longer appear on the key. Instead, the key is illuminated, for example, with a white light regardless of the prevailing schedule of reinforcement (VI or extinction). The white light signals a mixed schedule in which the rate of food reinforcement for key pecking is an average from the VI and extinction components. In the present example, if the VI and extinction components are in effect for equal lengths of time, the rate of reinforcement in the mixed schedule is 30 reinforcers per hour. The mixed stimulus provides no exteroceptive stimulation indicating whether the VI or extinction component is currently in effect. However, if the subject makes an additional response (e.g., depressing a perch), the stimulus associated with the currently active component is presented in place of the mixed stimulus. That is, perch depressions

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turn off the white light and produce either the red or green light. This added response is called an *artificial* observing response.

The artificial observing response makes it possible for the subject's sensory receptors to contact the relevant discriminative stimuli, but the subject still must make additional adjustments (i.e., the natural observing responses such as turning its head toward the stimulus) for this sensory contact to occur. Thus, the artificial observing response is designed to function analogously to the natural observing response, but with the added benefit of being easily recorded. (Hereafter, artificial observing responses are referred to simply as observing responses, and, when necessary for conceptual or procedural clarity, are distinguished from natural observing responses.) The duration of the stimulus presentation following an observing response may be determined by the experimenter or may be left under the control of the subject. When the experimenter fixes the duration of the stimulus (e.g., each observing response produces a 5-s stimulus presentation), the procedure is called *experimenter controlled.* Under an experimenter-controlled procedure, the subject controls the onset of the stimulus but not its duration. Of course, the subject can terminate the natural observing response at any point during the stimulus presentation (e.g., by turning away), but the experimental apparatus does not typically record these natural terminations. Under the *subject-controlled* procedure, an observing response produces the appropriate discriminative stimulus as long as the response is maintained (e.g., as long as the perch remains depressed). This procedure allows the subject to control both the onset and the termination of the stimulus and may reduce the likelihood of unrecorded natural terminations of the observing response uncorrelated with the measured observing response (Dinsmoor, 1983). Regardless of whether experimenter-controlled or subject-controlled procedures are used, observing responses serve only to produce discriminative stimuli and have no impact on the scheduling or receipt of food reinforcement.

Given that the observing response does not alter the frequency of primary reinforcement, it is reasonable to ask why the subject engages in observing. One view is that observing is maintained by conditioned reinforcement; that is, it places the subject in contact with a stimulus (S+) that has been correlated with primary reinforcement. One apparent difficulty with conditioned reinforcement interpretations, however, is that observing also places the subject in contact with the stimulus (S−) that has been correlated with extinction. In fact, in the presence of the mixed-schedule stimulus, any one isolated observing response is equally likely to produce S+ or S−. Relative to the mixed-schedule stimulus, the S+ is correlated with an increased rate of reinforcement and should be a conditioned reinforcer. But the S− is correlated with a decrease in the rate of reinforcement and thus should be a conditioned punisher. If the S+ and S− are produced equally by observing, the effects might be expected to cancel, at least to some extent, resulting in little or no net reinforcement for observing (Dinsmoor, 1983; Dinsmoor, Mueller, Martin, & Bowe, 1982).

Yet observing is maintained, which has led some to propose alternative sources of reinforcement. One prominent account emphasizes the reinforcing value of information (Berlyne, 1957; Hendry, 1969). Proponents of the information interpretation assume that stimuli that reduce uncertainty (i.e., provide information) about the availability of primary reinforcement are reinforcing. The reduction in uncertainty is reinforcing because it allows the organism to allocate its behavior so as to optimize access to primary reinforcement (Davis, 1983; Hendry, 1983; Thompson & Wilcox, 1983). From this perspective, the transition from the mixed stimulus to either the S+ or the S− reduces uncertainty. Thus, both transitions are positive in sign, thereby explaining the maintenance of observing.

Despite the intuitive appeal of information-based accounts, two lines of evidence argue in favor of conditioned reinforcement interpretations of observing. First, when access is restricted to only one of the two stimuli (S+ or S−), the effects are dramatically different. If observing is allowed to produce the discriminative stimulus only during the richer reinforcement component, observing is maintained at a high rate; but if observing is allowed to be effective only during the extinction component, the rate of observing declines to a low level (Allen & Lattal, 1989; Dinsmoor, Browne, & Lawrence, 1972; Mueller & Dinsmoor, 1986; Mulvaney, Dinsmoor, Jwaideh, & Hughes, 1974; Preston, 1985). Similar results are obtained even when S+ and S− signal different rates or magnitudes of intermittent reinforcement (Auge, 1973a, 1974; Jwaideh & Mulvaney, 1976). Such data are inconsistent with the information interpretation, which suggests that both S+ and S− should reinforce observing. The data are consistent, however, with relativistic conceptions of conditioned reinforcement that imply that S+ should become a conditioned positive reinforcer for observing, whereas S− should function as a conditioned aversive stimulus, decreasing the frequency of observing (Dinsmoor, 1983; Fantino, 1977, 2001).

Although they provide strong evidence of the conditioned reinforcing value of S+, the findings just described do not provide an answer to the question of why the reinforcing effects of S+ are not counterbalanced by the punishing effects of S−. A second line of evidence provides a potential answer to this question. Dinsmoor et al. (1982) reinforced pigeons' key pecking according to a mixed VI 60-s extinction schedule. The birds could also depress a perch, which produced the discriminative stimulus correlated with the currently active schedule for as long as the perch was depressed. Under such conditions, the pigeons generated greater exposure to S+ than to S−, a phenomenon referred to as *selective observing* (Dinsmoor et al., 1982; see also Browne & Dinsmoor, 1974). They did so by responding differentially after the stimulus was initially produced. Production of S+ set the occasion for continuing the observing episode, whereas production of S− set the occasion for terminating the observing episode. Consequently, even though S+ and S− may be produced equally often, the total sum of conditioned positive reinforcement is greater than the total sum of conditioned aversive stimulation. That is, the punishing effect of S− is minimized by self-termination.

The clearest demonstrations of selective observing have come from experiments like Dinsmoor et al.'s (1982) in which the subject controlled both the onset and duration of the discriminative stimuli (see also Browne & Dinsmoor, 1974). According to interpretations based on conditioned reinforcement and conditioned punishment by S+ and S−, selective observing should also occur in procedures in which the experimenter controls the duration of the stimulus displays (e.g., stimulus turned on for 5 s per lever press; see Dinsmoor, 1983). However, aspects of the experimenter-controlled procedure make it difficult to measure selective observing to determine if it is indeed occurring. In the experimenter-controlled procedure, the subject controls the onset of the discriminative stimulus but can terminate it only through altering a naturally occurring observing response (e.g., by turning away). Because the recording equipment is insensitive to such natural terminations of the discriminative stimuli (and records the entire stimulus presentation as time spent observing), it might, in fact, yield an inflated duration of observing S− (Dinsmoor, 1983, 1985).

Pigeons have, in fact, been observed to turn away from S− more than from S+ in a discrimination learning task (e.g., Rand, 1977). However, the absence of direct empirical evidence has made it possible to question the generality of selective observing to situations in which the experimenter controls the stimulus duration (Branch, 1983; Fantino, 1983; Shull, 1983). Thus, it would be useful to determine whether evidence can be found for selective observing in an experimenter-controlled procedure.

Such a demonstration would also be important because, despite some advantages, subject-controlled procedures are limited in some significant respects. First, designing the experimental space is challenging. The proximity of the operandum for observing and the operandum for producing food must be close enough to allow both responses to occur concurrently; however, they should not be so close that the responses are inevitably conjoined (Hirota, 1972). In addition, with the subject-controlled procedure, the rate of primary reinforcement will be higher given the joint response (holding down perch and key pecking simultaneously) than given the food-producing response alone (key pecking). In other words, the joint response required in the subject-controlled procedure results in a built-in contingency between perch depressions and food reinforcement even though observing has no effect on the delivery of food reinforcement (Dinsmoor, 1983). Under such circumstances, the two conceptually independent responses (perch depressing and key pecking) may become functionally one response unit. In this case, differential contact with S+ compared to S− would appear to be the result of the differential discriminative performance rather than the conditioned reinforcing effects of the stimulus observed. Thus, finding evidence of selective observing in an experimenter-controlled procedure would weaken interpretations based on the association between the observing response and delivery of primary reinforcement fostered by the subject-controlled procedure.

Several additional considerations led to the present study. The generality of the evidence for selective observing has been questioned because the evidence has come almost exclusively from experiments with pigeons (Badia & Abbott, 1983; D'Amato, 1983). In addition, selective observing has yet to receive much empirical support in situations in which both schedule components provide intermittent primary reinforcement (Moore, 1983). One relevant study with rats (Preston, 1985) demonstrated that compared to baseline, when observing produced both S+ and S−, rates of observing were stable when S+ was the only available outcome but decreased when observing produced only S−. Similarly, Bowe and Green (1988) found that rats exposed to a mixed variable-time extinction schedule would observe stimuli providing information about the temporal proximity to reinforcement (see also Badia, Ryan, & Harsh, 1981) but not stimuli providing information about the spatial location where reinforcement was to be delivered. Thus, the sparse literature with rats supports conditioned reinforcement interpretations of observing. However, these studies did not employ schedules that offered different rates of primary reinforcement, nor did they seek evidence of selective observing. The present study does both.

The present experiment was designed to determine whether evidence of differential observing could be found with the experimenter-controlled procedure, with rats as subjects, and with components arranging reinforcement according to VI versus extinction or rich VI versus lean VI schedules. Given the difficulty in measuring selective observing under the experimenter-controlled procedure, as described above, some explanation of how this was done in the present study is needed. Although the recording under the experimenter-controlled procedure is insensitive to premature (natural) termination of the observing response, it is not insensitive to responding that extends the duration of the observing episode. It is possible to record the latency from the offset of the stimulus until the subject makes a follow-up observing response (Dinsmoor, Flint, Smith, & Viemeister, 1969). Rapid follow-up responses can be conceptualized as behavior that extends the observing episode, whereas long disengagements can be conceptualized as terminations of the observing episode. According to this line of reasoning, selective observing would be evidenced by more rapid follow-up responses given an S+ than an S− and longer periods of disengagement from observing following an S− than an S+.

To have a reasonable chance of identifying a pattern of differential follow-up observing responses, we tried to ensure that our observing procedure would be favorable to generating follow-up observing. Specifically, we arranged components of at least 60 s in duration that were substantially longer than the 5-s discriminative stimulus presentations. Consequently, a rapid follow-up observing response was likely to produce a repetition of the most recently observed discriminative stimulus. If, instead, the components had been set to alternate randomly from second to second, the consequence of a follow-up observing response would likewise have been random. That is, follow-ups to S+ would have been no more likely to produce S+, the putative reinforcer for the follow-up response, than to produce S−, the putative punisher for the follow-up response. Thus, there would have been no basis for differential observing. In addition, if stimulus presentations had been very long (e.g., 30 s), the opportunity for follow-up observing responses would be small and the likelihood of unrecorded natural terminations of observing high.

A potential problem, however, with using fixed-duration components is that observing might seldom occur because the ''information'' from follow-up observing responses is highly redundant. As such, we wanted to ensure that the stimuli presented on the key were those that maintained observing and that the level of observing obtained was sufficient to replicate some of the basic phenomena demonstrated in previous studies of observing. Therefore, in addition to seeking evidence of selective observing, we compared the rate of observing during baseline (when observing responses produced both S+ and S−) to that generated by the following manipulations: (a) allowing observing to produce the discriminative stimulus only during the lean reinforcement component (S− only), (b) allowing observing to produce the discriminative stimulus only during the rich reinforcement component (S+ only), (c) making the observing response totally ineffective either by having the mixed-schedule stimulus on regardless of observing or by having the appropriate multiple-schedule discriminative stimulus on regardless of observing. Manipulations a and c were expected to produce a decrease in the rate of observing compared to baseline. Maintenance of observing was expected in Condition b.

METHOD

Subjects

The subjects were 4 male Long Evans hooded rats obtained from a commercial breeder at approximately 6 weeks of age. At the beginning of this project the rats were about 12 months old and had served previously in a different study of observing involving multiple and mixed VI extinction schedules of reinforcement. The rats were housed in individual plastic cages with free access to water. The housing rooms were maintained at about 22 °C and were on a 12:12 hr light/dark cycle; the experimental sessions were conducted during the light periods.

The feeding regimen consisted of a period of free access to food for approximately 1 hr shortly after each daily session. This feeding schedule maintained the rats' weight between 310 and 350 g, with few exceptions. For male Long Evans hooded rats, this weight range has been described as an appropriate and effective level of deprivation (Ator, 1991).

Apparatus

The experimental chambers were four identical Gerbrands two-lever operant chambers (30 cm wide by 32 cm deep by 30 cm high) constructed of sheet metal (top and three sides) and clear plastic (rear door, 21 cm by 30 cm). The floor was made of stainless steel rods (0.7 cm diameter) spaced 1 cm apart. In the middle of the front panel, centered 4.3 cm above the floor, was a rectangular opening (4.4 cm by 4.4 cm) giving access to a small metal food tray. An electrical pulse to a pellet dispenser caused a food pellet (45-mg Noyes Formula A) to drop into the food tray. The operation of the dispenser made an audible click preceding the pellet landing in the tray, which also made an audible ''plinking'' sound.

To the right and left of the food cup were two levers mounted 5.1 cm above the floor and 3.6 cm from the right and left walls, respectively. The left lever served as the observing operandum during this experiment. A force of approximately 0.35 N was required to operate the lever. A lamp was centered 5.7 cm above each lever, and an additional lamp (28-VDC bulb and orange cap) that served as the houselight was mounted 8.9 cm above the left lever. The houselight was illuminated before the start of each daily session, went off to mark the beginning of the session, and was illuminated again at the end of the session.

Located on the left wall was a round hole (1.9 cm diameter) behind which was a translucent plastic key (a Lehigh Valley Electronics pigeon key). The center of the key was located 5.1 cm toward the rear from the front wall and 6.2 cm above the floor. Pushing the key a distance of 1 to 2 mm with a force of 0.18 N (three of the four chambers) or 0.3 N (the fourth chamber) produced a brief click that resulted from the operation of a small snap-action switch connected to the key. The key could be transilluminated with either a blinking white light (two flashes per second) or a continuously illuminated (steady) white light (two bulbs operated at 28 VDC). The straight-line distance between the lever and the key was 5 to 6 cm, such that the two operanda were in close proximity but not so close that the rat could operate them simultaneously.

A water bottle was suspended outside the chamber on the left wall, approximately 24 cm toward the rear from the front wall. A metal drinking spout, connected to the bottle and protruding approximately 1 cm into the chamber through a small hole in the wall 2.5 cm above the floor, allowed free access to water during experimental sessions.

During the experiment, the chambers were placed on a cart, two to a shelf. Because it was apparent that each rat quickly learned to go to its food tray only when its own feeder operated, no attempt was made to attenuate sounds in the chambers. The experimental sessions were conducted with the room darkened. Experimental events were controlled and data records generated for each chamber by dedicated special-purpose computers (Walter & Palya, 1984).

Procedure

Because the rats had prior experience with multiple and mixed schedules in which a steady light was associated with a higher rate of response-contingent food reinforcement and a blinking light was associated with a lower rate of response-contingent food reinforcement, we began immediately with the observing procedure.

Each daily session began with the offset of the houselight. At that point, one of two 60-s components began. One of the components arranged a relatively rich VI schedule of reinforcement for key poking, and the other component arranged either a relatively lean VI schedule or extinction, depending on the rat.[1] (See Table 1 for the schedule values associated with each component for each rat.) A cycle consisted of two 60-s components in succession, one rich and one lean; each session consisted of 40 such cycles. Within each cycle, the order in which the components were presented was randomized. Thus, two rich or two lean components could occur back to back, but no more frequently. Likewise, rich or lean components could be separated by no more than two components. There was no timeout between components. Key poking was reinforced by food pellets according to whichever component was currently engaged. But, unless the rat pressed the lever, the keylights remained off so that there was no discriminative stimulus on the key (nor anywhere else in the chamber) that indicated which of the two components was currently engaged. If, however, the rat pressed the left lever (thereby making an observing response), the keylight was turned on for 5 s; either steady (S+) if the rich component was engaged, or blinking (S−) if the lean component was engaged. If the component terminated before the completion of the stimulus presentation, the remainder of the stimulus presentation was canceled. Additional lever presses that occurred during the stimulus presentation had no effect.

Table 1

Schedules of reinforcement, order or stimulus conditions, and number of training sessions during each condition for each rat.

Rat	Schedule	Stimulus condition	Number of sessions
2	VI 60 s VI 240 s	S+/S− 1	25
		S− only	10
		S+ only	8
		S+/S− 2	27
		Multiple schedule	16
		S+/S− 3	15
		Mixed stimulus only	16
		S+/S− 4	29
		Reversal	1
5	VI 30 s VI 480 s	S+/S− 1	82
		S− only	20
		S+ only	22
		S+/S− 2	35
		Multiple schedule	40
		S+/S− 3	54
		Mixed stimulus only	25
		S+/S− 4	36
		Reversal	1
9	VI 60 s VI 240 s	S+/S− 1	25
		S− only	10
		S+ only	8
		S+/S− 2	26
		Mixed stimulus only	16
		S+/S− 3	15
		Multiple schedule	16
		S+/S− 4	30
		Reversal	1
11	VI 30 s extinction	S+/S− 1	57
		S+ only	24
		S− only	24
		S+/S− 2	30
		Mixed stimulus only	20
		S+/S− 3	35
		Multiple schedule	40
		S+/S− 4	36
		Reversal	1

For all conditions, each of the VI schedules consisted of 14 different intervals and provided a roughly constant probability of rein-

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[1] The particular schedules chosen in the present study were based on our previous work, which determined values that would maintain a sufficient and relatively stable amount of baseline observing for each rat.

forcement in time since the last reinforcer (Fleshler & Hoffman, 1962; Hantula, 1991). Upon the first presentation of a component and immediately following each presentation of an assigned reinforcer, one of the 14 intervals was randomly selected (with replacement). If an assigned reinforcer had not been delivered when the current 60-s component ended, the reinforcer assignment was saved and carried over to the next presentation of that component. Likewise, at the end of a 60-s component, the time elapsed during an interval of a VI schedule was saved so that the interval resumed timing at the same point when the program returned to that component. The session concluded with the onset of the houselight.

The number of training sessions during each condition is shown in Table 1. Our goal for the four conditions during which both S+ and S− were available was to establish baseline rates of observing, with key poking as the food-reinforced response under the discriminative control of S+ and S−. The baseline observing rates were used to assess the level of selective observing and to serve as a reference for determining the effects of the following independent variables: (a) allowing a lever press to produce the discriminative stimulus only during the lean reinforcement component (S− only), (b) allowing a lever press to produce the discriminative stimulus only during the rich reinforcement component (S+ only), (c) making the lever press totally ineffective either by having the mixed-schedule stimulus on regardless of lever pressing or by having the appropriate multiple-schedule discriminative stimulus on independent of lever pressing. Following the final S+/S− condition, the light conditions were reversed for one session, thus allowing further assessment of selective observing (see below). Throughout the experiment, condition changes were initiated at convenient times when visual inspection of the data suggested no systematic trends and the authors agreed that the effect of the manipulation of interest (see above) had been demonstrated.

Analysis of Selective Observing

The performances from the last five sessions of each of the four S+/S− baseline conditions were used to assess the presence of selective observing. Typically, selective observing consists of maintaining contact with S+ and terminating contact with S−. As such, under the current conditions, a rapid follow-up observing response can be conceptualized as an extension of the previous observing episode that serves to maintain contact with the previously produced stimulus. Following this line of reasoning, our primary evidence for selective observing came from analyzing the latencies to follow-up observing responses separately after production of S+ and S−. Additional analyses of selective observing examined the rate of observing. We calculated observing rate in the rich and the lean components, first for all occurrences of each component type and then only for components in which no reinforcement was delivered (i.e., for naturally occurring "probes"). In these analyses, selective observing is evidenced in a difference in the rate of observing favoring S+ over S−.

The rate calculations were considered secondary to the follow-up analyses because in the experimenter-controlled procedure, rate (or proportion of time the stimuli were displayed on the key) is an insensitive measure. Determining the rate of observing involves dividing the number of observations by some interval of time (e.g., number of observations per 1-min component). This calculation results in insensitivity for three reasons (all of which are not applicable or less applicable to the analysis of follow-up latencies). First, the numerator includes time during which the subject may have naturally terminated the observing response (e.g., by looking away while the key remained illuminated). Second, time attributable to observing responses that produce initial contact and those that maintain contact are aggregated in the numerator. Finally, the denominator in the rate calculation treats all time in which the key is dark as available for observing. However, observing competes with other sources of control. For instance, the opportunity to consume food pellets would be expected to preempt observing. Because the rate of reinforcement in the present experiment was higher in the S+ than in the S− components, the rats may have spent a greater amount of time during the S+ components engaged in consummatory responses, thereby reducing the time available to observe. However, components in which no reinforcers were delivered serve as naturally occurring probe components, in which the rate of observing would not be influenced by competing consummatory responses, thereby partially controlling for the third limitation. Based on these considerations, we calculated both the all-component observing rate and the observing rate in probe components, with the latter expected to be a more sensitive measure. Given the schedules of reinforcement, the number of available S− probe components was necessarily greater than the number of available S+ components. Thus, to make sure that the probe component rates were not misleading due to different sample sizes, probe rates were calculated during one session in which the light conditions were reversed. If selective observing is a relatively stable aspect of performance, differential response to the lights should persist in this single reversal session, and the time spent in consummatory responses would now favor S− over S+ and the number of probe components would favor S+ over S−.[2]

RESULTS

Selective Observing

Figure 1 presents the follow-up latencies. For each rat, the latencies from the last five sessions of each of the four S+/S− conditions were combined and sorted into six bins: the proportions that occurred from 0 to 2 s, 2 to 4 s, 4 to 6 s, 6 to 8 s, 8 to 10 s, and more than 10 s since the offset of the stimulus (unboxed data points). In addition, the proportion of follow-up observing responses that fell in the 0- to 2-s bin and the >10-s bin during the reversal session were included (boxed data points). To the extent that the follow-up latencies were distributed similarly between S+ and S−, the points should lie on the diagonal; however, to the extent that the frequencies of follow-up latencies favored S+ or S−, the points should lie below and above the diagonal, respectively. For Rats 5, 9, and 11, an observing response was more likely to result in a rapid follow-up if it had produced S+ than if it had produced S−; that is, the open circles (proportion of 0- to 2-s follow-ups) and, for Rats 5 and 11, the open squares (proportion of 2- to 4-s follow-ups) clustered below the diagonal. Moreover, for Rats 2, 5, and 11, an observing response was more likely to result in a long latency (i.e., a long disengagement from observing) if it had produced S− than if it had produced S+; that is, the filled circles (proportion of latencies longer than 10 s) clustered above the diagonal.

Figure 2 shows, for the 0- to 2-s and >10-s bins, the mean difference between the proportion of S+ and S− follow-up observing responses calculated for each rat across the 20 S+/S− sessions (i.e., the last five sessions from the four S+/S− conditions). Values of zero represent no difference in follow-ups to S+ and S−, whereas positive and negative values represent a greater proportion of follow-ups to S+ and S−, respectively. Standard deviation bars show the variability in the daily data. Given the variability, we tested whether the mean values for each rat were significantly different from zero. Testing the mean value for the 0- to 2-s and >10-s bins for each of the 4 rats resulted in eight analyses. As such, we determined the alpha level using a Bonferroni correction, which involves dividing a conventional alpha level (e.g., $\alpha < .05$) by the number of analyses to be conducted. Based on this correction, alpha was set at < .006 (i.e., .05/8) and resulted in statistically significant differences favoring S+ in the 0- to 2-s bins for Rat 5 ($t = 6.37$), Rat 9 ($t = 14.55$), and Rat 11 ($t = 4.46$), and statistically significant differences favoring S− in the >10-s bins for Rat 5 ($t = -8.32$) and Rat 11 ($t = -10.70$). These data confirm the visual analysis of Figure 1.

The total-session observing rates and probe component observing rates are presented in Table 2. Not unexpectedly, the total-session rates of lever pressing were higher during the rich reinforcement component than during the lean reinforcement component for only 2 rats (Rats 5 and 11). These rats generated the most differentiated patterns of follow-ups (see Figures 1 and 2) such that despite the limitations associated with calculating overall rate, evidence of selective observing emerged. Un-

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[2] During the light-reversal session, it is most accurate to refer to the steady light as the former S+ (now S−) and the blinking light as the former S− (now S+). However, because this one reversal session was designed to characterize relatively stable aspects of performance learned prior to the switch, for clarity we refer to the stimuli according to their baseline designation as S+ or S−.

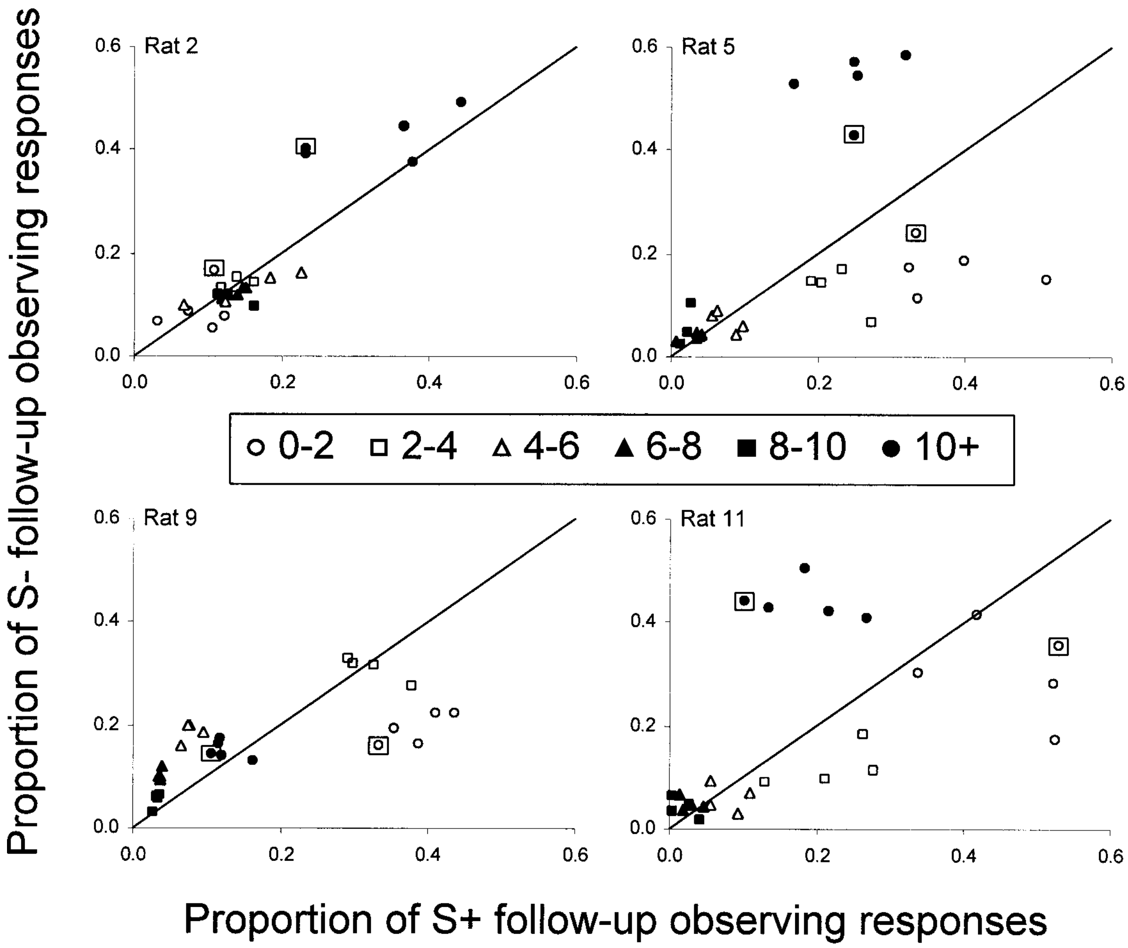

Fig. 1. The proportion of follow-up observing responses occurring from 0 to 2, 2 to 4, 4 to 6, 6 to 8, 8 to 10, and >10 s since the offset of the S+ (*x* axis) and S− (*y* axis) across the last five sessions of each of the four S+/S− conditions. The data points in squares represent the proportion of 0- to 2-s and >10-s follow-ups during the reversal session. Points below the diagonal indicate differential latencies favoring S+, and points above the diagonal indicate differential latencies favoring S−.

like Rats 5 and 11, Rats 2 and 9 observed at a slightly higher rate during the lean reinforcement component. However, Table 2 shows that when the light conditions were reversed, reducing the number of competing consummatory responses in S+ (and increasing consummatory responses in S−), the all-component observing rates of all 4 rats favored S+.

In the probe components, across the four replications of S+/S− and the reversal session, Rats 2 and 9 demonstrated higher rates of observing S+ than S−. The relative observing rates for S+ also increased for Rat 11 in the probe components. For Rat 5 the relative observing rate remained essentially unchanged in two replications (S+/S− Conditions 1 and 3), but decreased, demonstrating greater rates of observing during the lean reinforcement component, in the other two (S+/S− Conditions 2 and 4). Thus, across the 4 rats, selective observing was noted in 14 of 16 replications using data from the S+/S− probe components and in 18 of 20 replications that included the reversal session. The probe data concur with the differential pattern of follow-up observing responses to provide evidence of selective observing.

Table 3 presents the reinforcement rates during the rich and lean components and in the presence of S+, S−, and the mixed stim-

Table 2

All-component (AC) observing rates and probe observing rates across the last five sessions for each of the four S+/S− conditions and the one reversal session. The # column indicates the average number of S+ and S− probe components in each session.

		AC observing rate			Probe observing rate				
Rat	Condition	S+	S−	Relative	S+	#	S−	#	Relative
2	S+/S− 1	2.02	2.52	.44	4.27	12	2.86	31	.60
	S+/S− 2	2.78	2.96	.48	5.37	16	3.54	29	.60
	S+/S− 3	2.05	2.82	.42	3.96	12	3.34	31	.54
	S+/S− 4	1.88	2.40	.44	3.46	16	2.92	31	.54
	Reversal	2.94	1.67	.64	3.61	30	3.14	12	.54
5	S+/S− 1	1.29	1.02	.56	1.67	6	1.03	35	.62
	S+/S− 2	1.04	0.74	.58	0.73	7	0.74	32	.49
	S+/S− 3	1.63	1.23	.57	1.52	7	1.22	36	.55
	S+/S− 4	1.54	1.34	.54	1.23	7	1.31	35	.49
	Reversal	2.94	1.45	.67	2.93	34	1.65	9	.64
9	S+/S− 1	6.34	6.75	.48	10.31	15	7.84	32	.57
	S+/S− 2	7.18	7.83	.48	12.69	15	9.33	30	.58
	S+/S− 3	6.35	6.93	.48	10.71	13	7.71	33	.58
	S+/S− 4	6.15	7.47	.45	9.80	16	8.84	32	.53
	Reversal	8.28	5.08	.62	9.30	32	8.92	16	.51
11	S+/S− 1	6.32	4.85	.57	12.92	5	4.85	40	.73
	S+/S− 2	5.25	2.84	.65	12.02	6	2.84	40	.81
	S+/S− 3	4.20	2.39	.64	6.47	5	2.39	40	.73
	S+/S− 4	6.06	3.07	.66	9.60	7	3.07	40	.76
	Reversal	10.16	3.11	.77	10.16	40	3.20	11	.76

ulus. The overall rates of reinforcement received in the rich and lean components were consistent with the programmed values for each rat. The reinforcement rates in the presence of S+ and S−, as presented in Table 3, are deflated to some unknown degree, which is likely greater in S− than S+, due to natural terminations of observing.[3] Despite this deflation, the five-session averages show that in 14 of 16 cases across the 4 rats, the transition from the mixed schedule to S+ signaled an average increase in the rate of reinforcement. In the two cases in which the average reinforcement rates did not favor S+, we recalculated the rates including the two previous sessions (resulting in seven session averages). In both cases, the new averages minimally favored S+ over the mixed stimulus. (The newly determined reinforcement rates in S+ and the mixed stimulus were 0.68 and 0.65, respectively, for Rat 2 and 0.72 and 0.69, respectively, for Rat 9.) These data verify that the received rates of reinforcement were consistent with the programmed rates and support the notion that production of S+ could function as a conditioned reinforcer for observing.

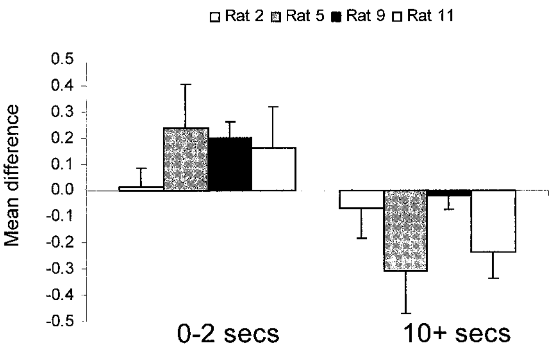

Fig. 2. The mean difference between the proportion of S+ and S− follow-up observing responses in the 0- to 2-s and >10-s bins across the 20 sessions (last five sessions each) from the four S+/S− conditions. Positive values indicate a higher rate of follow-ups to S+, negative values indicate a higher rate of follow-ups to S−, and zero indicates no difference. The error bars represent one standard deviation of the mean.

Table 4 presents the key-poke rates and relative rates of key poking for each rat across conditions. Relative rate of responding pro-

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[3] The reinforcement rate in the presence of the mixed stimulus is not influenced, at least technically, because looking away from the S+ or S− does not reinstate the nominal mixed stimulus: the dark key (see Shull, 1983).

Table 3

Average reinforcement rates across the last five sessions for each of the four S+/S− conditions. Reinforcement rate is presented as the overall rate delivered during that component regardless of observing (rich vs. lean) and the rate in the presence of the S+, S−, and mixed stimulus (Mix).

Rat	Condition	Rich	Lean	S+	S−	Mix
2	S+/S− 1	0.98	0.23	0.79	0.15	0.63
	S+/S− 2	0.94	0.29	0.63	0.16	0.67
	S+/S− 3	0.97	0.26	0.81	0.13	0.65
	S+/S− 4	0.73	0.24	0.68	0.22	0.49
5	S+/S− 1	1.48	0.13	1.52	0.07	0.80
	S+/S− 2	1.46	0.15	1.27	0.09	0.81
	S+/S− 3	1.38	0.11	0.89	0.06	0.77
	S+/S− 4	1.56	0.13	1.02	0.00	0.88
9	S+/S− 1	0.94	0.22	0.69	0.03	0.69
	S+/S− 2	0.69	0.21	0.96	0.16	0.40
	S+/S− 3	1.05	0.19	0.96	0.10	0.67
	S+/S− 4	0.86	0.22	0.83	0.12	0.59
11	S+/S− 1	1.77	0.00	1.69	0.00	0.87
	S+/S− 2	1.80	0.00	2.47	0.00	0.70
	S+/S− 3	1.62	0.00	2.54	0.00	0.62
	S+/S− 4	1.63	0.00	3.53	0.00	0.33

vides an index of discriminative control of key poking during the observing procedure. These data show that substantially higher rates of key poking occurred when the key was illuminated with S+ than with S−. For instance, during S+/S− baseline conditions, the relative rates were well over .50 for all rats (range, .60 to .97). In the absence of key illumination relative rates were reduced for each rat, hovering around .50 for Rats 2 and 9 and around higher values for Rats 5 (range, .58 to .61) and 11 (range, .72 to .88). These higher relative rates for Rats 5 and 11 appeared to be due to bursts of responding, which began in the presence of the S+ but did not terminate until after the offset of the light. Overall, these response-rate data show that the rats discriminated between the two light conditions, and in all S+/S− baseline conditions the absence of the light reduced discriminative performance (see Table 4). In other words, the dark key appeared to function as a mixed stimulus.

Systematic Replication

Figure 3 presents the rate at which the rats pressed the observing lever during each of the last five sessions of each condition. From left to right, the first segment of each panel presents the rate of observing when lever presses produced both the steady and blinking lights (S+/S−). The next two segments show the rate of observing when lever presses produced only S− or only S+. In all cases, the rate of observing decreased when S− was the only result of lever pressing and was maintained, or slightly increased, when S+ was the only result of lever presses. Likewise, compared to return-to-baseline conditions (S+/S−), the rate of observing responses decreased substantially during extinction of observing; that is, when the multiple schedule stimuli were already present on the key or when observing failed to alter the mixed stimulus.

DISCUSSION

In the current study, rats' observing behavior was differentiated in a manner indicative of selective observing. Follow-up latencies were more likely to be short when S+ was produced than when S− was produced, whereas long disengagements from observing were more likely when S− was produced than when S+ was produced. These findings are noteworthy in that they provide evidence of selective observing during an experimenter-controlled procedure. Selective observing has been hypothesized to occur during these procedures, and the present data show that it can. These data also support the proposed mechanism that produces selective observing; specifically, that S+ sets the occasion for maintenance of observing, whereas S− sets the occasion for termination (Branch, 1970; Dinsmoor, 1983, 1985; Dinsmoor et al., 1982). A criticism of extending the selective observing interpretation to experimenter-controlled procedures has been that null findings could be interpreted as consistent with selective observing due to differential natural termination of stimuli. In the present experiment we hypothesized that a differential tendency to naturally terminate or maintain episodes of observing would have measurable implications on follow-up observing responses (see also Dinsmoor et al., 1969). This approach provided a stringent test of the selective observing hypothesis and found strongly supportive results from 3 of 4 rats and suggestive evidence from the 4th.

Evidence of selective observing traditionally involves demonstrating that subjects respond so as to spend a greater proportion of

Table 4

Key-poke rates (per minute) and relative rates of key poking in the presence and absence of the stimuli correlated with the schedules of reinforcement, for each rat averaged across the last five sessions of each condition.

Rat	Condition	S+	S−	Relative	No S+	No S−	Relative
2	S+/S−	78.93	39.63	.66	38.51	45.05	.46
	S− only	80.32	51.82	.61	39.66	51.01	.44
	S+ only	78.39	57.63	.58	42.97	46.67	.48
	S+/S−	66.41	44.12	.60	40.10	41.12	.49
	Multiple	44.07	24.26	.65			
	S+/S−	61.79	38.24	.62	31.16	35.02	.47
	Mixed only				32.71	45.12	.42
	S+/S−	64.29	39.08	.62	26.81	31.55	.46
	Reversal	67.03	41.94	.62	40.55	20.17	.67
5	S+/S−	26.97	2.54	.91	9.52	6.75	.59
	S− only	8.06	6.71	.52	7.71	7.15	.52
	S+ only	21.49	6.20	.77	7.32	5.35	.58
	S+/S−	25.35	1.95	.93	6.12	4.35	.58
	Multiple	9.19	1.78	.84			
	S+/S−	15.64	1.32	.93	6.92	4.88	.59
	Mixed only				5.52	5.75	.49
	S+/S−	14.32	1.09	.93	6.77	4.35	.61
	Reversal	14.61	1.69	.90	6.42	4.60	.58
9	S+/S−	67.74	19.00	.78	38.12	36.99	.51
	S− only	65.38	45.63	.59	38.64	44.00	.47
	S+ only	68.81	32.49	.68	36.38	41.41	.47
	S+/S−	68.13	22.43	.75	33.47	33.34	.50
	Mixed only				32.00	38.23	.46
	S+/S−	70.98	21.99	.76	35.92	35.12	.51
	Multiple	38.32	20.55	.65			
	S+/S−	60.86	16.40	.79	24.43	29.46	.45
	Reversal	53.41	15.47	.78	29.44	22.00	.57
11	S+/S−	74.28	7.26	.91	28.13	10.69	.72
	S+ only	108.51	10.11	.92	28.46	5.39	.84
	S− only	93.21	59.97	.61	26.61	22.35	.54
	S+/S−	121.87	11.14	.92	27.73	7.05	.79
	Mixed only				21.87	23.39	.48
	S+/S−	107.01	7.78	.93	20.77	5.46	.79
	Multiple	54.90	2.19	.96			
	S+/S−	94.15	2.76	.97	13.28	1.84	.88
	Reversal	108.65	35.05	.76	8.53	8.39	.50

the available time in the presence of S+ than S−. Such results have been documented when the subject controls both the onset and duration of each stimulus presentation (Browne & Dinsmoor, 1974; Dinsmoor et al., 1982). It has been suggested that the experimenter-controlled procedure, due to the fixed duration of the stimulus, is insensitive to natural selective observing that occurs in spite of similar rates of stimulus initiations. The present findings support this interpretation. Despite the evidence of selective observing in terms of differential follow-ups, the total-session observing rate during the four S+/S− conditions was suggestive of selective observing for only 2 of 4 rats (8 of 16 assessments). However, given the differential tendency to follow up more quickly after S+ than S−, one might still question why a higher rate of observing did not emerge despite the experimenter-controlled procedure. It is clear that, over short time periods at least, the differential latencies to follow-up observing responses would result in differential exposure to S+ over S−. An answer to why differential exposure was not apparent in overall observing rate might lie in a better understanding of alternative sources of control to which the organism allocates behavior. For instance, when time allocated to consuming food pellets is controlled for by isolating probe components, a higher rate of observ-

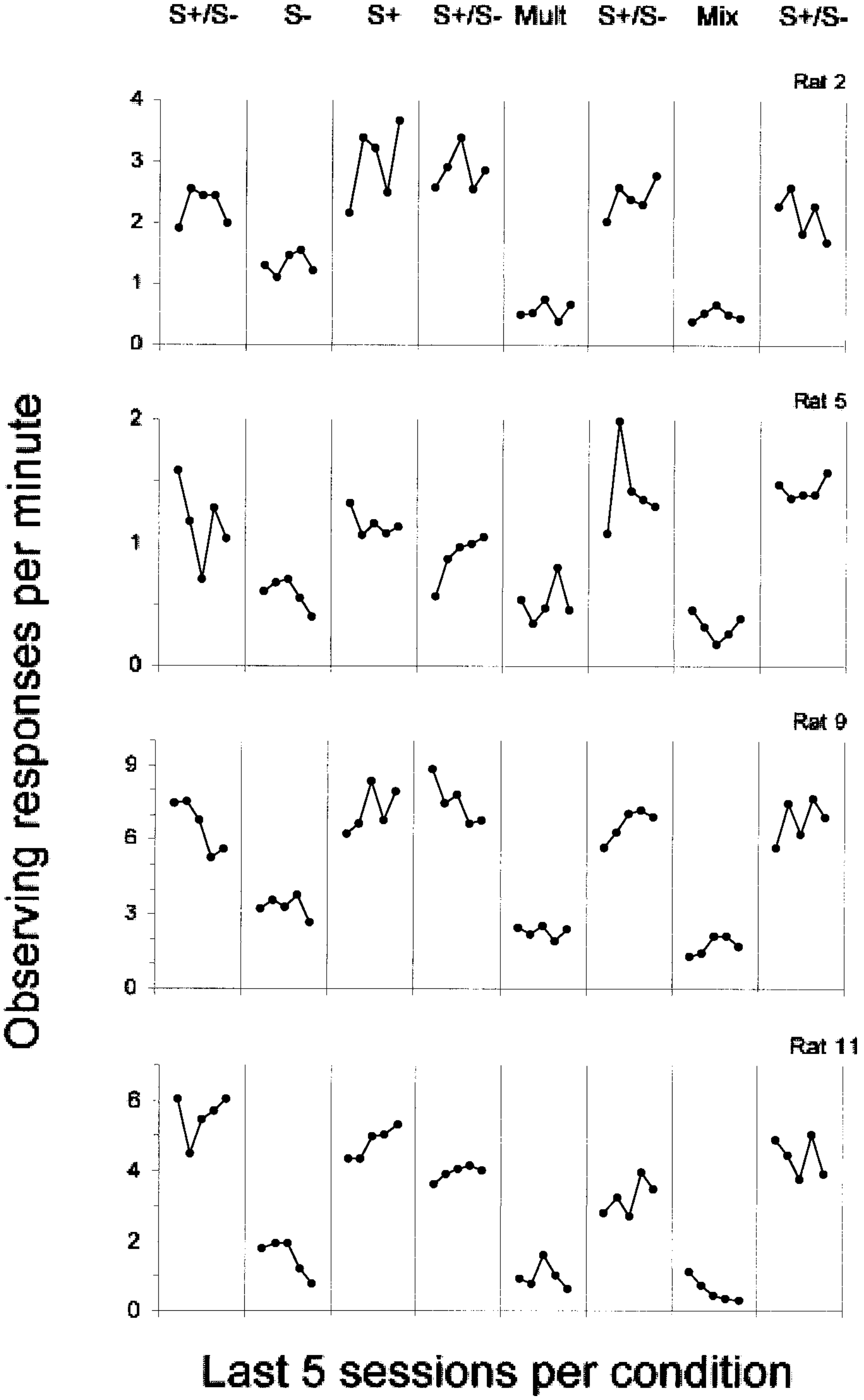

Fig. 3. Overall rates of observing (i.e., lever presses) during the last five sessions of the S+/S−, S+ only, S− only, standard multiple-schedule (Mult), and mixed-stimulus only (Mix) conditions. To simplify comparison among the rats, the stimulus conditions are presented in the same order for each rat, despite some differences in the actual ordering (see Table 1).

ing S+ than S− was found for 18 of 20 assessments.

The majority of data supportive of selective observing have come from pigeons responding on mixed schedules in which one of the components is always extinction. In the present experiment rats were the subjects, and both of the components, in three of four cases, provided VI schedules of food reinforcement. The present results therefore extend the generality of selective observing not only to the experimenter-controlled procedure but also to rats and mixed schedules in which both components offer intermittent food reinforcement. That differential observing occurred despite the fact that the putative S− also signaled food provides further support for relativistic conceptualizations of conditioned reinforcement (Dinsmoor, 1983; Fantino, 1977, 2001). That said, it should be noted that the strongest outcomes occurred for Rats 5 and 11, the subjects that experienced the greatest discrepancy in reinforcement rates between the components signaled by S+ and S−.

It should also be noted that the use of fixed-duration components that were fairly long (i.e., 60 s) and discriminative stimulus presentations that were fairly brief (i.e., 5 s) probably was critical for generating differential follow-up latencies. Under such conditions, a rapid follow-up response is more likely to produce the same discriminative stimulus than the other one, and this consistency could provide a basis for the differential reinforcement of follow-ups. Differential latencies seem unlikely to develop if the components are very short (e.g., 1 s) or if they change randomly, such that at any second the probability that either stimulus would be produced is .50. The range of component durations likely to reveal differential follow-up latencies, however, might be rather wide (see Branch, 1973).

The use of VI schedules may have also been important for our results. On VI schedules, the probability of reinforcement assignment increases as a function of elapsed time without a response. Then once a response is made, the likelihood of a reinforcement assignment immediately drops. Consequently, a response on the VI may come to signal a brief period of reduced likelihood of reinforcement, which could decrease the competition between the response that is maintained by the VI schedule and the follow-up observing response. This would not be the case, for example, under a fixed-ratio schedule in which each food-producing response increases the likelihood of reinforcement. Thus, it is not surprising that when schedules of reinforcement compete with observing, observing responses tend to occur once and then not again until primary reinforcement has been delivered (Kendall & Gibson, 1965).

The rates of observing in the S+/S− condition relative to those in the S+ only, S− only, mixed-stimulus only, and standard multiple-schedule conditions replicate a variety of important findings in the observing literature. Consistent with a large body of evidence, primarily from studies using pigeons as subjects, observing occurred at a higher rate when it produced both S+ and S− or only S+ than when S− was the only outcome of observing (see Allen & Lattal, 1989; Auge, 1974; Bowe & Green, 1988; Dinsmoor et al., 1972; Jwaideh & Mulvaney, 1976; Mueller & Dinsmoor, 1986; Preston, 1985). In addition, when observing responses were unnecessary or failed to produce stimuli correlated with the prevailing schedules of reinforcement, the rate of observing decreased (see Auge, 1973b; Bowe & Green, 1988). Thus, these data are consistent with conditioned reinforcement interpretations of observing, which suggest that contact with S+ is critical to maintaining observing (Dinsmoor, 1983; Fantino, 1977). That we were able to replicate such a wide array of previous findings regarding observing makes it unlikely that our results on selective observing are due to some idiosyncratic feature of the present procedure.

The nature of the present findings contributes to the body of evidence against several potential alternative interpretations of observing. The present data are not easily interpretable in terms of the information (uncertainty-reduction) hypothesis (Hendry, 1969, 1983), which suggests that observing behavior is reinforced by the information value (uncertainty reduction) the stimulus provides about the availability of primary reinforcement. The information hypothesis could adequately account for the decrease in observing rate in the mixed only and standard multiple-schedule conditions, in which ob-

Table 5

Number of responses per reinforcer across the last five sessions of the four S+/S− conditions (arranged vertically from first to last for each rat), calculated by dividing response rate (from Table 4) by reinforcement rate (from Table 3). Empty cells are from conditions in which no reinforcers were received in the presence of the S−, resulting in a denominator of zero.

Rat	S+	S−	Total S+/ S−	Mix
2	99.91	264.21	126.13	66.32
	105.41	275.73	139.91	60.61
	76.28	294.12	106.41	50.91
	94.54	177.63	114.85	59.55
5	17.75	36.35	18.57	10.17
	19.96	21.62	20.07	6.46
	17.57	21.96	17.85	7.66
	14.04		15.11	6.30
9	98.18	633.38	120.48	54.43
	70.97	140.21	80.86	83.52
	73.93	219.89	87.70	53.01
	73.33	136.68	81.33	45.68
11	43.96		48.25	22.31
	49.34		53.85	
	42.13		45.19	
	26.67		27.45	

serving provided no added information. However, the differential responding in the S+ only and S− only conditions, and the differential latencies to reinitiate contact with S+ and S−, cannot be accounted for based on the assumption that S+ and S− are both similarly reinforcing.

One could argue, however, that although maintaining S− might be aversive, the onset of S− is reinforcing because the onset provides sufficient information for the organism to allocate its behavior efficiently (Davis, 1983; Hendry, 1983; Thompson & Wilcox, 1983). This argument suggests that the differential follow-up responses to S+ and S− noted in the present experiment were maintained by enhanced efficiency—obtaining the most reinforcement for the least response cost. One index of efficiency is the number of responses per reinforcer. Table 5 shows the number of responses per reinforcer for the 4 rats during the four S+/S− conditions. In all cases but one (15 of 16), performance was less efficient while the lights were on than while the lights were off (i.e., while the mixed stimulus was present on the key). Thus, the results do not appear to be consistent with explanations that emphasize increased efficiency. They are, however, entirely consistent with an interpretation based on conditioned reinforcement (Dinsmoor, 1983; Fantino, 1977).

It might also be argued that observing was maintained as the result of an adventitious contingency between the lever press and subsequent food reinforcement (obtained via key poking). In previous studies, brief changeover delays (of several seconds) have been imposed between the initiation of an observing response and the delivery of scheduled food reinforcement. Such delays are most appropriate when stimulus presentations are long (e.g., 30 s), but were not used in the present procedure given the relatively short (5-s) stimulus presentations. Shorter stimulus presentations were used to allow increased sensitivity in detecting differential follow-up observing responses. Despite the lack of a changeover delay, an interpretation in terms of a superstitious contingency does not seem plausible. The systematic differences in observing across conditions (especially those in which the relation between lever presses and key-poke-produced food was maintained, but the relation between lever presses and stimulus presentations was discontinued) and the differential rates of key poking demonstrate sensitivity to the stimulus produced.

One might still suggest that due to the differential rates of reinforcement, an adventitious contingency between observing and food reinforcement could account for selective observing. Arguing against such an interpretation is that during the experimenter-controlled procedure, unlike during the subject-controlled procedure, there is no necessity that observing responses (i.e., lever presses) and food-producing responses (i.e., key pokes) be conjoined. In fact, it was physically impossible for the rats to make the two responses simultaneously, such that there was a built-in, albeit short, changeover delay. Furthermore, when observing responses were made redundant by presenting the component stimulus on the key, both S+ and S− observing responses decreased, despite the fact that any developed superstitious chain between lever presses and food-reinforced key pokes would not be disrupted. Thus, the pattern of observing reported appears to be the result of its conditioned reinforcing effects rather than adventitious primary reinforcement.

The generality of selective observing to conditions in which the stimuli are not visual remains to be thoroughly tested. For instance, auditory stimuli present a challenge because peripheral adjustments cannot easily terminate an auditory signal (Badia et al., 1981). However, follow-up observing responses to auditory stimuli could be assessed readily using the experimenter-controlled procedure. The experimenter-controlled procedure may also be useful for studying the relation between observing and other stimulus control phenomena, such as resistance to change. A robust finding is that multiple-schedule performance is more resistant to disruption (e.g., extinction) in the component that provided the greater rate of baseline reinforcement (Nevin & Grace, 2000). One notable exception to this robust conclusion occurs when auditory stimuli are used (Mauro & Mace, 1996). Because it appears to be intuitively easier to selectively attend to visual stimuli than to auditory stimuli, these results suggest a potential role for differential observing or attending in producing differential resistance to change.

In conclusion, by tracking the latency of follow-up observing responses during an experimenter-controlled procedure, the present investigation revealed a pattern of subject-generated differential observing controlled by the previously contacted stimulus. Consistent with previous interpretations of the mechanism that results in selective observing (see Dinsmoor, 1983), production of S+ was more likely to result in a rapid follow-up observing response, whereas production of S− was more likely to result in a prolonged disengagement from observing. This pattern of observing supports conditioned reinforcement interpretations of the maintenance of observing (Dinsmoor, 1983; Fantino, 1977, 2001).

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