

*OBSERVING BEHAVIOR: EFFECTS OF RATE AND  
MAGNITUDE OF PRIMARY REINFORCEMENT*

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Four experiments examined the free-operant observing behavior of rats. In Experiment 1, observing was a bitonic function of random-ratio schedule requirements for the primary reinforcer. In Experiment 2, decreases in the magnitude of the primary reinforcer decreased observing. Experiment 3 examined observing when a random-ratio schedule or a yoked random-time schedule of primary reinforcement was in effect across conditions. Removing the response requirement for the primary reinforcer increased observing, suggesting that the effects of the random-ratio schedule in Experiment 1 likely were due to an interaction between observing and responding for the primary reinforcer. In Experiment 4, decreasing the rate of primary reinforcement by increasing the duration of a random-time schedule decreased observing monotonically. Overall, these results suggest that observing decreases with decreases in the rate or magnitude of the primary reinforcer, but that behavior related to the primary reinforcer can affect observing and potentially affect measurement of conditioned reinforcing value.

*Key words:* observing, conditioned reinforcement, reinforcement rate, reinforcement magnitude, lever press, rats

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Observing responses produce discriminative stimuli associated with the conditions of availability of primary reinforcement, but do not alter the availability of primary reinforcement (Wyckoff, 1952). In the most common experimental arrangement, observing responses produce one stimulus (S+) if primary reinforcement is available on some schedule and a different stimulus (S-) if extinction is in effect (i.e., a multiple schedule of reinforcement). In the absence of observing responses, a third stimulus is present regardless of the schedule in effect for primary reinforcement (i.e., a mixed schedule of reinforcement). Much of the experimental analysis of observing has focused on the role of information in the maintenance of observing behavior (e.g., Dinsmoor, Browne, & Lawrence, 1972; Lieberman, 1972; McMillan, 1974; Perone & Baron, 1980; Wilton & Clements, 1971). Relatively little is known, however, about how basic parameters of the primary reinforcer affect observing. Under-

standing the effects of basic parameters of the primary reinforcement on observing is important because the observing-response procedure avoids well-known difficulties associated with studying conditioned reinforcement with extinction-based procedures, second-order schedules, and chained schedules of reinforcement (see Branch, 1983; Dinsmoor, 1983; Williams, 1994).

Only two studies have systematically examined the effects of rate of primary reinforcement on observing, and these studies provide conflicting data. Lieberman (1972) examined the effects of variable-ratio (VR) 5 to VR 100 schedules of sucrose delivery on the observing behavior of monkeys. Observing was a negatively accelerated *increasing* function of VR schedule requirement for sucrose. In contrast, Branch (1973) found that observing of pigeons was little affected by increases in random-ratio (RR) schedules of food delivery between RR 50 to RR 200, but decreased somewhat at RR 400. One difference between these studies was that Lieberman used primates as subjects, and Branch used pigeons. On the other hand, both studies showed that observing was relatively insensitive to ratio values between 50 and 100, whereas only Lieberman examined ratios less than 50 and only Branch examined ratios above 100. Thus, Branch and Lieberman may have each examined half of a bitonic function relating observing to response requirement for the

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This research was supported by USPHS Grant AA12892 from the National Institute on Alcohol Abuse and Alcoholism. I thank Amy Odum for her many contributions to this work, Curt Mower for his comments, and Jessica Doucette, David Savastano, Tom Murphy, and Jessica Milo for their help in conducting this research.

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primary reinforcer. The present Experiment 1 examined the relation between rate of primary reinforcement and observing in procedures similar to those of Lieberman and Branch by varying the RR schedule requirement for food across a wide range.

The relation between magnitude of the primary reinforcer and observing also has not been well characterized. The majority of experiments on this topic (Daly, 1985; Levis & Perkins, 1965; Mitchell, Perkins, & Perkins, 1965) have used the discrete-trials E-maze observing procedure (Prokasy, 1956) and have examined only a limited range of primary reinforcer magnitudes. In general, these studies have found that reinforcer magnitudes described as small (e.g., one food pellet, 0.4 cc water) appear to produce no preference for outcome-correlated stimuli, whereas larger reinforcer magnitudes (e.g., 5, 15, or 25 food pellets, 2 cc water) do produce preference for outcome-correlated stimuli. The data of Mitchell et al. appear to show faster acquisition of observing for a group of rats that received 25 food pellets than for a group that received 5 food pellets; however, this difference was not apparent at the end of training when observing was near asymptotic levels. Also, using a number of variations on the typical free-operant observing procedure, Case and Fantino (1989) found that changes in the monetary value of points had no systematic effect on the observing behavior of humans. The present Experiment 2 varied the concentration of a sucrose solution across a wide range to more fully characterize the relation between magnitude of the primary reinforcer and observing. Experiments 3 and 4 explored the role of the response requirement for the primary reinforcer in producing differences in results obtained by varying reinforcement rate (Experiment 1) and magnitude (Experiment 2) of the primary reinforcer.

### EXPERIMENT 1

This experiment examined the effects of varying the response requirement for the primary reinforcer on the observing behavior of rats. Response requirement was manipulated across conditions by increasing the value of an RR schedule of food delivery in the free-operant observing procedure.

## METHOD

### *Subjects*

Four male Long-Evans rats maintained at 80% of their adult free-feeding weights and obtained from Charles River (Portage, MI) were used. The rats were approximately 120 days old at the beginning of the experiment and were experimentally naive. The rats were housed individually in a temperature-controlled colony with a 12:12 hr light/dark cycle (lights on 6:00 a.m.) and had free access to water.

### *Apparatus*

Four identical Coulbourn modular operant chambers were used. Each chamber was approximately 29 cm long, 24 cm wide, and 29 cm high, and was housed in a sound-attenuating enclosure. The chambers were equipped with two response levers centered 13 cm apart on the front wall and 6.5 cm above the grid floor. A series of three 28-V DC lamps positioned above each lever was lit when that lever was active. Each chamber also contained a 28-V DC houselight at the top center of the front panel and a Sonalert (2900  $\pm$  500 Hz, 75 to 85 dB) connected in series to a 4.7-k $\Omega$  resistor. A rectangular opening (6.5 cm wide by 4.2 cm high) that was vertically divided in half provided access to delivered reinforcers and was centered on the front wall between the levers with its bottom edge 2 cm above the grid floor. The right side of the opening provided access to Noyes pellets (45 mg Formula A/I) delivered through a tube. Pellet deliveries were accompanied by an audible click, a 45-ms flash of a 28-V DC light inside the opening, and the darkening of the lever lights. A ventilation fan and white noise masked extraneous sounds. Control of experimental events and data recording were conducted with Med Associates interfacing and programming.

### *Procedure*

Following magazine training, pressing the right lever was hand shaped in the first session for each rat. During approximately the next three to four sessions, the response requirement on the right lever was gradually increased from a fixed-ratio (FR) 1 schedule to an FR 12 schedule of reinforcement. In the next session, an RR 5 schedule of reinforce-

Table 1

Order of conditions and number of sessions per condition in Experiment 1. Numbers in parentheses refer to the order in which conditions were presented.

| Condition | Rat           |               |               |               |
|-----------|---------------|---------------|---------------|---------------|
|           | R1            | R2            | R3            | R4            |
| RR 10     | 47 (8)        | 41 (8)        | 29 (8)        |               |
| RR 15     | 41 (7)        |               | 34 (7)        | 50 (7)        |
| RR 25     | 30, 48 (1, 6) | 54, 38 (1, 7) | 39, 18 (1, 6) | 49, 40 (1, 6) |
| RR 50     | 33 (2)        | 35 (2)        | 24 (2)        | 33 (2)        |
| RR 100    | 20, 32 (3, 9) | 20, 33 (3, 6) | 44, 55 (3, 5) | 24 (3)        |
| RR 150    | 20 (4)        | 32 (4)        | 20 (4)        | 17 (4)        |
| RR 200    | 22 (5)        | 53 (5)        |               | 55 (5)        |

ment was introduced. The value of the RR schedule was gradually increased during the next four or five sessions to RR 50. The light over the right lever was on during these and all subsequent sessions.

Next, a multiple RR 50 extinction schedule was introduced. Extinction components were associated with a constant houselight and constant tone (S-), and RR components were associated with a houselight and tone alternating between 0.5 s on and 0.5 s off (S+). In the first 12 sessions of exposure to the multiple schedule, the average duration of the RR component was 60 s (range, 10 to 110 s), and the average duration of the extinction component was 20 s (range, 10 to 30 s). On the 13th session of multiple-schedule training, the duration of the extinction component was increased to an average of 60 s (range, 10 to 110 s). The durations of RR and extinction components were randomly selected without replacement from separate lists of values constructed according to arithmetic series. On the 17th session, the RR schedule was decreased to RR 25 and sessions continued for 80 reinforcers or 45 min, whichever occurred first. Ten sessions later the observing-response procedure was introduced, the lights over the left lever (observing lever) were turned on, and sessions terminated after 40 min.

In the observing-response procedure, an RR 25 schedule alternated with extinction on a mixed schedule of reinforcement with 60-s average-duration components programmed as described above. In the presence of both the RR schedule and extinction, the houselight and the tone were off (mixed-schedule stimulus). Following a single observing response (a press on the left lever), the stimuli

correlated with the available schedule (either RR 25 or extinction) were presented for 15 s. Further responses to the observing lever during the 15-s stimulus presentation had no effect. Alternations of the RR 25 and extinction schedules occurring during 15-s stimulus presentations were accompanied by the appropriate change in stimulus conditions.

The value of the RR schedule for food was then increased to 50, 100, 150, and 200 across conditions. Following a replication of RR 100 for 2 rats and return to RR 25 for all rats, each rat was exposed to either one or two additional RR schedule values (15 or 10). Each condition was in effect for a minimum of 15 sessions and until the number of 15-s schedule-correlated stimuli per session and response rates on the food lever appeared to be stable (no consistent trend or excessive variability) across 10 sessions, as judged visually. Table 1 presents the order of conditions and number of sessions per condition for each rat. For Rat R1, the RR 200 condition was terminated before stability because responding dropped precipitously to near zero in the final two sessions. Similarly, for Rat R3, the RR 150 condition was terminated before stability, and the RR 200 condition was omitted.

## RESULTS

Figure 1 shows the percentage of the session spent in the presence of the schedule-correlated stimuli in the last six sessions of each condition. In addition, the percentage of each session spent in the presence of the stimulus correlated with the RR schedule (S+) and the stimulus associated with extinction (S-) are presented. Data for this and all subsequent figures are averages across the last

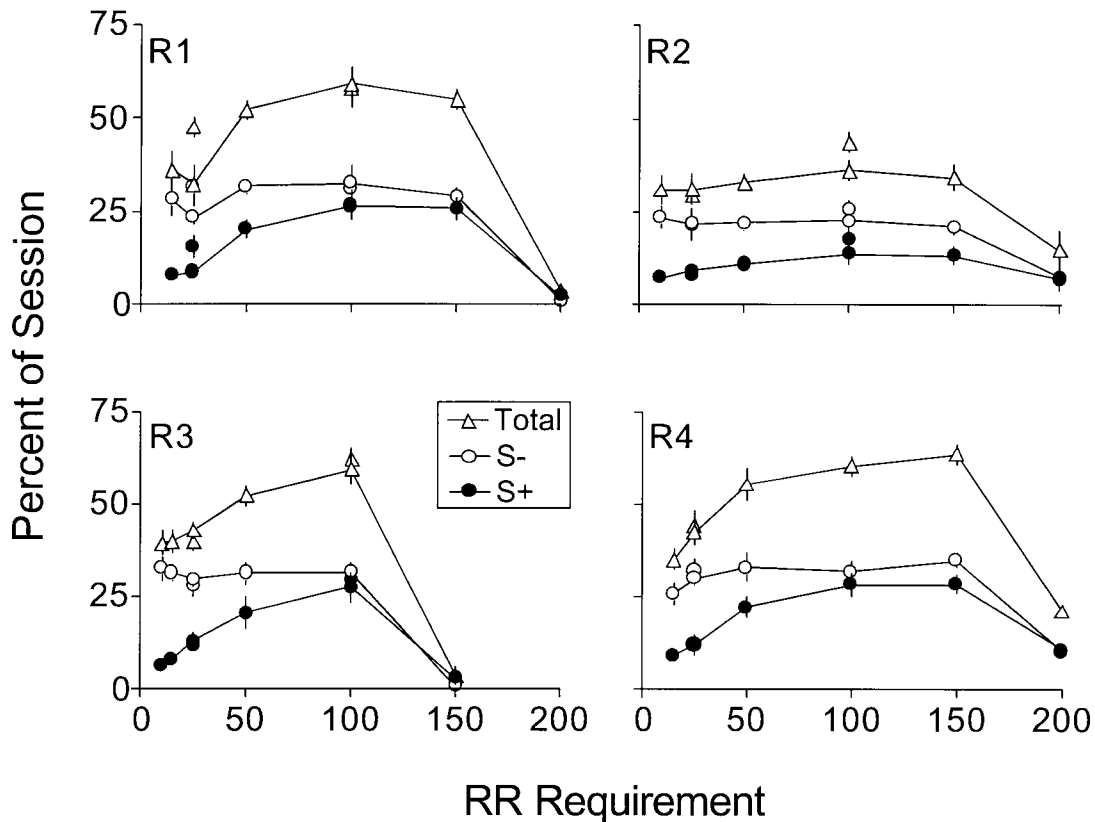


Fig. 1. Percentage of the session spent in the presence of the schedule-correlated stimuli (total) as a function of the RR response requirement for food pellets. Data are also presented separately for the percentage of the session spent in the presence of S+ and S-. Data points connected by lines are from the first exposure to each condition. Data points not connected by lines are from replications. Data are means for the last six sessions of each condition. Error bars represent  $\pm 1$  SD.

six sessions of each condition (see captions for details). For all 4 rats, the percentage of time spent in the presence of the schedule-correlated stimuli increased with increases in the RR schedule requirement through approximately RR 100 and then decreased (i.e., the function was bitonic). Most of the increases in total percentage of time spent in the schedule-correlated stimuli resulted from increases in time spent in the presence of S+.

Figure 2 shows the median latency between the offset of either S+ or S- and the next observing response (i.e., follow-up latencies; Gaynor & Shull, 2002). For each rat, follow-up latencies for observing responses preceded by the termination of S+ were considerably longer than those preceded by the termination of S-, especially at lower RR requirements. Follow-up latencies after S+ decreased with increases in the RR response re-

quirement, but latencies following S- were not affected systematically by the RR value. Follow-up latencies increased substantially for Rats R1 and R3 at the highest RR value, but these latencies were based on very few observing responses in a session and should be interpreted with caution.

Figure 3 shows mean response rates on the food lever during the RR and extinction components in the presence of the multiple-schedule and mixed-schedule stimuli. Response rates during the RR schedule generally increased and then decreased with increases in the response requirement in the presence of both S+ and the mixed schedule stimulus. The similar response rates during the RR component in the presence of S+ and the mixed stimulus suggest that there was some discriminative control by pellet deliveries. Response rates during extinction in the

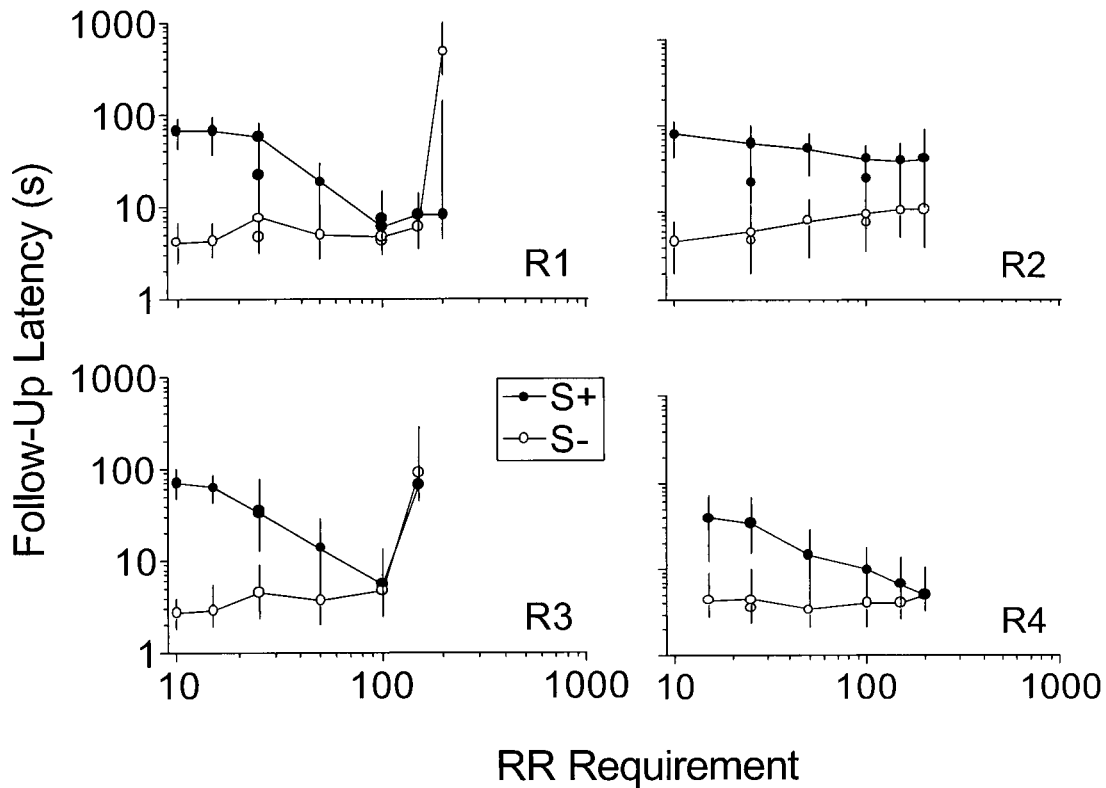


Fig. 2. Observing-response follow-up latencies after the termination of S+ and S- as a function of the RR schedule value. Data are medians for the last six sessions of each condition. Error bars extend to the 25th and 75th percentiles. Both axes are logarithmic. Data points not connected by lines are from replications.

presence of S- were low across the entire range of response requirements. Response rates in extinction in the presence of the mixed-schedule stimulus were higher at low response requirements and decreased with increases in response requirement.

#### DISCUSSION

The present results show that observing behavior is a bitonic function of increases in the response requirement for the primary reinforcer. These results suggest that the different results obtained by Lieberman (1972) with monkeys and Branch (1973) with pigeons are not necessarily due to a species difference, but rather likely reflect the different ranges of response requirements examined in the two studies. Unfortunately, the possibility of a species difference cannot be entirely ruled out by the present data because rats were used as subjects. Although unlikely, it is possible that the function is not bitonic with pigeons or monkeys. Nonetheless, the increas-

ing limb of the function relating observing and response requirement for the primary reinforcer obtained here is somewhat anomalous in the context of the well-established finding that, all else being equal, conditioned reinforcement value decreases with decreases in rate of primary reinforcement (e.g., Herrnstein, 1964). The longer follow-up latencies after presentations of S+ suggest that increases in observing with increases in the RR requirement for food may be due to an interaction between observing and behavior related to the primary reinforcer. The potential role of such competition in the present results will be explored further in Experiments 3 and 4.

#### EXPERIMENT 2

This experiment examined the effects of a range of magnitudes of the primary reinforcer on the observing behavior of rats. Reinforcement magnitude was varied across con-

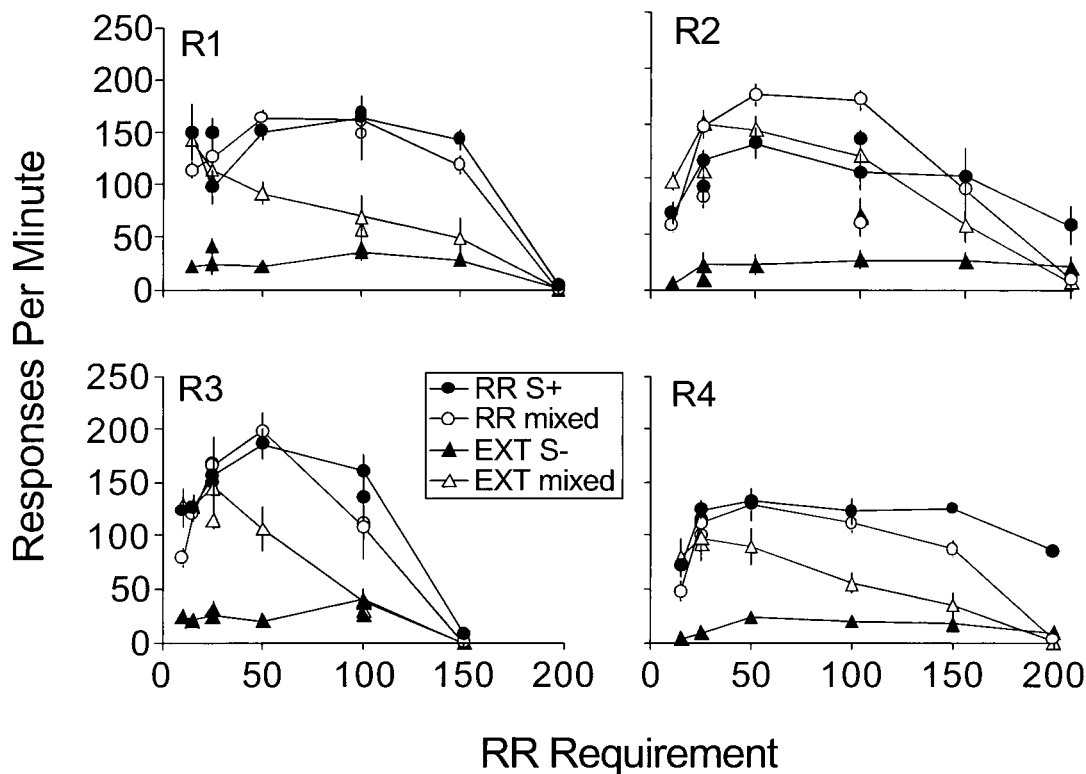


Fig. 3. Response rates as a function of the RR response requirement when the RR schedule or extinction was in effect. Data are presented separately for periods when the multiple (RR S+ and EXT S-) or mixed (RR mixed and EXT mixed) schedules were in effect. Other details are as in Figure 1.

ditions by changing the concentration of a sucrose solution.

#### METHOD

##### Subjects

Four male Long-Evans rats maintained at 80% of their adult free-feeding weights and obtained from Charles River (Portage, MI) were used. The rats were approximately 180 days old at the beginning of the experiment and had participated in an experiment in which they responded on a random-interval 30-s schedule of reinforcement for approximately 30 days. Rats R9 and R11 had received eight 1 mg/kg doses of *d*-amphetamine, and Rats R10 and R12 had received one 1 mg/kg dose of *d*-amphetamine in the previous experiment. Training for the present experiment started approximately 25 days after the last injection of drug. The rats were housed and cared for as described in Experiment 1.

##### Apparatus

The apparatus was that described in Experiment 1 except that the reinforcer was 3-s access to sucrose solution. The left side of the magazine opening provided access to 0.1 ml of fluid delivered by a solenoid-operated dipper. Dipper deliveries were accompanied by an audible click, the lighting of a 28-V DC light inside the opening, and the darkening of the lever lights. Sucrose solutions were prepared as percentage weight per volume from distilled water and table sugar.

##### Procedure

On the 1st day of training, the light above the right lever was lit and responses were reinforced with an 18% sucrose solution on an FR schedule that was gradually increased throughout the session (FR 1 through FR 7). Across the next three sessions, an RR schedule and its correlated stimulus (S+; house-light and tone alternating between on and off

Table 2

Order of conditions and number of sessions per condition in Experiment 2. Numbers in parentheses refer to the order in which conditions were presented.

| Condition | Rat           |               |               |               |
|-----------|---------------|---------------|---------------|---------------|
|           | R9            | R10           | R11           | R12           |
| 32.0%     |               | 32 (7)        |               | 50 (7)        |
| 25.0%     | 23 (7)        | 21 (6)        | 47 (6)        | 47 (6)        |
| 18.0%     | 43, 30 (1, 6) | 62, 21 (1, 5) | 52 (1)        | 54, 27 (1, 5) |
| 9.3%      | 39, 21 (2, 5) | 15 (2)        | 25, 39 (2, 5) | 24 (2)        |
| 5.0%      | 49 (3)        | 65 (3)        | 64 (3)        | 37 (3)        |
| 3.0%      | 33 (8)        |               |               | 29 (8)        |
| 2.0%      | 63 (4)        | 51 (4)        | 44 (4)        | 24 (4)        |
| 1.5%      |               |               | 21 (7)        |               |

every 0.5 s) were introduced. The schedule of sucrose delivery was increased to RR 25 by the beginning of the fourth session. A multiple RR 25 extinction schedule was introduced on the sixth session. The extinction-correlated stimulus was a constant houselight and constant tone (S-). The duration of the RR component averaged 60 s (range, 10 to 110 s), and the extinction component increased from an average of 30 s to an average of 60 s (range, 10 to 110 s) across the next five or six sessions. The observing response procedure was introduced following six or seven sessions of training with the final multiple-schedule component durations. The observing-response procedure was arranged as in Experiment 1. The S+ continued to be present during 3-s dipper deliveries, and RR components scheduled to end during dipper deliveries were postponed until the end of the 3 s.

The concentration of the sucrose solution was varied across sessions. Each rat was exposed to at least six sucrose concentrations. All rats were exposed to sucrose concentrations of 25% (0.73 M), 18% (0.53 M), 9.3% (0.27 M), 5% (0.15 M), and 2% (0.06 M). In addition, some rats were exposed to one or more of the following sucrose concentrations: 1.5% (0.04 M), 3% (0.09 M), and 32% (0.94 M). The sucrose concentration decreased across conditions from 18% to as low as 1.5%, and at least one of these values was replicated before each rat was exposed to at least one higher concentration. Table 2 shows the order of conditions and number of sessions in each condition for each rat. Stability was determined as in Experiment 1. Sessions were 40 min long.

## RESULTS

Figure 4 shows the percentage of the session spent in the presence of the schedule-correlated stimuli. The data are presented as in Figure 1. The percentage of the session spent in the presence of schedule-correlated stimuli increased with increases in the concentration of sucrose and reached asymptotic levels near a concentration of 9.3%. Although observing decreased somewhat at the highest concentration for Rat R11, there was no consistent evidence of a decrease in observing at the highest concentrations examined. Observing increased during both the RR (S+) and extinction (S-) components with increases in the concentration of sucrose, but the percentage of time spent in the presence of S- was consistently higher.

As shown in Figure 5, follow-up latencies after S+ terminations usually were longer than those after S- terminations across the range of sucrose concentrations. Latencies for each rat except R12 (for which no observing occurred at 2% sucrose) increased substantially at the lowest concentration. These values at the lowest sucrose concentration are based on a very limited number of observing responses and thus should be interpreted with caution.

Figure 6 shows response rates on the sucrose lever during the RR and extinction components in the presence of the multiple-schedule and mixed-schedule stimuli. Data are presented as in Figure 3, but time accrued during the 3-s dipper presentations was excluded from the calculations of response rate. Response rates during the RR component increased with increases in the concen-

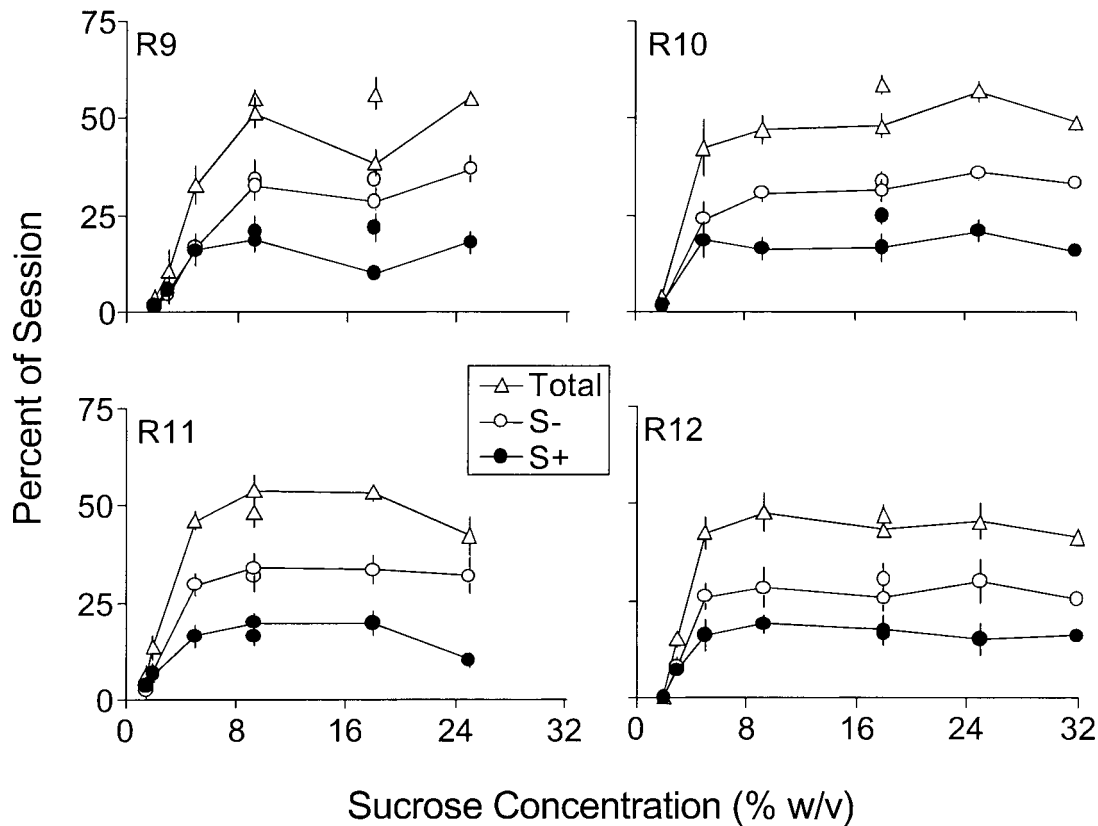


Fig. 4. Percentage of the session spent in the presence of schedule-correlated stimuli as a function of concentration of sucrose. Data are presented as in Figure 1.

tration of the sucrose solution in the presence of both S+ and the mixed-schedule stimulus. Response rates tended to be higher in the presence of S+ than in the presence of the mixed-schedule stimulus at the lowest sucrose concentrations. Response rates also increased in extinction during the mixed schedule with increases in the concentration of sucrose. Response rates in the presence of S- were usually low across all sucrose concentrations.

#### DISCUSSION

Observing was a negatively accelerated increasing function of increases in the magnitude of the primary reinforcer and showed little sign of decreasing at the highest reinforcer magnitudes examined here. Response rates on the primary reinforcement lever were a similar negatively accelerated increasing function of increases in magnitude of the primary reinforcer. Increases in observing

usually occurred at those reinforcement magnitudes that also increased response rates on the primary reinforcement lever. As in Experiment 1, observing-response follow-up latencies after presentations of S+ were longer than those after presentations of S-; however, these latencies were not affected systematically by magnitude of the primary reinforcer.

The present data are consistent with the vast majority of the data available on the effects of reinforcement magnitude on conditioned reinforcing value (e.g., Neuringer, 1967; Schwartz, 1969; see Nevin, 1973, for review). The different effects of magnitude (this experiment) and rate (Experiment 1) of primary reinforcement are inconsistent with previous findings from concurrent-chains procedures (Navarick & Fantino, 1976; Neuringer, 1967; Ten Eyck, 1970). The longer observing-response follow-up latencies after S+ presentations in both experiments suggest,



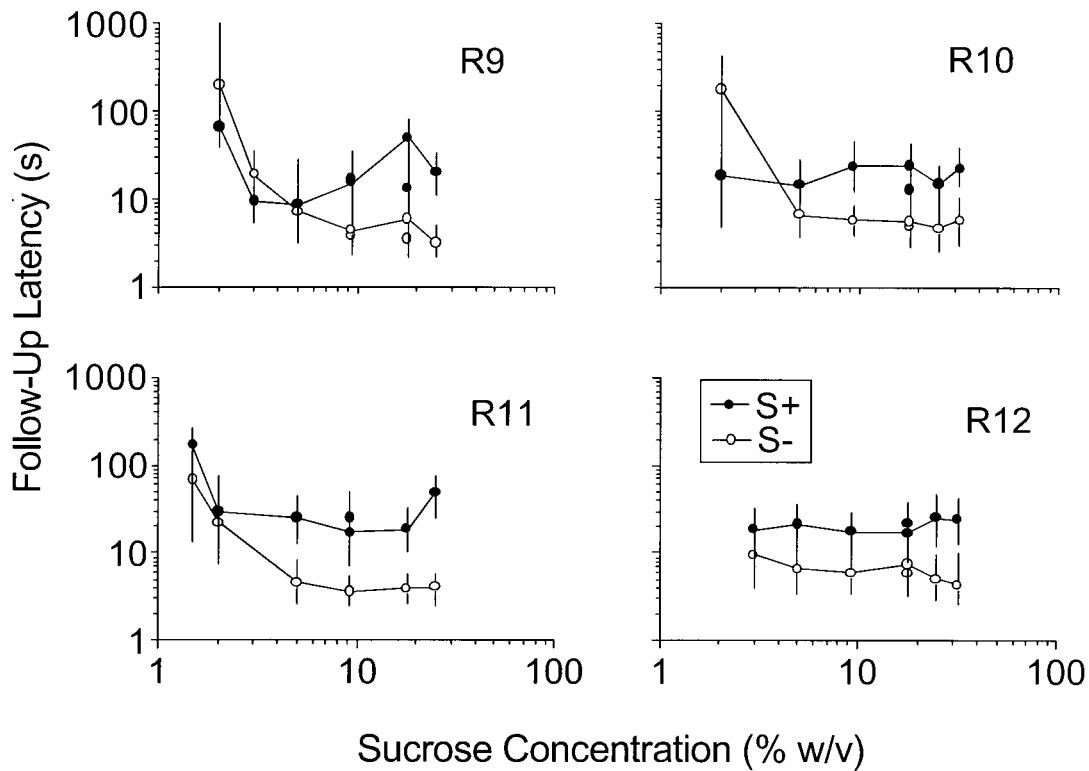


Fig. 5. Observing-response follow-up latencies after the termination of S+ and S- as a function of concentration of sucrose. Data are presented as in Figure 2.

however, that the RR schedules used in these experiments may produce competition between observing and behavior controlled by the RR schedule. That is, the longer follow-up latencies after S+ presentations may reflect the fact that the S+ presentations occasioned behavior appropriate to the primary reinforcer that interfered with observing. Others have previously noted that responding maintained by the primary reinforcer may interfere with observing (e.g., Kelleher, Riddle, & Cook, 1962; Kendall, 1965). If the increases in observing with decreases in reinforcement rate in Experiment 1 are due to some sort of interaction between responding controlled by the primary reinforcer and observing, then observing might be expected to increase when the response requirement for the primary reinforcer is removed.

### EXPERIMENT 3

This experiment examined the effects of removing the response requirement for the

primary reinforcer on the observing behavior of rats. Following Experiment 1, observing behavior of the rats from that experiment was compared when an RR schedule or a random-time (RT) schedule yoked from the average interreinforcer interval of the RR schedule was in effect. In another condition, a changeover delay (COD) between observing responses and RT schedule sucrose deliveries was imposed to verify that any increases in observing obtained with the yoked RT schedule were not due merely to the adventitious reinforcement of observing by response-independent primary reinforcer deliveries.

### METHOD

#### *Subjects and Apparatus*

The rats from Experiment 1 were used.

Four Coulbourn modular operant chambers (not those from Experiments 1 and 2) were used. Each chamber was approximately 29 cm long, 24 cm wide, 29 cm high, and was

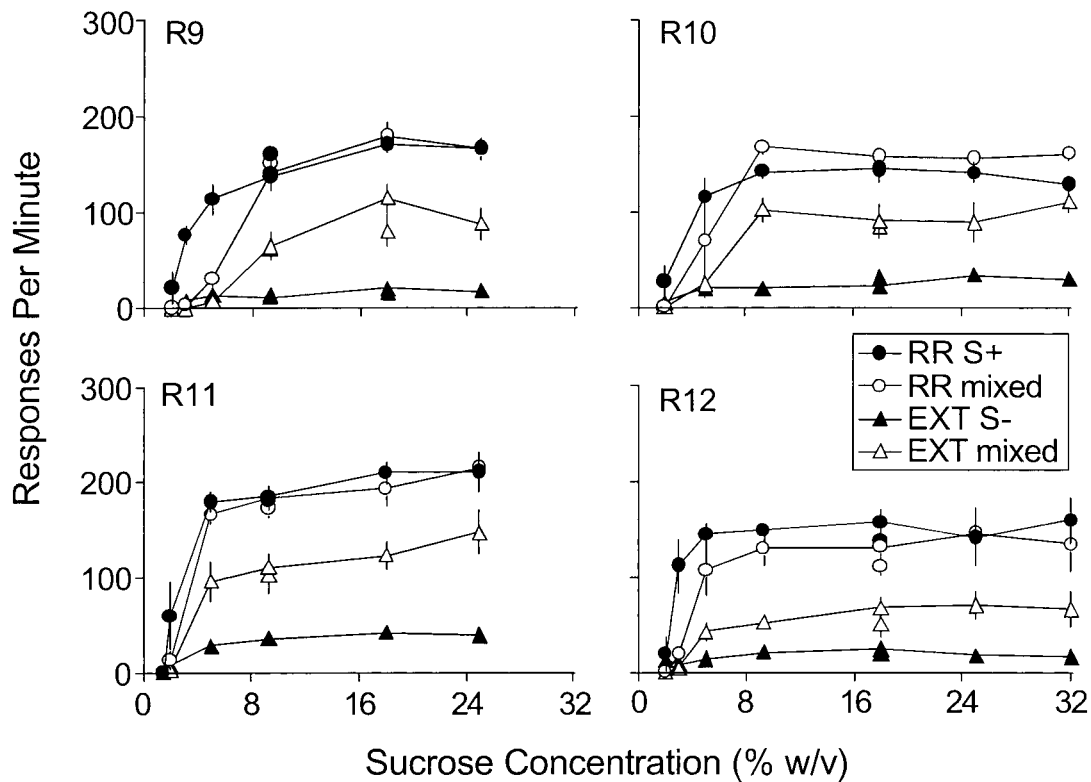


Fig. 6. Response rates as a function of the concentration of sucrose when the RR schedule or extinction was in effect. Data are presented as in Figure 3.

housed in a sound-attenuating enclosure. The chambers were equipped with two response levers centered 13 cm apart on the front wall of the chamber and 6.5 cm above the grid floor. The right lever of each chamber was retractable. A green light above each lever was lit when that lever was active. Each chamber also contained a 28-V DC houselight at the top center of the front panel and a Sonalert ( $2900 \pm 500$  Hz, 75 to 85 dB) connected in series to a 4.7-k $\Omega$  resistor. A rectangular opening (5.1 cm wide by 5.1 cm high) provided access to delivered reinforcers and was centered on the front wall between the levers with its bottom edge 2 cm above the grid floor. Noyes pellets (45 mg Formula A/I) were delivered into a circular metal dish (3 cm diameter) located inside the rectangular opening. Pellet deliveries were accompanied by an audible click, a 45-ms flash of a 28-V DC light inside the opening, and the darkening of the lever lights. A ventilation fan and white noise masked extraneous sounds. Control of experimental events

and data recording were conducted with Med Associates interfacing and programming.

#### Procedure

Training started after Experiment 1 ended. All rats were exposed immediately to the observing-response procedure in the new experimental chambers with all details as described in Experiment 1. The schedule of reinforcement on the primary reinforcement lever increased from RR 10 through RR 100 within and across four daily sessions for Rats R1 and R2. Rats R3 and R4 were exposed to an RR 10 schedule of primary reinforcement for approximately four sessions and were then placed on an RR 15 schedule.

Following stability in observing behavior with the RR schedule in effect, an RT schedule replaced the RR schedule. The RT schedule was yoked from the mean time taken to complete the response requirement in the last six sessions of exposure to the RR schedule. The RT schedule was arranged by sampling a probability gate every 0.75 s with the

Table 3

Order of conditions and number of sessions per condition in Experiment 3.

| Rat | Condition           | Sessions |
|-----|---------------------|----------|
| R1  | RR 100              | 62       |
|     | RT 45.8 s (no COD)  | 44       |
|     | RT 45.8 s (2-s COD) | 21       |
| R2  | RR 100              | 35       |
|     | RR 100              | 31       |
|     | RT 70.5 s (2-s COD) | 35       |
| R3  | RT 70.5 s (no COD)  | 39       |
|     | RR 100              | 26       |
|     | RR 15               | 48       |
| R4  | RT 7.9 s (no COD)   | 16       |
|     | RT 7.9 s (2-s COD)  | 15       |
|     | RR 15               | 28       |
| R4  | RR 15               | 31       |
|     | RT 18.0 s (2-s OD)  | 29       |
|     | RT 18.0 s (no COD)  | 39       |
|     | RR 15               | 15       |

probability of a food pellet fixed at a value appropriate to the desired average interreinforcer interval. In the RT conditions, the right lever was retracted for the duration of the session and pellets were delivered independently of responding. A 2-s COD was programmed for Rats R2 and R4 such that responses on the observing lever prevented the delivery of any scheduled RT food pellets for 2 s. No COD was programmed for Rats R1 and R3. Following stability in this condition, a 2-s COD was implemented for Rats R1 and R3, and the COD was removed for Rats R2 and R4. Next, the RR schedule arranged in the initial condition was reinstated. The order of conditions, the number of sessions in each condition, and the value of the yoked RT schedule for each rat are shown in Table 3. Stability was determined by visual inspection of the number of 15-s schedule-correlated stimuli earned per session.

### RESULTS

Figure 7 shows the percentage of the session spent in the presence of the schedule-correlated stimuli. Data are also presented separately for time spent in the presence of S<sup>-</sup> and S<sup>+</sup>. The total time spent in the presence of the schedule-correlated stimuli increased for all rats when the RT yoked from the previous RR schedule was in effect and then decreased when the RR schedule was reintroduced. This effect was least apparent for Rat R1, for which observing was relatively

high in the RR conditions. Increases in the total time spent in the presence of schedule-correlated stimuli resulted from increases in both the percentage of time spent in S<sup>+</sup> and S<sup>-</sup>. The presence or absence of the COD had no large or systematic effect on observing.

Figure 8 shows follow-up latencies for observing responses after presentations of S<sup>+</sup> and S<sup>-</sup>. Follow-up latencies after S<sup>+</sup> terminations decreased when the response requirement for the primary reinforcer was removed for Rats R2, R3, and R4. For these rats, follow-up latencies were similar following S<sup>+</sup> and S<sup>-</sup> presentations in both RT conditions, but S<sup>+</sup> latencies were consistently marginally higher. For Rat R1, follow-up latencies were short and similar following S<sup>+</sup> and S<sup>-</sup> presentations across all conditions. The presence or absence of the COD did not systematically affect follow-up latencies.

### DISCUSSION

Removing the response requirement for the primary reinforcer increased observing under conditions in which the average interreinforcer interval for the primary reinforcer was held constant. The presence or absence of a COD between presses on the observing lever and RT schedule food deliveries had no systematic effect on observing. Thus, it is unlikely that the increase in observing was due to the adventitious reinforcement of pressing the observing lever by the response-independent deliveries of food. Removing the response requirement for the primary reinforcer also eliminated the long observing-response follow-up latencies that occurred following S<sup>+</sup> presentations in the RR conditions.

In previous experiments, removal of the response requirement had little or no effect on the observing of pigeons (Dinsmoor, Bowe, Green, & Hanson, 1988) or baboons (Steiner, 1967). The reason for the differences between the present experiment and these previous experiments is unclear, but it is worth noting that both of the previous experiments used interval schedules of primary reinforcement. Regardless, the present findings suggest that the increases in observing with increases in RR schedule response requirement in Experiment 1 may be due to competition between observing and behavior maintained by the primary reinforcer. Given that the function relating observing to rate of primary

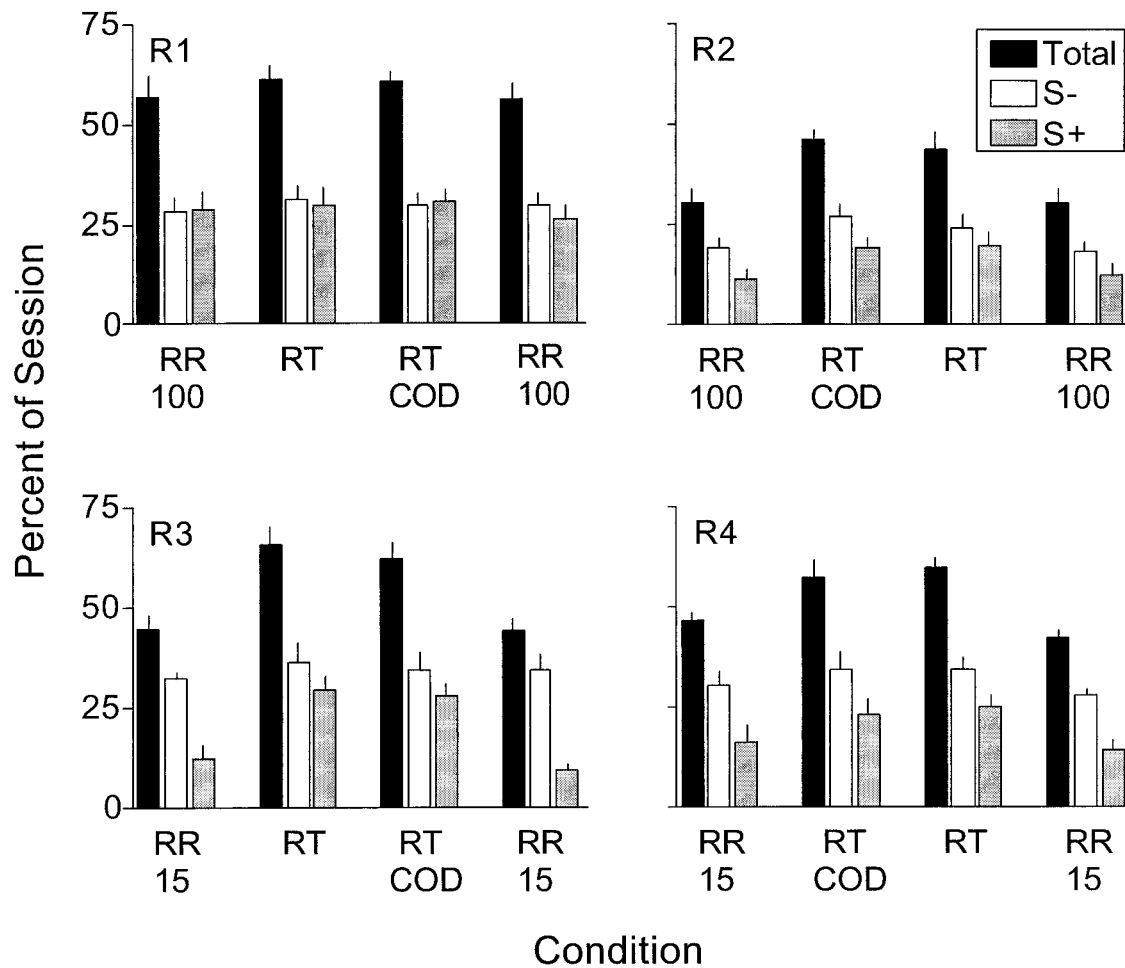


Fig. 7. Percentage of the session spent in the presence of the schedule-correlated stimuli in conditions in which an RR schedule or a yoked RT schedule was in effect. RT COD refers to conditions in which a 2-s COD was arranged following responses on the observing lever. Data are means for the last six sessions of each condition. Error bars represent  $\pm 1$  SD.

reinforcement was apparently influenced by this competition, the effects of rate of primary reinforcement on observing were examined by varying the rate of response-independent primary reinforcement.

#### EXPERIMENT 4

This experiment examined the effects of varying the rate of response-independent deliveries of sucrose on the observing behavior of rats. In a free-operant observing-response procedure similar to those in Experiments 1 through 3, a 10% sucrose solution was delivered on an RT schedule of reinforcement.

The duration of the RT schedule was varied across conditions.

#### METHOD

##### *Subjects and Apparatus*

The rats were those used in Experiment 2. The apparatus was that used in Experiment 3. Unlike Experiment 3, a sucrose solution was delivered into the metal cup (2 cm diameter) by the 1.1-s activation of a syringe pump. A 3-s lighting of a 28-V DC light inside the magazine opening and the darkening of the lever lights accompanied sucrose deliveries.

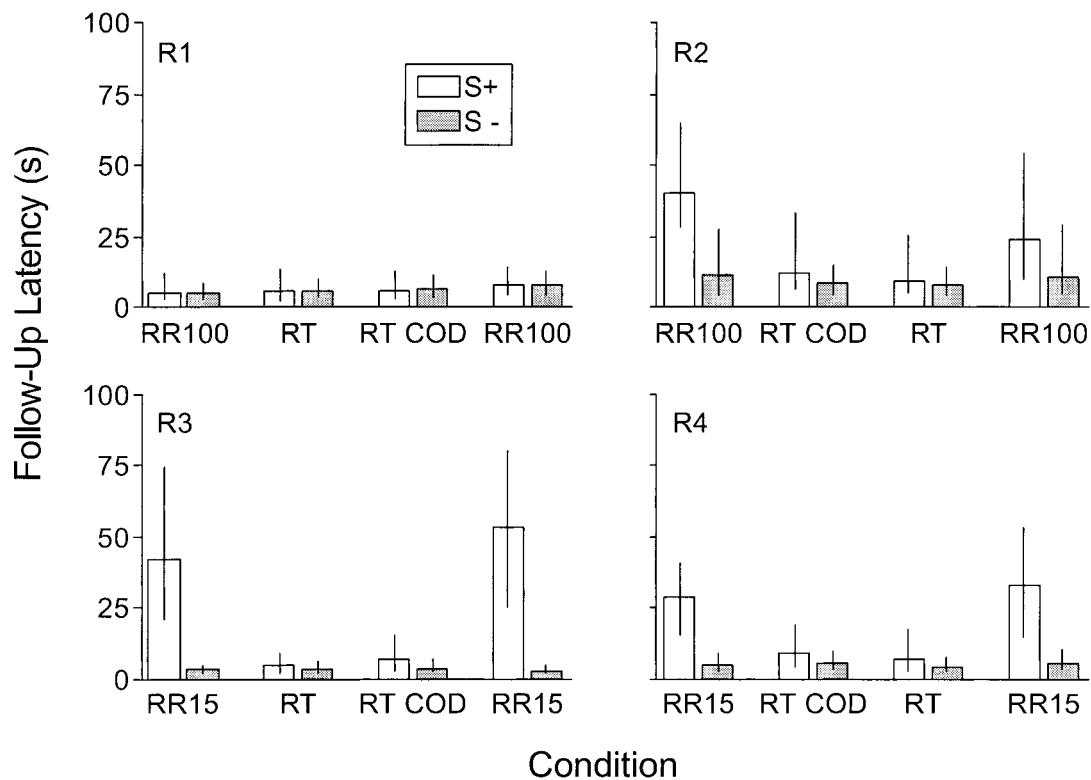


Fig. 8. Observing-response follow-up latencies after the termination of S+ and S- in conditions in which an RR schedule or a yoked RT schedule was in effect. RT COD refers to conditions in which a 2-s COD was arranged following responses on the observing lever. Data are medians for the last six sessions of each condition. Error bars extend to the 25th and 75th percentiles.

#### Procedure

Training started immediately after Experiment 2 ended. All rats were exposed immediately to the observing-response procedure in the new experimental chambers. Details of the operation of the observing-response procedure were the same as described in Experiment 1, with the following modifications. The primary reinforcer was a 0.1-ml delivery of a 10% sucrose solution. The right lever was retracted at all times and the 10% sucrose solution was delivered on an RT schedule of reinforcement. Intervals in the RT schedule were arranged as described in Experiment 2. A 2-s COD arranged on the observing lever (left lever) postponed sucrose deliveries for 2 s following each response on the observing lever. The duration of the RT schedule was increased across conditions, and then at least one value was replicated. The order of conditions and number of sessions in each are

presented in Table 4. Stability of conditions was determined as in Experiment 3.

#### RESULTS

Figure 9 shows the percentage of the session spent in the presence of schedule-correlated stimuli during each condition. The data are presented as in Figures 1 and 4. The total time spent in the presence of the schedule-correlated stimuli was a negatively accelerated decreasing function of increases in the RT schedule. The percentage of the session spent in the presence of S- tended to be somewhat higher than the percentage of the session spent in the presence of S+ at the lowest RT schedule values. Relatively small percentages of the session were spent in the presence of the schedule-correlated stimuli by Rats R10 and R11, even at the shortest RT schedule values.

Figure 10 shows that observing-response

Table 4

Order of conditions and number of sessions per condition in Experiment 4. Numbers in parentheses refer to the order in which conditions were presented. RT schedule values are in seconds.

| Condition | Rat           |               |               |               |
|-----------|---------------|---------------|---------------|---------------|
|           | R9            | R10           | R11           | R12           |
| RT 15     | 55, 55 (1, 8) | 40, 39 (1, 8) | 26, 35 (1, 7) | 38, 61 (1, 8) |
| RT 30     | 37 (2)        | 32, 49 (2, 7) | 30 (2)        | 21 (2)        |
| RT 60     | 28 (3)        | 21 (3)        | 32 (3)        | 26, 25 (3, 7) |
| RT 120    | 19, 24 (4, 7) | 31 (4)        | 39 (4)        | 54 (4)        |
| RT 240    | 22 (5)        | 17 (5)        | 29 (5)        | 17 (5)        |
| RT 500    | 18 (6)        | 16 (6)        | 54 (6)        | 16 (6)        |

follow-up latencies increased with increases in the RT schedule value (i.e., decreases in rate of sucrose delivery). At short RT values, follow-up latencies tended to be longer after presentations of S+ than after presentations of S-. As the RT schedule increased, however, follow-up latencies after S+ and S- tended to become more similar. As in the previous experiments, latencies at the higher RT

values were based on very few observing responses in many cases, except for Rat R11, and should be interpreted with caution.

DISCUSSION

Observing decreased monotonically with decreases in the rate of response-independent deliveries of sucrose. These data suggest that when the interaction between respond-

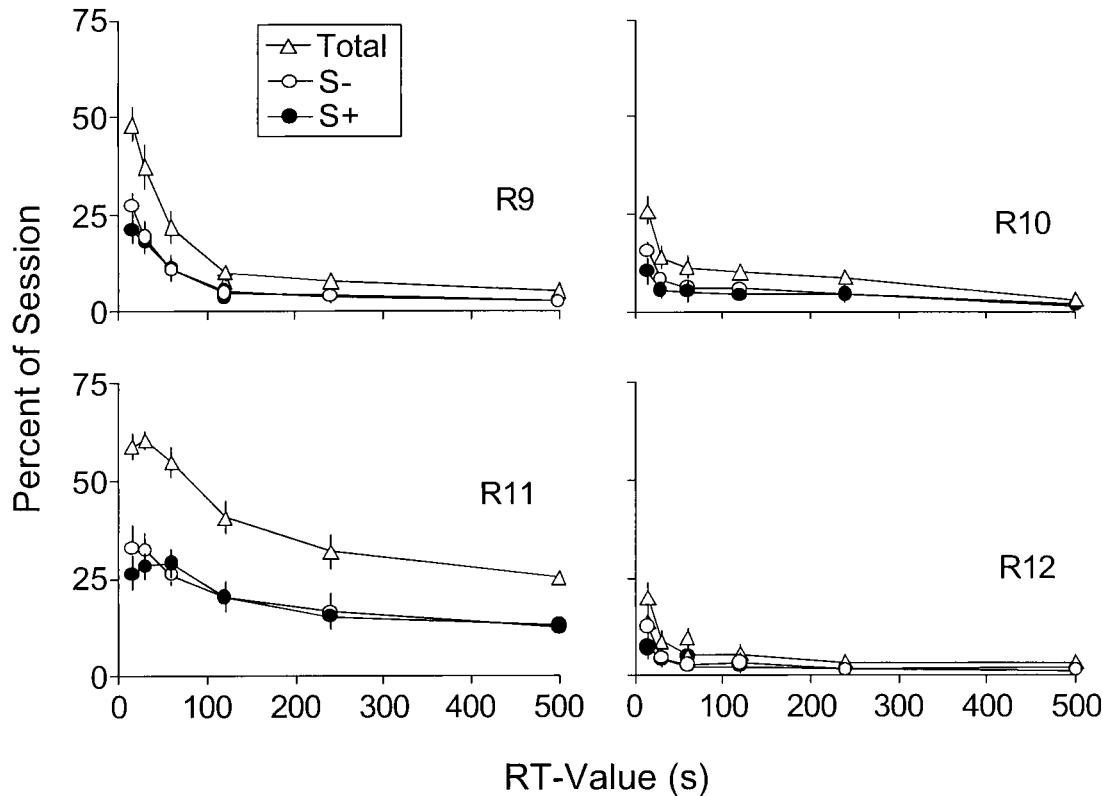


Fig. 9. Percentage of the session spent in the presence of schedule-correlated stimuli as a function of RT schedule value. Data are presented as in Figure 1.

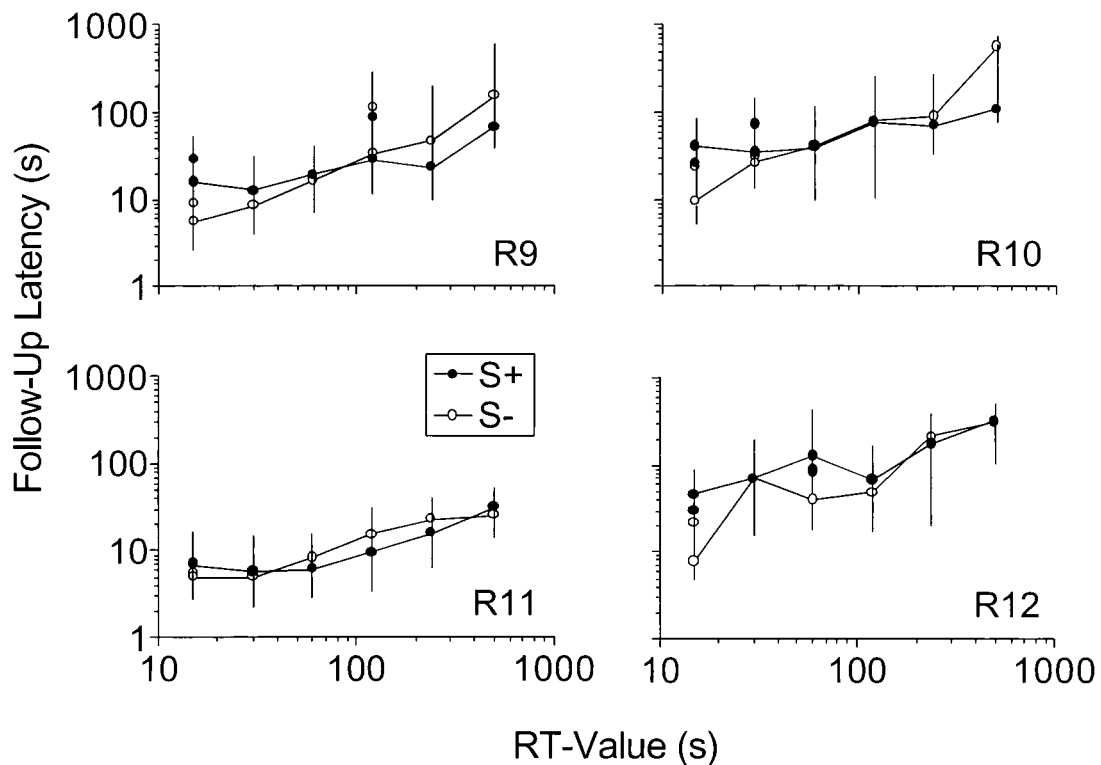


Fig. 10. Observing-response follow-up latencies after the termination of S+ and S- as a function of RT schedule value. Data are presented as in Figure 2.

ing for the primary reinforcer and observing behavior is eliminated, the increases in observing obtained with decreases in reinforcement rate are also eliminated. The larger percentages of time spent in the presence of S- and the longer follow-up latencies after S+ presentations suggest that some behavior controlled by the primary reinforcer may compete with observing at higher reinforcement rates, even when the primary reinforcer is presented response independently. This competition may result from behavior directed at the food cup and postingestive behavior. Given this likely competition at high reinforcement rates, higher rates of response-independent sucrose delivery than used here could potentially decrease observing.

Although observing varied systematically with decreases in the rate of sucrose delivery, overall observing rates were low for 2 rats. The reasons for these low rates of observing are not clear. Nonetheless, the decreases in observing obtained with decreases in the rate

of response-independent sucrose deliveries are consistent previous data (e.g., Herrnstein, 1964) and with how common theories of choice calculate conditioned reinforcement value (e.g., Grace, 1994; Mazur, 2001; Squires & Fantino, 1971).

#### GENERAL DISCUSSION

In Experiment 1, observing was a bitonic function of an RR response requirement for the primary reinforcer. Observing increased with increases in the magnitude of the primary reinforcer in Experiment 2. Experiment 3 showed that observing increased when the response requirement for the primary reinforcer was removed. In Experiment 4, decreasing the rate of primary reinforcement by increasing the time between response-independent sucrose deliveries monotonically decreased observing.

The finding in Experiment 1 that observing initially increased with decreases in rate of primary reinforcement produced by in-

creasing the response requirement for the primary reinforcer replicates Lieberman's (1972) findings with monkeys. Lieberman suggested that observing decreased with increases in the rate of primary reinforcement because higher reinforcement rates increased the discriminability of the schedule in effect and decreased the informational value of the schedule-correlated stimuli. That is, deliveries of the primary reinforcer signaled which component was in effect and made the schedule-correlated stimuli redundant. Two additional findings from Experiment 1 are consistent with Lieberman's information-based interpretation of the increasing limb of the bitonic function. First, response rates on the food lever were usually higher during RR than during extinction when the mixed schedule was in effect. This finding suggests discriminative control by pellet deliveries. Second, most of the increases in observing with increases in the response requirement for the primary reinforcer occurred as a result of increases in observing during the RR component of the mixed schedule. This finding is what would be expected if decreases in discriminative control provided by less frequent pellet deliveries produced the increases in observing. Thus, as suggested by Lieberman, the schedule-correlated stimuli could have provided redundant information at lower response requirements (i.e., higher reinforcement rates). Although this account seems plausible enough, it is difficult to reconcile with (a) the persistent failures of information theory to account for observing behavior in general (for reviews, see Dinsmoor, 1983; Fantino, 1977) and (b) the data from Experiments 3 and 4.

The data from Experiments 3 and 4 are inconsistent with Lieberman's (1972) account because removing the response requirement for the primary reinforcer should not have changed the informational value of primary reinforcer deliveries. Response-independent deliveries of the primary reinforcer should signal which component is in effect as well as response-dependent reinforcer deliveries. Removing the response requirement for the primary reinforcer, however, increased observing in Experiment 3 and eliminated the ascending limb of the bitonic function in Experiment 4. Thus, it appears unlikely that observing was lower with smaller

RR response requirements in Experiment 1 because of the redundancy of the information provided by the schedule-correlated stimuli.

Another possibility is that responding on the primary reinforcement lever competes with responding on the observing lever. More generally, response competition has been used previously to explain why, as in the present experiments, observing often produces S- more frequently than it produces S+ (Kelleher et al., 1962; see Dinsmoor, 1983, for discussion). That is, observing is thought to be more likely during extinction than when the primary reinforcer is available because responding maintained by the primary reinforcer competes with observing. Consistent with this suggestion, the response requirement for the primary reinforcer appears to play a critical role in the increases in observing with increases in RR schedule requirement in Experiment 1. Observing increased when the response requirement for the primary reinforcer was removed and reinforcement rate was held constant in Experiment 3. Also, observing decreased monotonically with decreases in the rate of response-independent sucrose deliveries, as opposed to the increases in observing obtained when response requirement was increased. Similarly, follow-up latencies were considerably longer after S+ presentations, especially at lower RR requirements in Experiment 1. Removal of the response requirement for the primary reinforcer reduced S+ follow-up latencies (Experiments 3 and 4). Although these effects could be due to the removal of the response requirement for the primary reinforcer, they could also be due to the interval nature of the RT schedules. However, Escobar, Bruner, and Avila<sup>1</sup> recently reported results similar to those of Experiment 1 when rate of the primary reinforcer was varied using random-interval schedules.

Response competition alone cannot entirely account for the increases in observing with increases in the RR requirement. Response rates on the primary reinforcement lever increased both with increases in response re-

<sup>1</sup> Escobar, R., Bruner, C. A., & Avila, R. (2001, May). *Effects of reinforcement frequency and extinction-component duration on observing responses in rats*. Paper presented at the meeting of the Association for Behavior Analysis, New Orleans.



quirement for the primary reinforcer (Figure 3) and with increases in the magnitude of the primary reinforcer (Figure 6). In both cases, observing increased with increases in primary reinforcement responding. These increases in responding maintained by the primary reinforcer should have competed more with observing, not less. Regardless, the effects of removal of the response requirement for the primary reinforcer on overall observing and on the duration of S+ follow-up latencies cannot be disregarded. These effects point to competition between observing and responding on the primary reinforcement lever as a source of some suppression of observing.

In a related account, Fantino (1977) suggested that the increasing limb of the function obtained by Lieberman (1972), and replicated in Experiment 1, could reflect the fact that the free-operant observing procedure arranges a choice between the primary reinforcer and the schedule-correlated stimuli. Fantino noted that based on what is known about the interactions of concurrent schedules of reinforcement, "it would be expected that the greater the VR value for food-reinforced responding, the more responding should be maintained by any concurrently available schedule (in this case observing responding)" (p. 321). Thus, observing may decrease with increases in reinforcement rate as a result of the increasing *relative* value of the primary reinforcement alternative. One prediction of such an account is that other methods of increasing the relative value of the primary reinforcer should decrease observing. Thus, increases in reinforcement magnitude and decreases in the time between response-independent sucrose deliveries would be expected to increase the relative value of the primary reinforcement alternative, and thus, to decrease observing. In Experiments 2 and 4, however, observing increased with increases in the value of the primary reinforcement alternative produced by changing reinforcement magnitude and rate, respectively. These data are not consistent with an account based solely on competitive interaction of relative values of the primary and conditioned reinforcers.

An account related to those described above appears to provide a reasonable explanation of the data from the present experiments. The combined effects of time spent

responding on the primary reinforcement lever and engaging in other behavior related to the primary reinforcer (e.g., food-cup tending, postingestive behavior) may have produced the lower rates of observing at smaller RR response requirements. As the RR schedule increased, response rates maintained by the primary reinforcer increased, but time spent engaging in other behavior related to the primary reinforcer may have decreased disproportionately. In Experiment 2, the use of a constant RR schedule may have helped to minimize the impact of this other behavior on measurement of conditioned reinforcement value as a function of reinforcement magnitude. In Experiments 3 and 4, removal of the response requirement eliminated the competitive effects of responding on the primary reinforcement lever, leaving other behavior related to the primary reinforcer insufficient to compete effectively with observing. It should be noted, however, that more time was spent in the presence of S- than S+, and follow-up latencies after S+ were longer at the highest rates of response-independent reinforcement in Experiment 4. These findings suggest that behavior related to the primary reinforcer, but not required for its production, could eventually compete with observing at extremely high rates of response-independent reinforcement delivery.

In summary, these results suggest that observing decreases with decreases in the rate or magnitude of the primary reinforcer, but that responding maintained by the primary reinforcer and other behavior related to the primary reinforcer can affect observing and measurement of conditioned reinforcing value. The impact of this artifact on measurement of conditioned reinforcement value seems to be minimized when response requirements for the primary reinforcer are absent or held constant. Thus, although the observing-response procedure may avoid some of the problems of using chained schedules to study conditioned reinforcement (cf. Dinsmoor, 1983), caution must also be exercised when inferring changes in conditioned reinforcement value from changes in observing behavior.

## REFERENCES

- Branch, M. (1973). Observing responses in pigeons: Effects of schedule component duration and schedule

- value. *Journal of the Experimental Analysis of Behavior*, 20, 417–428.
- Branch, M. (1983). Observing observing. *Behavioral and Brain Sciences*, 6, 705.
- Case, D. A., & Fantino, E. (1989). Instructions and reinforcement in the observing behavior of adults and children. *Learning and Motivation*, 20, 373–412.
- Daly, H. B. (1985). Observing response acquisition: Preference for unpredictable appetitive rewards obtained under conditions predicted by DMOD. *Journal of Experimental Psychology: Animal Behavior Processes*, 11, 294–316.
- Dinsmoor, J. A. (1983). Observing and conditioned reinforcement. *Behavioral and Brain Sciences*, 6, 693–728.
- Dinsmoor, J. A., Bowe, C. A., Green, L., & Hanson, J. (1988). Information on response requirements compared with information on food density as a reinforcer of observing in pigeons. *Journal of the Experimental Analysis of Behavior*, 49, 229–237.
- Dinsmoor, J. A., Browne, M. P., & Lawrence, C. E. (1972). A test of the negative discriminative stimulus as a reinforcer of observing. *Journal of the Experimental Analysis of Behavior*, 18, 79–85.
- Fantino, E. (1977). Conditioned reinforcement: Choice and information. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior* (pp. 313–339). Englewood Cliffs, NJ: Prentice Hall.
- Gaynor, S. T., & Shull, R. L. (2002). The generality of selective observing. *Journal of the Experimental Analysis of Behavior*, 77, 171–187.
- Grace, R. C. (1994). A contextual model of concurrent-chains choice. *Journal of the Experimental Analysis of Behavior*, 61, 113–129.
- Herrnstein, R. J. (1964). Secondary reinforcement and rate of primary reinforcement. *Journal of the Experimental Analysis of Behavior*, 7, 27–36.
- Kelleher, R. T., Riddle, W. C., & Cook, L. (1962). Observing responses in pigeons. *Journal of the Experimental Analysis of Behavior*, 5, 3–13.
- Kendall, S. B. (1965). Competing behavior and observing responses. *Psychonomic Science*, 3, 279–280.
- Levis, D. J., & Perkins, C. C. (1965). Acquisition of observing responses (Ro) with water reward. *Psychological Reports*, 16, 114.
- Lieberman, D. A. (1972). Secondary reinforcement and information as determinants of observing behavior in monkeys (*Macaca mulatta*). *Learning and Motivation*, 3, 341–358.
- Mazur, J. E. (2001). Hyperbolic value addition and general models of animal choice. *Psychological Review*, 108, 96–112.
- McMillan, J. C. (1974). Average uncertainty as a determinant of observing behavior. *Journal of the Experimental Analysis of Behavior*, 22, 401–408.
- Mitchell, K. M., Perkins, N. P., & Perkins, C. C. (1965). Conditions affecting acquisition of observing responses in the absence of differential reward. *Journal of Comparative and Physiological Psychology*, 60, 435–437.
- Navarick, D. J., & Fantino, E. (1976). Self-control and general models of choice. *Journal of Experimental Psychology: Animal Behavior Processes*, 2, 75–87.
- Neuringer, A. J. (1967). Effects of reinforcement magnitude on choice and rate of responding. *Journal of the Experimental Analysis of Behavior*, 10, 417–424.
- Nevin, J. A. (1973). Conditioned reinforcement. In J. A. Nevin & G. S. Reynolds (Eds.), *The study of behavior: Learning, motivation, emotion, and instinct* (pp. 154–198). Glenview, IL: Scott Foresman.
- Perone, M., & Baron, A. (1980). Reinforcement of humans' observing behavior by a stimulus correlated with extinction or increased effort. *Journal of the Experimental Analysis of Behavior*, 34, 239–261.
- Prokasy, W. F. (1956). The acquisition of observing responses in the absence of differential external reinforcement. *Journal of Comparative and Physiological Psychology*, 49, 131–134.
- Schwartz, B. (1969). Effects of reinforcement magnitude on pigeons' preference for different fixed-ratio schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 12, 253–259.
- Squires, N., & Fantino, E. (1971). A model for choice in simple concurrent and concurrent-chains schedules. *Journal of the Experimental Analysis of Behavior*, 15, 27–38.
- Steiner, J. (1967). Observing responses and uncertainty reduction. *Quarterly Journal of Experimental Psychology*, 66, 18–29.
- Ten Eyck, R. L., Jr. (1970). Effects of rate of reinforcement-time upon concurrent operant performance. *Journal of the Experimental Analysis of Behavior*, 14, 269–274.
- Williams, B. A. (1994). Conditioned reinforcement: Experimental and theoretical issues. *The Behavior Analyst*, 17, 261–285.
- Wilton, R. N., & Clements, R. O. (1971). The role of information in the emission of observing responses: A test of two hypotheses. *Journal of the Experimental Analysis of Behavior*, 16, 161–166.
- Wyckoff, L. B., Jr. (1952). The role of observing responses in discrimination learning. *Psychological Review*, 59, 431–442.

Received February 25, 2002  
Final acceptance May 7, 2002