STIMULUS- AND PELLET-INDUCED DRINKING DURING A SUCCESSIVE DISCRIMINATION

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In three experiments, interim water drinking was examined in rats exposed to a multiple schedule whose two components were extinction and a variable-time 30-s schedule of food delivery. Two different drinking patterns were observed in Experiment 1. *Pellet-induced drinking*, characterized by high rates of postpellet drinking in the variable-time component, with little or no drinking in extinction, occurred when the acquisition of stable postpellet drinking preceded discrimination training. *Stimulus-induced drinking*, characterized by a burst of drinking at the onset of extinction, with no drinking during the variable-time schedule, occurred when discrimination training preceded all other experimental conditions. With extended training, stimulus-induced drinking eventually was accompanied by postpellet drinking. In Experiment 2, the rate of stimulus-induced drinking and the number of sessions during which it occurred without postpellet drinking were found to be inversely related to component duration. In Experiment 3, the rate of schedule-induced drinking was found to vary directly with component duration.

Key words: interim behavior, adjunctive behavior, drinking, multiple schedule, mixed schedule, component duration, rats

Hungry rats develop a stereotyped drinking pattern when exposed to an intermittent schedule of food delivery (Falk, 1961, 1967). The pattern is characterized by consumption of a small quantity of water shortly after the ingestion of each food pellet, which often results in excessive total fluid intake (i.e., schedule-induced polydipsia) during experimental sessions.

One explanation for this phenomenon is that schedule-induced polydipsia is an exaggeration of normal prandial drinking (Allen & Porter, 1977; Lotter, Woods, & Vasselli, 1973; Stein, 1964). Because of constraints on the quantity of and temporal access to food during intermittent food delivery, each pellet may be treated as a small "meal," and the stimuli (taste, dry mouth) and responses (chewing, swallowing) involved in eating may give rise to a drinking bout. Alternatively, stereotyped drinking may represent a unique class of activities that occur during periods of nonreinforcement (Falk, 1971; Staddon & Simmelhag, 1971). For example, Staddon (1977) viewed inter-

mittent reinforcement as an instance of Pavlovian temporal conditioning (Pavlov, 1927). From this view, each food delivery begins a brief interval during which subsequent food delivery is unlikely (i.e., an S- period). This negative stimulus-reinforcer relation engenders a unique motivational state (an *interim* state) in which excessive drinking, wheel running, aggression, and so forth are likely to occur. As postfood time increases, temporal cues predict forthcoming food (an S+ period). A second, *terminal*, state, which motivates food-related behavior, occurs in anticipation of the reinforcer.

Unfortunately, the contributions of post-ingestional and discriminative factors to schedule-induced drinking have been difficult to assess when responding is maintained by periodic food schedules. Both factors are maximal immediately after food deliveries, and the two interpretations do equally well in accommodating a postpellet drinking pattern. However, if interim responding is engendered by stimuli that reliably accompany the absence of food, drinking should come under the control of an exteroceptive S- that lacks the ingestional properties of food.

Corfield-Sumner, Blackman, and Stainer (1977) exposed rats to a second-order schedule in which brief stimuli were occasionally presented in lieu of a food pellet. Conditions were

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arranged such that each event (food delivery or brief stimulus) signaled a period of non-reinforcement. Even though the brief stimuli lacked consummatory properties, drinking occurred after both events. Stimulus-induced drinking also occurred when a fixed-ratio 10 (FR 10) schedule alternated randomly with a chained FR 10 FR 90 schedule (Alferink, Bartness, & Harder, 1980). In this procedure, completion of 10 responses occasionally produced a stimulus that accompanied a long interval to reinforcement (i.e., the FR 90 link of the chain). Most drinking in a session occurred immediately after the onset of this S- rather than after food deliveries. Minor and Coulter (1982) obtained S- drinking during a successive discrimination for the presence and absence of food. No drinking followed food deliveries during a stimulus that accompanied increased likelihood of food delivery (S+). A postdiscrimination generalization test yielded a peaked, decremental gradient with maximum drinking in the presence of the training stimulus, indicating that drinking was controlled by S-.

Whereas these data are consistent with Staddon's (1977) motivational hypothesis, attempts to produce S- drinking using multiple (Dougan, McSweeney, & Farmer, 1985; Hamm, Porter, & Kaempf, 1981; Jacquet, 1972; Porter & Allen, 1977) or second-order schedules (Allen & Porter, 1977; Iversen, 1977; McCoy & Christian, 1976; Porter, Azarie, Holbrook, Cheek, & Allen, 1975; Rosenblith, 1970) generally have been unsuccessful. The lack of S- drinking was not caused by a failure of these schedules to establish interim responding, for robust postpellet drinking was evident in each study. Whether the difficulty in obtaining S- drinking reflects a special relationship between eating and drinking or stems from some aspect of the conditioning procedure remains unclear. Unfortunately, few parametric studies have attempted to determine why nominally similar procedures generate S- drinking on some occasions but not others.

The present study examined patterns of interim drinking during a successive discrimination. Rats were exposed to a multiple schedule whose components were extinction and variable-time schedules of food delivery (*mult* EXT VT). The phasic changes typically achieved with periodic food deliveries were mimicked by regularly alternating periods of

EXT with periods in which food was presented on the VT schedule. Explicit stimuli were correlated with EXT (S-) and VT (S+) components. Thus, S- maintained the discriminative properties of periodic food delivery, but did not give rise to stimuli or behavior patterns associated with eating. Minor and Coulter (1982) demonstrated that S- drinking does develop under these conditions. However, critical aspects of the procedure have not been determined. Several variables were examined in three experiments in an attempt to identify some boundary conditions of stimulus-induced drinking.

EXPERIMENT 1

Perhaps the simplest explanation for a failure to obtain stimulus-induced drinking is that the putative S- did not accrue inhibitory properties. Several studies in which interim drinking was not produced in a multiple schedule may have used discriminations that were too difficult to establish strong inhibitory stimulus control. Discriminations based on intradimensional stimuli (i.e., tones differing in frequency) or the presence and absence of a single visual cue (Dougan et al., 1985; Hamm et al., 1981; Jacquet, 1972; Porter & Allen, 1977) resulted in enhanced rates of postpellet drinking, with little or no drinking produced by S-. In contrast, drinking developed during and was confined to the presence of S- when extradimensionally differing stimuli (light and noise) differentially accompanied the EXT and VT components of a multiple schedule (Minor & Coulter, 1982). Intradimensional and presence-absence discriminations facilitate generalization between schedule components, thereby weakening differential control by S+ and S- (Gutman, Minor, & Sutterer, 1984; Gutman & Sutterer, 1977). Stimulus-induced drinking may not occur in the absence of a strong cue for nonreinforcement.

A second likely explanation for failures to obtain stimulus-induced drinking arises from the fact that postpellet drinking is often pre-trained before exposure to S- (Allen & Porter, 1977; Dougan et al., 1985; Jacquet, 1972; Porter et al., 1975; Rosenblith, 1970). Robust stimulus-induced drinking has not been obtained under these conditions. In contrast, S- was introduced at the start of training in all successful demonstrations of the phenomenon

(Alferink et al., 1980; Corfield-Sumner et al., 1977; Minor & Coulter, 1982). Because of the tendency of rats to alternate bouts of eating and drinking (Kissileff, 1969), food may be more relevant to drinking than are other events (see Millenson, Allen & Pinker, 1977; Minor & Coulter, 1982, for a thorough discussion). Once postpellet drinking develops, S- might fail to control drinking simply because it lacks the relevance of, or is too different from, food. If so, stimulus-induced drinking should be easier to obtain when the critical discrimination precedes the acquisition of a postpellet drinking pattern.

Thus, at least two variables may affect the pattern of interim drinking in a multiple schedule: discrimination difficulty and training sequence. Each variable was examined in Experiment 1. Discrimination difficulty was assessed by comparing performance under mixed and multiple schedules. A distinct stimulus (light or noise) was correlated with each component of the multiple schedule. The absence of such cues in the mixed schedule provided a difficult discrimination. Training sequence was examined by exposing rats to easy or difficult discriminations (a) prior to any other experimental treatment, or (b) after postpellet drinking was well established. Because of the focus on acquisition and the possibility of order effects, four independent groups were used to assess the effects of these variables.

METHOD

Subjects

Sixteen experimentally naive male Long-Evans rats, weighing 350 to 400 g (90 to 120 days old), were reduced to and maintained at 80% of their free-feeding body weights. Each rat was housed in an individual cage with free access to water in a colony room maintained on a 12:12 light/dark cycle. Experimentation occurred during the light portion of the cycle.

Apparatus

Four rat chambers were housed in sound- and light-attenuating enclosures containing exhaust fans that masked extraneous noises. Two chambers (Grason-Stadler Model 1111-P) had interior dimensions of 31 by 30 by 29 cm; the other chambers (Grason-Stadler Model E31258-100) measured 29 by 23 by 19 cm. A recessed food magazine was located in the cen-

ter of the front panel of each chamber, 2 cm above the level of the grid floor. Standard 45-mg Noyes food pellets could be delivered into the magazine from a solenoid-operated feeder located outside the chamber. A ball-tipped water spout extended into each chamber through a 1.2-cm circular aperture in the front wall. This opening was 10 cm to the right of the food magazine in the larger chambers and 8 cm to the right of the magazine in the smaller chambers. Bare-skin contacts with the water spout were monitored by BRS-LVE (Model 101) drinkometers.

Light and white noise served as the stimuli that differentially accompanied components of the multiple schedule. In the small chambers, a 6-W light was presented from outside the upper corner of the clear Plexiglas side door; white noise (80 dB SPL re: 0.0002 dynes/cm²) was delivered through a speaker located to the left of the magazine and below the level of the grid floor. In the large chambers, both the 6-W light and white noise were presented from the upper left-hand corner of the front wall. Interfood intervals in the VT schedule were based on an arithmetic scale (range, 5 to 180 s). Experimental events were programmed with solid-state circuitry located in an adjoining room.

Procedure

Rats were assigned randomly to one of four groups of 4 rats each. Each rat initially received three daily 1-hr pretraining sessions. The number of food pellets to be presented subsequently during each session of the first experimental phase was freely available on these days. Thus two groups received 60 pellets and two groups had access to 120 pellets during each session. Lick totals were recorded and served as pretraining levels of drinking.

All rats began a two-phase experimental procedure on Day 4. Phase 1 consisted of 25 daily 1-hr sessions; Phase 2 consisted of 20 daily 1-hr sessions. The groups differed in terms of the phase in which discrimination training occurred (Phase 1 or 2) and discrimination difficulty (mixed or multiple schedule). Two groups received discrimination training immediately in Phase 1. One group was exposed to a multiple schedule whose components were extinction and variable time 30-s (*mult EXT VT 30 s*). The EXT and VT components were signaled, respectively, by light

(S-) and white noise (S+). The other group was exposed to a similar mixed schedule (*mix* EXT VT 30 s) with the same pattern of food delivery, but without the accompanying light and noise. For both groups, each session consisted of 10 3-min presentations of EXT and VT in regular alternation. In Phase 2, the first component of the mixed and multiple schedules was changed from EXT to VT; that is, a *mult* (or *mix*) VT 30-s VT 30-s schedule. All other conditions were the same as in Phase 1.

For the two groups receiving delayed-discrimination training, the order of exposure to the above schedule conditions was reversed. A postpellet drinking pattern was established in Phase 1 by exposing one group to a *mult* VT 30-s VT 30-s schedule and a second group to a *mix* VT 30-s VT 30-s schedule. During the discrimination sessions of Phase 2, the first component of the multiple or mixed schedule was shifted from VT to EXT. All other conditions of training were as described above. The total number of licks in each component of the mixed or multiple schedule was recorded separately for each session of Phases 1 and 2.

RESULTS

Pretraining

Water consumption varied with the amount of food available in each pretraining session. Mean lick totals for the final session in the 60- and 120-pellet conditions were 209.6 and 569.6, respectively. This difference was statistically significant, $F(1, 12) = 10.27, p < .01$. These data simply indicate that consuming more food pellets produced slightly greater drinking prior to experimental treatment.

Immediate Discrimination Training

Figure 1 shows the effects of immediate discrimination training on lick rates in each component of the multiple (easy discrimination) and mixed (difficult discrimination) schedules as a function of sessions. The plots in the upper portion of the figure are for rats in the multiple-schedule group; those in the lower portion are from the mixed schedule.

Drinking was confined to S- during the early sessions of Phase 1 under the easy discrimination, with lick rates during S- increasing over sessions to levels ranging between 39.3 and 101.2 licks per minute for individual rats.

Although these rates were low compared to those produced by periodic food schedules (e.g., Falk, 1971), peak S- drinking exceeded pretraining levels in all rats. The number of sessions during which drinking was confined to S- periods ranged from 6 to 17 sessions across individuals. Thereafter, all rats showed a rapid rise in postpellet drinking during the VT component. VT rates ranged between 132.1 and 178.9 licks per minute for individual subjects. All rats continued drinking during S- during these later sessions, albeit at reduced levels. Unfortunately, cumulative records were not available for this study, and it was unclear from simply observing animals whether EXT drinking was the continuation of postpellet licking from the preceding component or represented continued control by S-.

The shift to a *mult* VT 30-s VT 30-s schedule in Phase 2 resulted in postpellet drinking during both components that was comparable to the rate during S+ of the final session of Phase 1.

Exposure to the difficult discrimination in Phase 1 (lower panels of Figure 1) resulted in low drinking rates (note the different ordinate scales in the upper and lower plots of Figure 1). For 3 rats (P11, P12, and P14), lick rates tended to be higher during the EXT component of the mixed schedule. Rat P13 distributed drinking more equally between components early in training and then drank at consistently higher rates in the VT component later in training. Following the shift to *mix* VT 30-s VT 30-s in Phase 2, drinking increased for all rats, but still remained low relative to the multiple schedule. Thus, initial exposure to a *mix* EXT VT 30-s schedule not only retarded drinking in Phase 1, but reduced Phase 2 drinking as well.

Delayed Discrimination Training

Figure 2 shows the effects of delayed discrimination training on lick rates during each component of the multiple (upper panels) and mixed (lower panels) schedules for all sessions of Phases 1 and 2. All rats rapidly acquired postpellet drinking in both components of the multiple or mixed schedule during Phase 1. All rats showed polydipsia contrast (Jacquet, 1972) when the first component was shifted from VT to EXT in Phase 2: Drinking decreased in the altered (EXT) component and

Fig. 1. Lick rates during successive sessions for individual rats during the altered and unaltered components of multiple (upper panels) and mixed (lower panels) schedules. Rats were exposed to a *mult* (or *mix*) EXT VT 30-s schedule in Phase 1 and shifted to a *mult* (or *mix*) VT 30-s VT 30-s schedule in Phase 2. (Note that the ordinate scale (licks per minute) is different in upper and lower plots).

Fig. 2. Lick rates during successive sessions for individual rats in the altered and unaltered components of multiple (upper panels) and mixed (lower panels) schedules. Rats were exposed to a *mult* (or *mix*) VT 30-s VT 30-s in Phase 1 and shifted to a *mult* (or *mix*) EXT VT 30-s schedule in Phase 2.

increased in the unaltered (VT) component relative to Phase 1 levels.

Comparisons of mean lick rates in the last five sessions of Phase 1 and the first 10 sessions

of Phase 2 indicated that drinking increased significantly in the unaltered VT component, $t(3) > 4.02$, $p < .05$, and decreased significantly in the altered EXT component in both

groups, $t(3) > 13.6$, $p < .003$. The increase in VT drinking during Phase 2 was statistically equivalent between groups, $t(6) = 0.89$, $p > .05$, as was the decrease in EXT, $t(6) = 1.04$, $p > .05$. Thus, discriminative stimuli were not necessary for polydipsia contrast and did not increase the rate of S- drinking.

DISCUSSION

Drinking patterns were determined mainly by the training phase in which the discrimination was introduced. Immediate exposure to a multiple EXT VT schedule resulted in drinking during S-, the stimulus that accompanied extinction. This stimulus-induced drinking was accompanied by high rates of postpellet drinking with extended training. In contrast, S- failed to control drinking when postpellet licking was acquired before exposure to the multiple EXT VT schedule; instead, enhanced rates of schedule-induced drinking occurred in the VT component (i.e., polydipsia contrast).

Discrimination difficulty had no effect in the delayed discrimination. Mixed and multiple schedules produced equally high VT rates and low EXT rates of licking. Thus, it is likely that earlier failures to obtain S- drinking in a multiple schedule were not simply the result of weak stimulus control owing to a difficult discrimination (Dougan et al., 1985; Jacquet, 1972; Porter & Allen, 1977). On the other hand, an effect of discrimination difficulty was evident in the immediate conditions. However, the presence of discriminative stimuli appeared only to enhance the response tendency generated by the mixed EXT VT schedule.

Immediate exposure to the mixed EXT VT 30-s schedule was expected to facilitate postpellet drinking, because the overall rate of food delivery was similar to a VT 60-s schedule and EXT and VT periods presumably were not discriminable. Not only was postpellet drinking retarded in this condition, but 3 rats showed a trend toward EXT drinking. Apparently, some discrimination between components was possible despite the lack of accompanying stimuli. One possibility is that regular alternation of EXT and VT schedules, in conjunction with a long component duration, generated discriminable periods of high and low reinforcer probability. The first food presentation after a prolonged period of non-reinforcement was correlated with an interval

in which food was delivered at a high rate. Conversely, after several consecutive food deliveries, the probability of an extended no-food period increased as time since the last pellet delivery increased. The presence of EXT drinking suggests that the rats were sensitive to these local probabilities. Even so, the transition from VT to EXT should have been less discernible in the mixed schedule than in the multiple schedule. The inability to clearly identify transitions from one schedule to the other may account for the lack of stable or robust responding during immediate exposure to a mixed EXT VT schedule. Apparently, such considerations are important only during acquisition, because discriminative factors did not constrain drinking with delayed exposure to the discrimination procedure.

The stimulus-induced drinking produced by immediate exposure to a multiple EXT VT schedule differed in two important respects from the pattern reported by Minor and Coulter (1982). First, overall rates of S- drinking were lower in the present study. Second, whereas drinking was confined to S- periods throughout all 30 sessions of the earlier research, postpellet drinking accompanied S- drinking after only a few sessions in the present study. The only major difference in the procedure of these experiments was the component durations of the multiple schedule (180 s in the present study and 60 s in the earlier study). The difference suggests that drinking may be confined to S- for a greater number of sessions and may reach a higher asymptote when components are relatively short in duration. The following two experiments examined the effects of component duration on drinking patterns during immediate (Experiment 2) or delayed (Experiment 3) discrimination training.

EXPERIMENT 2

The effect of component duration on stimulus-induced drinking on multiple schedules was examined in Experiment 2. Because S- drinking was limited to the first few sessions of training in Experiment 1, an independent-group design was used in the present study: Five groups of rats received immediate discrimination training, each with a different component duration.

Fig. 3. Top panel: Group median lick rates during S+ and S- (VT 30 s and extinction components of a multiple schedule, respectively) for successive blocks of five sessions. Each group received discrimination training under one of five component durations, as indicated for successive columns. Lower panels: Median lick rates for blocks of sessions for 2 individual rats representing extremes about the group median.

METHOD

Subjects and Apparatus

Forty experimentally naive male Long-Evans rats, weighing 330 to 350 g (90 to 100 days old), were reduced to and maintained at 80% of their free-feeding body weights. The apparatus was the same as in Experiment 1.

Procedure

Each rat was assigned randomly to one of five groups of 8 rats each. All rats received three daily pretraining sessions in which water and 56 food pellets were freely available. During the next 40 daily sessions, each rat was exposed to a *mult* EXT VT 30-s schedule in which EXT and VT periods were accom-

panied, respectively, by light (S-) and white noise (S+). These schedules regularly alternated every 15, 30, 60, 120, or 240 s for independent groups. Session duration was held constant at 56 min for all groups. Licks were recorded separately in EXT and VT components. These data were supplemented occasionally with cumulative records of licking.

RESULTS

Pretraining

A single-factor ANOVA indicated that drinking was equivalent among groups during the final pretraining session ($F < 1$). Mean lick totals in the 15-, 30-, 60-, 120-, and 240-s groups were 264.8, 111.3, 258.9, 196.9, and 238.9, respectively.

Overall Drinking Patterns

Figure 3 shows the effects of discrimination training on drinking in all five groups. Median lick rates during S- and S+ are presented for blocks of five sessions in the upper panel of the figure. The lower panels are data for 2 rats from each group that represented extremes about the group median.

The rate of S- drinking and the number of sessions during which S- controlled a greater proportion of total licks decreased as component duration increased. All rats in the 15- and 30-s groups drank at higher rates during S- than during S+ throughout training. At longer durations, drinking usually developed in and was confined to S- early in training. However, the tendency for the primary locus of drinking to shift from S- to S+ increased with component duration. Although median lick rates were consistently higher in S- than in S+ at 60-s duration, substantial S+ drinking did occur for 3 rats in this group. For Rat D11 (lower panel of Figure 3), S+ drinking exceeded that in S- after only five sessions. The onset of S+ drinking occurred late in training for the other 2 rats and remained below the S- rate. All rats in the 240-s group, and all but 1 rat (D54) in the 120-s group, eventually acquired postpellet drinking during S+. Fewer sessions were required for this shift at the 240-s duration. Once S+ drinking emerged, further development of S- drinking was impaired. Drinking during S- usually continued at or slightly below the level attained prior to the onset of S+ drinking (e.g., Rats D11, D51, and D64).

Figure 4A (top) shows that, as component duration decreased, S+ lick rates remained fairly constant and S- rates decreased. Each data point is the average of the final 10 sessions of discrimination training. A mixed-design ANOVA (Component Duration $\times$ Stimulus) yielded a significant main effect of Stimulus, $F(1, 35) = 16.85$, $p < .001$, and a significant Component Duration $\times$ Stimulus interaction, $F(4, 35) = 6.37$, $p < .001$. Newman-Keuls comparisons ($\alpha = .05$) indicated that S- drinking was significantly greater in the 15-s group than in the 120-s and 240-s groups. In addition, S- lick rates were significantly higher in the 30-s group than at the longest component duration. In contrast, S+ rate was statistically equivalent at all component durations.

Figure 4B shows that the mean percentage of total drinking that occurred during S- decreased differentially across training sessions at the longer component durations. A mixed-design ANOVA (Component Duration $\times$ Session Block) yielded a significant main effect of Session, $F(7, 245) = 21.62$, $p < .001$, and a significant Duration $\times$ Session interaction, $F(28, 245) = 3.31$, $p < .001$. With the exception of the 15-s group, virtually all drinking was confined to S- early in training. Newman-Keuls comparisons indicated that S- controlled an equivalent percentage of total drinking in the 30-, 60-, 120-, and 240-s groups during the first session block; percentage of S- drinking was significantly reduced from these levels in the 15-s group. Relatively less drinking occurred during S- as training continued, with greater decreases occurring at the longer component durations. Newman-Keuls comparisons indicated that percentage of S- drinking was significantly lower for the 240-s group than for the 15-, 30-, and 60-s groups during the last block of sessions; the mean for the 120-s group was lower than in the 30-s group. Thus, the portion of total drinking controlled by S- decreased over training sessions, and the magnitude of this decrease was greatest at longer component durations.

Cumulative Records

Local drinking patterns for 3 rats in the 240-s group are shown in Figure 5. These records are from Session 20 of training. The upper response pen moved upward with each

Fig. 4. Panel A: Mean lick rates during S+ and during S- (VT 30 s and extinction components of a multiple schedule, respectively) as a function of component duration. Each point is the average for the last five sessions of discrimination training. Panel B: Mean percentage of total drinking during S- across blocks of five sessions at each of five component durations.

lick and was reset at the end of each component of the multiple schedule. Food deliveries are shown as downward deflections of the response pen. Schedule conditions are represented by the lower event pen. For Rat D64 (top panel) licking was induced by food presentations during S+. Drinking occurred during S- only as the continuation of a postpellet bout. In contrast, drinking was confined to S- for Rat D64 (center panel). Onset of S- initiated a bout of drinking that terminated before the end of the trial. Rat D33 (lower panel) showed a combination of stimulus- and pellet-induced drinking. Importantly, whereas Rat D33 drank only during S- during the first nine sessions of training, Rat D64 never drank during S-.

Fig. 5. Cumulative records for 3 rats exposed to a *mult* EXT VT 30-s schedule with a 240-s component duration. The lower event pen was reset after each S- trial. The response pen was reset at the end of each component; downward slashes of the response pen indicate food deliveries.

Fig. 6. Cumulative records of drinking for 3 rats exposed to a *mult* EXT VT 30-s schedule with 120-s (upper panel), 60-s (middle panel), or 15-s (lower panel) component duration. Other details are the same as in Figure 5.

Although food deliveries in the S+ component eventually induced higher overall rates of drinking, S- continued to induce drinking for Rat D33. This pattern held for all subjects. If postpellet drinking emerged prior to S- drink-

ing, S- did not induce drinking bouts. However, if drinking was confined to S- during initial training sessions, S- continued to induce drinking after postpellet drinking emerged.

The effect of component duration on S- drinking can be seen by comparing the center panel of Figure 5 with the three panels in Figure 6. At the 240-s duration, drinking terminated prior to the end of each S- component. The portion of a schedule component occupied by a bout increased as component duration decreased, such that it filled the entire S- period at the 60-s component duration.

The lower panel of Figure 6 shows a cumulative record for 1 rat in the 15-s group. This pattern was typical for all rats in the group. Drinking occurred only after food deliveries and was not confined to S- periods at any point in training. Drinking during S- occurred only as a continuation of a postpellet bout.

DISCUSSION

Component duration had two general effects on stimulus-induced drinking in the present experiment. First, the number of sessions during which drinking was confined to the S- component increased as component duration decreased. Second, the rate of drinking during S- also varied inversely with component duration. Cumulative records indicated that drinking was initiated by the onset of S-, and the resulting bout occupied a greater portion of the trial duration as component duration decreased. Because total S- time in a session was held constant across component durations, this effect resulted in higher overall rates at shorter durations.

The exception to these generalizations was the group for which the schedule components alternated every 15 s. Cumulative records indicated that for this condition, drinking was initiated only by food deliveries throughout the experiment. The high rate of licking during S- was an artifact of the short component duration, for drinking initiated by a food delivery often continued into one or more S- periods. Because there were no events (i.e., food presentations) to disrupt drinking during S-, the overall rate for the session exceeded that in S+ components.

The failure to obtain S- drinking in the 15-s group may have resulted from the early acquisition of postpellet drinking. Data from the present experiment and Experiment 1 suggest that stimulus-induced drinking is retarded once postpellet drinking emerges. This effect

was most obvious in Experiment 1 when postpellet drinking was acquired prior to discrimination training. Here, drinking continued to occur in a postpellet manner during discrimination training; S- failed to control drinking. Moreover, even though drinking initially was confined to S- components when discrimination training occurred immediately after pretraining, longer durations resulted in a shift in the primary locus of drinking from S- to S+. Further increases in S- drinking did not occur after this shift. Thus, several observations suggest that an early onset of postpellet drinking may have prevented acquisition of S- drinking in the 15-s group.

Two factors may have contributed to the early onset of postpellet drinking in the 15-s group. First, the trial duration was shorter than the average rate of food delivery in the VT component of the multiple schedule. On average, a food pellet was presented during only 50% of the S+ components in a session, whereas at least one pellet was delivered per exposure to S+ at the longer component durations. The weaker stimulus-reinforcer contingency may have retarded acquisition of stimulus control and the ability of S+ and S- to engender schedule-induced behavior. Second, as discussed earlier, regular alternation of EXT and VT schedules generated discriminable periods of relatively low and high rates of food delivery. At long durations, the first food delivery after an extended period of nonreinforcement signaled an interval in which additional food deliveries were highly likely, whereas the likelihood of an extended period of nonreinforcement increased as time since the last food presentation increased. As seen in Experiment 1, the patterning of food deliveries generated by a 3-min component duration retarded the acquisition of drinking in the absence of explicit stimuli accompanying EXT and VT periods. However, such patterning effects were absent at the 15-s component duration; in fact, the distribution of food deliveries across the session was similar to that generated by a simple VT 60-s schedule, a condition that is highly effective in producing postpellet drinking (Falk, 1967). Thus, a combination of weak stimulus control and the absence of a distinct pattern of food deliveries may have contributed to the early onset of postpellet drinking in the 15-s group.

EXPERIMENT 3

Experiment 3 examined the effects of component duration on schedule-induced drinking and polydipsia contrast. Polydipsia contrast was obtained in Experiment 1 when postpellet drinking was acquired prior to discrimination training. The pattern was characterized by enhanced rates of drinking in the unaltered (VT) component relative to the preceding nondifferential phase, with little or no drinking in EXT.

Predictions for this study were based on the assumption that terminal and interim behaviors compete (Staddon, 1977). Thus, conditions that increase terminal responding during discrimination training should reduce the opportunity for interim responding, and vice versa.

The shift from a multiple VT VT to a multiple EXT VT schedule often results in enhanced rates of food-reinforced or food-oriented responding in the unaltered (VT) component in conjunction with decreased rates in the altered (EXT) component; that is, positive behavior contrast (Reynolds, 1961). The magnitude of the response increase is greatest just after the transition from S- to S+ and then decreases across the S+ component (Gutman & Minor, 1976; Nevin & Shettleworth, 1966). As component duration decreases, the early seconds of each component constitute a greater proportion of the total component duration. When total VT time in a session is held constant, the magnitude of behavioral contrast increases as component duration decreases (Rachlin, 1973; Shimp & Wheatley, 1971; Silberberg & Schrot, 1974). Increased time allocation to terminal behavior in the VT component of a multiple EXT VT schedule should decrease the opportunity for interim responding. Thus, the magnitude of polydipsia contrast should decrease as component duration decreases.

Component duration should have a smaller effect on polydipsia contrast in a mixed EXT VT schedule. Positive behavioral contrast generally does not occur in a mixed schedule; in the rat, the effect is obtained reliably only when distinct stimuli are correlated with EXT and VI periods (Gutman et al., 1984). Consequently, competition from terminal behavior should not be a major constraint on the rate of interim responding in the VT component,

and the magnitude of polydipsia contrast should be fairly constant over different component durations.

The present study examined the effects of short (15 s), medium (90 s), and long (360 s) component durations on polydipsia contrast. Independent groups were exposed to a series of mixed or multiple schedules in six phases. All odd-numbered phases consisted of a *mult* (or *mix*) VT 30-s VT 30-s schedule; all even-numbered phases were a *mult* (or *mix*) EXT VT 30-s schedule.

METHOD

Subjects and Apparatus

Twelve experimentally naive male Long-Evans rats, weighing 330 to 410 g (90 to 120 days old), were reduced to and maintained at 80% of their free-feeding body weights. The apparatus was the same as in Experiment 1.

Procedure

Each rat was assigned randomly to one of two groups of 6 rats each. All rats initially received three 1-hr pretraining sessions. Water intake resulting from the consumption of 120 grouped food pellets was recorded to obtain preexperimental drinking levels.

One group was exposed to a series of multiple schedules over six experimental phases (70 sessions). All odd-numbered phases consisted of a *mult* VT 30-s VT 30-s schedule. The schedule components regularly alternated every 90 s during nondifferential training. Discrimination training consisting of a *mult* EXT VT 30-s schedule occurred in all even-numbered phases. The schedule components alternated every 15, 90, or 360 s during discrimination training. Only one component duration was examined in each discrimination phase. The order of presentation of these durations was block-randomized for subjects within the multiple-schedule group. Phase 1 consisted of 20 1-hr sessions; all other phases consisted of 10 1-hr daily sessions. Light served as S1, and white noise as S2, during all phases.

The second group was exposed to a series of mixed schedules over six phases of training: a *mix* VT 30-s VT 30-s schedule during all odd phases and a *mix* EXT VT 30-s schedule in all even phases. Only one component duration was examined in each even-numbered phase as above.

Table 1

Mean licks per minute in the altered and unaltered components of multiple and mixed schedules during each nondifferential baseline phase (BL: *mult* or *mix* VT30-s VT 30-s) and the following phase of discrimination training (DT: *mult* or *mix* EXT VT 30-s). A different component duration was examined in each discrimination phase.

Sub- ject	Component	Component duration					
		15 s		90 s		360 s	
		BL	DT	BL	DT	BL	DT
Multiple Schedule							
PC11	Altered:	*71.2	96.4	107.9	27.2	110.4	21.4
	Unaltered:	86.4	44.3	97.9	122.7	108.7	131.4
PC13	Altered:	87.6	110.2	95.2	32.2	116.9	14.9
	Unaltered:	94.4	69.3	90.8	123.7	117.6	155.3
PC22	Altered:	125.7	118.5	113.0	38.0	114.7	6.8
	Unaltered:	120.5	82.9	117.7	141.0	113.2	160.6
PC24	Altered:	176.0	159.6	193.8	124.1	206.4	25.7
	Unaltered:	180.8	123.9	184.5	202.2	220.8	251.5
PC31	Altered:	91.5	120.1	123.2	46.1	90.3	26.3
	Unaltered:	104.9	71.3	120.4	114.2	95.1	108.3
PC34	Altered:	150.9	134.3	147.0	41.1	119.3	15.1
	Unaltered:	151.1	97.7	146.1	155.2	114.1	155.3
Mixed Schedule							
PC12	Altered:	128.4	135.2	148.6	43.9	144.0	22.2
	Unaltered:	124.0	90.9	149.1	172.7	146.7	165.2
PC14	Altered:	128.5	151.4	163.0	64.7	148.8	48.9
	Unaltered:	130.8	95.9	162.4	190.5	149.2	186.2
PC21	Altered:	120.1	113.8	116.1	30.1	116.9	11.3
	Unaltered:	114.7	55.9	102.1	127.8	105.6	134.9
PC23	Altered:	146.4	131.1	135.8	31.2	151.2	19.4
	Unaltered:	143.3	81.9	131.2	147.4	146.6	183.0
PC32	Altered:	120.3	104.9	110.0	32.4	105.3	15.8
	Unaltered:	118.1	81.6	111.0	132.6	115.6	135.7
PC33	Altered:	189.1	174.4	163.8	111.8	158.6	49.0
	Unaltered:	170.9	155.7	165.3	197.7	140.7	226.9

*Note: BL lick rates are the average of the last 5 sessions of nondifferential training. DT rates are the average of all 10 sessions of discrimination training.

RESULTS

Pretraining

Mean lick totals during the last pretraining session in the mixed- and multiple-schedule groups were 587.0 and 611.7, respectively. This difference was not statistically significant ($F < 1$).

Phases 1 through 6

All rats rapidly acquired postpellet drinking during Phase 1 and continued to drink at high rates throughout the experiment. Table 1 shows mean lick rates for individual rats during each phase of training. Rates indicated for EXT and VT are the average of all 10 sessions of discrimination training at a given component

duration. Baseline rates for each schedule component are the average of the last five sessions of the immediately preceding nondifferential phase.

Discrimination training under a 15-s component duration resulted in decreased VT drinking relative to baseline in all rats. Three rats exposed to the multiple schedule (PC11, PC13, and PC31) and 2 rats exposed to the mixed schedule (PC12 and PC14) showed a relative increase in drinking in the altered EXT component; a small decrease in EXT drinking occurred for the other animals. By contrast, VT drinking was enhanced during discrimination training when component duration was 90 or 360 s. All but 1 rat (PC31) showed polydipsia contrast at the 90-s duration, and all

rats showed the effect at the 360-s duration. Large decreases in EXT drinking relative to baseline occurred at these longer component durations.

The relative magnitude of these effects was assessed by converting lick rates during discrimination training to a percentage of baseline drinking. This transformation ignored absolute differences in between- and within-subject baseline rates. Figure 7 shows the group means in EXT and VT as a function of component duration.

A mixed-design ANOVA (Group $\times$ Duration) of percentage of baseline drinking in the unaltered (VT) component yielded a significant main effect of Duration, $F(2, 22) = 113.9$, $p < .001$, indicating that drinking generally increased as component duration increased. Neither the main effect of Group nor the Group $\times$ Duration interaction was statistically significant; consequently, the data from both groups were pooled for subsequent analyses. Planned comparisons indicated that the increases in drinking from the 15-s to the 90-s and from the 90-s to the 360-s durations were statistically significant, $F(1, 11) > 6.1$, $p < .03$. Drinking was significantly below baseline when component duration was 15 s, $t(11) = 2.74$, $p < .01$, but was reliably above baseline at the 90- and 360-s durations, $t(11) > 1.84$, $p < .05$. This analysis indicates that polydipsia contrast does not occur when schedule components are very short in duration. Moreover, discrimination training had an identical effect on VT drinking in mixed and multiple schedules.

A mixed-design ANOVA (Group $\times$ Duration) indicated that drinking in the altered (EXT) component decreased relative to baseline as component duration increased, $F(2,20) = 92.6$, $p < .001$. Neither the main effect of Group nor the Group $\times$ Duration interaction was statistically significant; consequently, data for both groups were combined for subsequent analyses. Planned comparisons indicated that the decreases in drinking relative to baseline from the 15- to 90-s and from the 90- to 360-s durations were statistically significant, $F(1, 11) > 12.8$, $p < .006$. EXT drinking was not significantly different from baseline at the 15-s duration ($t < 1$), but was significantly below baseline at the 90- and 360-s durations, $t(11) > 4.81$, $p < .01$.

Figure 8 shows cumulative records of drink-

Fig. 7. Mean percentage of change from VT baseline in the EXT and VT components of mixed and multiple schedules at each of three component durations. Percentages were computed from the data shown in Table 1.

ing for Rat PC21. This subject was chosen by a naive observer as representative of the mixed-schedule group. A typical record was then chosen for baseline and discrimination sessions under the 15-, 90-, and 360-s component durations. These records also are reasonably representative of the multiple-schedule group, because cumulative records for the two groups were virtually indistinguishable.

Drinking was initiated by food deliveries and was distributed equally between the components of the mixed VT 30-s VT 30-s schedule during baseline (top panel). Discrimination training under a 15-s component duration produced discrete bouts of licking that were equally distributed throughout the session. At the 90- and 360-s durations, drinking was more clearly confined to the VT component. Drinking during EXT occasionally occurred as a continuation of postpellet licking from the preceding component. Polydipsia contrast may have resulted from increased drinking toward the end of discrimination sessions. Whereas drinking tended to decline over the session during baseline, food deliveries became increasingly effective in maintaining drinking bouts late in a session as component duration increased during discrimination training.

Fig. 8. Cumulative records for Rat PC21 during baseline, nondifferential training (*mix* VT 30-s VT 30-s schedule; top panel), and discrimination training under a *mix* EXT VT 30-s schedule with 15-s, 90-s, or 360-s schedule components (lower panels).

DISCUSSION

As predicted, polydipsia contrast increased as component duration increased in a multiple EXT VT schedule. Response competition, however, was not implicated as a factor in this relationship. Similar rates and patterns of drinking in mixed and multiple schedules suggest that neither S+ nor S- affected polydipsia contrast. Thus, the effect of component duration on VT drinking is difficult to explain in terms of competition from terminal behavior induced by S+. However, these data should not be taken as evidence that polydipsia contrast is independent of competition effects. The level of interaction between terminal and interim behavior remains in question, because terminal responding was not measured directly. Similar drinking patterns in mixed and multiple schedules could be accommodated by a competition hypothesis if terminal responding varied in an unpredicted manner in either schedule.

The mixed EXT VT schedule may have generated a higher rate of terminal responding than anticipated. In Experiment 1, immediate exposure to a mixed EXT VT schedule produced a trend toward EXT drinking, suggesting that some discrimination between schedule components was possible. Transitions from EXT to VT may have resulted in an analogous increment in terminal responding in the present study. Competition from such behavior might have been sufficient to produce similar VT lick rates in mixed and multiple schedules.

Alternatively, S+ may not have become a strong signal for food during discrimination training. Failure of S+ to differentially produce terminal responding in the multiple schedule would account for similar drinking in both schedules. More generally, if the component stimuli failed to accrue signal value, then discrimination training under mixed and multiple schedules was essentially identical. Similar drinking patterns would be expected, regardless of the amount of competition between response classes. Although the use of distinct component stimuli was intended to maximize stimulus control, a case can be made for weak control under the delayed discriminations of Experiments 1 and 3. The potential role of "blocking" (Kamin, 1969) in these studies is outlined below.

GENERAL DISCUSSION

Two drinking patterns occurred during discrimination training in the present study. *Stimulus-induced drinking*, characterized by high rates of licking at the onset of S-, with little or no drinking in the S+ component, occurred when the discrimination was introduced immediately after pretraining. *Pellet-induced drinking*, characterized by high rates of postpellet drinking in the presence of S+, with little drinking during S-, occurred when the discrimination was introduced after postpellet drinking was acquired. Each pattern is discussed below.

Stimulus-Induced Drinking

The present study identified some constraints on stimulus-induced drinking that may account for some of the reported difficulty in producing the phenomenon in earlier studies (see Porter & Hamm, 1984; Reid & Staddon, in press, for reviews). Training history was established as an important variable in Experiment 1. Drinking developed in, and was confined to, S- periods when discrimination training occurred immediately after pretraining. However, acquisition of a postpellet drinking pattern prior to discrimination training precluded S- drinking. The latter outcome probably is responsible for the absence of stimulus-induced drinking in several studies because postpellet licking was established before exposure to S- (e.g., Dougan et al., 1985; Iversen, 1977; Jacquet, 1972; Porter et al., 1975; Rosenblith, 1970). In contrast, in all successful demonstrations of stimulus-induced drinking (Alferink et al., 1980; Corfield-Sumner et al., 1977; Minor & Coulter, 1982) S- was introduced before stable interim responding had developed.

A comparison of mixed and multiple schedules in Experiment 1 indicated that discrimination difficulty affects interim drinking. Immediate exposure to a mixed EXT VT schedule (difficult discrimination) retarded the acquisition of drinking, but produced a trend toward EXT drinking in 3 of 4 rats. The presence of discriminative stimuli in the easy discrimination (*multiple* EXT VT schedule) enhanced acquisition and the tendency to drink during the EXT (S-) component.

Stimulus-induced drinking was confined to the initial sessions of discrimination training.

Most rats given immediate discrimination training eventually began drinking after food deliveries in the VT component. Once pellet-induced drinking emerged, further increases in S- drinking did not occur. In Experiment 2, the overall rate of stimulus-induced drinking and the number of sessions during which licking was confined to S- components were found to increase as component duration decreased.

The two drinking patterns seen during immediate discrimination training suggest that two sets of events can control interim behavior in a multiple EXT VT 30-s schedule: (a) the component stimuli, and (b) stimuli generated by intermittent food deliveries in the VT component. Different drinking patterns simply reflect control by one or more sets of these events. According to Staddon's (1977) motivational hypothesis, S- and food deliveries gained control of drinking because they signaled periods of nonreinforcement. If so, these events must have accrued inhibitory properties asymmetrically during the immediate discrimination, because stimulus-induced drinking emerged earlier in training than did pellet-induced drinking. This outcome may have occurred because the discrimination between S- and S+ was easier than was the temporal discrimination afforded by intermittent food deliveries, or because temporal cues in the VT component occurred in compound with S+, a strong signal for the presence of food. Summation of excitatory and inhibitory control in the VT component may have weakened the signal value of temporal cues, thus delaying the onset of postpellet drinking.

Pellet-Induced Drinking and Polydipsia Contrast

Delayed discrimination training resulted in an increase in lick rates in the unaltered VT component, and a decrease in drinking in the altered EXT component, in mixed and multiple schedules (polydipsia contrast; Experiments 1 and 3). In Experiment 3, the magnitude of polydipsia contrast was found to vary directly with component duration.

Polydipsia contrast resembles behavioral contrast, the increase in food-reinforced lever pressing in rats (Gutman, Sutterer, & Brush, 1975) or key pecking in pigeons (Reynolds, 1961), in the unaltered component of a multiple schedule during discrimination training. This similarity has been used to question Falk's (1971) classification of adjunctive (or interim)

activities as distinct from operant (or terminal) behavior (Hamm et al., 1981; Porter & Allen, 1977). If interim behavior is sensitive to manipulations that influence operant or terminal behavior (see Cohen, 1975; Reid & Staddon, in press, for additional parallels), the separation of types of behavior is questionable, especially to the extent that dual classification implies different mechanisms of control.

The present experiments, however, suggest that different mechanisms are responsible for behavioral contrast and polydipsia contrast, even though the two phenomena are similar in form. Whereas behavioral contrast in the rat does not occur reliably unless each component of a multiple schedule is signaled by a discriminative stimulus (Gutman et al., 1984), polydipsia contrast did not depend upon and was not influenced by component stimuli in the present study. Thus, whereas behavioral contrast has been attributed to the acquired signal value of S+ due to its differential correlation with food in a multiple EXT VI schedule (see Schwartz & Gamzu, 1977, for a review), this explanation cannot apply to polydipsia contrast. Instead, enhanced VT drinking is more likely to result from the reduction in food rate or lick rate in the altered EXT component following the shift from a multiple (or mixed) VT VT schedule to a multiple (or mixed) EXT VT schedule.

The comparison of mixed and multiple schedules (Experiments 1 and 3) also failed to provide evidence of stimulus-induced drinking during the delayed exposure to discrimination training. Drinking in EXT was equivalent in both schedules and occurred largely as a continuation of postpellet licking from the preceding component. This finding may indicate that initial control of drinking by food precludes later control by an S-. Alternatively, the failure of S- to enhance drinking could reflect weak or nonexistent inhibitory control.

The manipulation of immediacy of discrimination training was intended to assess the effects of pretraining postpellet drinking on subsequent responding during discrimination training. In retrospect, the immediate and delayed exposures to discrimination training differed not only on this dimension but also in the associative history of the component stimuli. As such, stimulus control may have differed markedly under each condition. Whereas immediate training may have maximized control by S+ and S-, the delayed procedure may

have blocked (Kamin, 1969) control by the component stimuli.

Blocking is a failure to obtain conditioning to the redundant element of a two-element compound because of initial pairings of the other element with a reinforcer (see Mackintosh, 1978, for a review). Delayed discrimination training paralleled the blocking experiment with respect to two signals for food in the multiple EXT VT schedule: (a) S+, and (b) the click accompanying a feeder operation. Feeder clicks were paired repeatedly with food during initial nondifferential training. This event and S+ formed a compound signal for food in later discrimination sessions. Even though S+ was differentially correlated with food in this phase, the presence of a pre-trained, highly valid signal may have blocked conditioning to S+, thereby reducing its ability to excite terminal responding. Moreover, when food is presented on a response-independent schedule, the absence of a feeder click is a perfect predictor of the absence of food. Thus, prior nondifferential training may have rendered S- a redundant signal for nonreinforcement, thereby reducing its ability to excite interim responding during discrimination training.

If blocking was a major factor in the delayed exposure to discrimination training, similar performance under mixed and multiple schedules is not surprising. Essentially, the multiple schedule was reduced to a mixed schedule. As this possibility cannot be dismissed without further research, two implications of the present data remain tenuous. First, pretraining a postpellet drinking pattern may not constrain subsequent control by S-. A strong inhibitor might shift control away from the pellet or simply enhance drinking in its presence. Second, polydipsia contrast in a multiple schedule may be substantially reduced relative to a mixed schedule when S+ exerts strong control over terminal responding. Competition from terminal behavior should inhibit drinking in the presence of S+ (Staddon, 1977), potentially shifting the interim response to S- components (Hinson & Staddon, 1978).

REFERENCES

- Alferink, L. A., Bartness, T. J., & Harder, S. R. (1980). Control of the temporal location of polydipsic licking in the rat. *Journal of the Experimental Analysis of Behavior*, **33**, 119-129.
- Allen, J. D., & Porter, J. H. (1977). Sources of control over schedule-induced drinking produced by second-order schedules of reinforcement. *Physiology & Behavior*, **18**, 853-863.
- Cohen, I. L. (1975). The reinforcement value of schedule-induced drinking. *Journal of the Experimental Analysis of Behavior*, **23**, 37-44.
- Corfield-Sumner, P. K., Blackman, D. E., & Stainer, G. (1977). Polydipsia induced in rats by second-order schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, **27**, 265-273.
- Dougan, J. D., McSweeney, F. K., & Farmer, V. A. (1985). Some parameters of behavioral contrast and allocation of interim behavior in rats. *Journal of the Experimental Analysis of Behavior*, **44**, 325-335.
- Falk, J. L. (1961). Production of polydipsia in normal rats by an intermittent food schedule. *Science*, **133**, 195-196.
- Falk, J. L. (1967). Control of schedule-induced polydipsia: Type, size, and spacing of meals. *Journal of the Experimental Analysis of Behavior*, **10**, 199-206.
- Falk, J. L. (1971). The nature and determinants of adjunctive behavior. *Physiology & Behavior*, **6**, 577-588.
- Gutman, A., & Minor, T. R. (1976). Local positive behavioral contrast in the rat. *Psychological Record*, **26**, 349-354.
- Gutman, A., Minor, T. R., & Sutterer, J. R. (1984). Discrimination training in semimixed and multiple schedules. *Psychological Record*, **34**, 427-435.
- Gutman, A., & Sutterer, J. R. (1977). The effect of discrimination training on the response rate and response duration of the rat. *Animal Learning & Behavior*, **5**, 247-252.
- Gutman, A., Sutterer, J. R., & Brush, F. R. (1975). Positive and negative behavioral contrast in the rat. *Journal of the Experimental Analysis of Behavior*, **23**, 377-383.
- Hamm, R. J., Porter, J. H., & Kaempff, G. L. (1981). Stimulus generalization of schedule-induced polydipsia. *Journal of the Experimental Analysis of Behavior*, **36**, 93-99.
- Hinson, J. M., & Staddon, J. E. R. (1978). Behavioral competition: A mechanism for schedule interactions. *Science*, **202**, 432-434.
- Iversen, I. H. (1977). Reinforcement omission and schedule-induced drinking in a response-independent schedule in rats. *Physiology & Behavior*, **18**, 535-537.
- Jacquet, Y. F. (1972). Schedule-induced licking during multiple schedules. *Journal of the Experimental Analysis of Behavior*, **17**, 413-423.
- Kamin, L. J. (1969). Predictability, surprise, attention, and conditioning. In B. A. Campbell & R. M. Church (Eds.), *Punishment and aversive behavior* (pp. 279-296). New York: Appleton-Century-Crofts.
- Kissileff, H. R. (1969). Food-associated drinking in the rat. *Journal of Comparative and Physiological Psychology*, **67**, 284-300.
- Lotter, E. C., Woods, S. C., & Vasselli, J. R. (1973). Schedule-induced polydipsia: An artifact. *Journal of Comparative and Physiological Psychology*, **83**, 478-484.
- Mackintosh, N. J. (1978). Cognitive or associative theories of conditioning: Implications of an analysis of blocking. In S. H. Hulse, H. Fowler, & W. K. Honig (Eds.), *Cognitive processes in animal behavior* (pp. 155-174). Hillsdale, NJ: Erlbaum.
- McCoy, J. F., & Christian, W. P. (1976). Schedule-

- induced drinking and reinforcement omission. *Physiology & Behavior*, **17**, 537-539.
- Millenson, J. R., Allen, R. B., & Pinker, S. (1977). Adjunctive drinking during variable and random-interval food reinforcement schedules. *Animal Learning & Behavior*, **5**, 285-290.
- Minor, T. R., & Coulter, X. (1982). Associative and postprandial control of schedule-induced drinking: Implications for the study of interim behavior. *Animal Learning & Behavior*, **10**, 455-464.
- Nevin, J. A., & Shettleworth, S. J. (1966). An analysis of contrast effects in multiple schedules. *Journal of the Experimental Analysis of Behavior*, **9**, 305-315.
- Pavlov, I. P. (1927). *Conditioned reflexes* (G. V. Anrep, Trans.). London: Oxford University Press.
- Porter, J. H., & Allen, J. D. (1977). Schedule-induced polydipsia contrast in the rat. *Animal Learning & Behavior*, **5**, 184-192.
- Porter, J. H., Azarie, R., Holbrook, J. W., Cheek, M. S., & Allen, J. D. (1975). Effects of variable and fixed second-order schedules on schedule-induced polydipsia in the rat. *Physiology & Behavior*, **14**, 143-149.
- Porter, J. H., & Hamm, R. J. (1984). Associative control of schedule-induced drinking. *Animal Learning & Behavior*, **12**, 339-340.
- Rachlin, H. (1973). Contrast and matching. *Psychological Review*, **80**, 217-234.
- Reid, A. K., & Staddon, J. E. R. (in press). Mechanisms of schedule entrainment. In S. J. Cooper & C. T. Dourish (Eds.), *Neurobiology of behavioral stereotypy*. Oxford: Oxford University Press.
- Reynolds, G. S. (1961). Behavioral contrast. *Journal of the Experimental Analysis of Behavior*, **4**, 57-71.
- Rosenblith, J. Z. (1970). Polydipsia induced in the rat by a second-order schedule. *Journal of the Experimental Analysis of Behavior*, **14**, 139-144.
- Schwartz, B., & Gamzu, E. (1977). Pavlovian control of operant behavior: an analysis of autoshaping and its implications for operant conditioning. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior* (pp. 53-97). Englewood Cliffs, NJ: Prentice-Hall.
- Shimp, C. P., & Wheatley, K. L. (1971). Matching to relative reinforcement frequency in multiple schedules with a short component duration. *Journal of the Experimental Analysis of Behavior*, **15**, 205-210.
- Silberberg, A., & Schrot, J. (1974). A yoked-chamber comparison of concurrent and multiple schedules: The relationship between component duration and responding. *Journal of the Experimental Analysis of Behavior*, **22**, 21-30.
- Staddon, J. E. R. (1977). Schedule-induced behavior. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior* (pp. 123-152). Englewood Cliffs, NJ: Prentice-Hall.
- Staddon, J. E. R., & Simmelhag, V. L. (1971). The "superstition" experiment: A reexamination of its implications for the principles of adaptive behavior. *Psychological Review*, **78**, 3-43.
- Stein, L. (1964). Excessive drinking in the rat: Superstition or thirst? *Journal of Comparative and Physiological Psychology*, **58**, 237-242.

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