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**ETHANOL-MAINTAINED PERFORMANCE  
OF RATS UNDER INTERVAL SCHEDULES**

**PATRICK M. BEARDSLEY  
GREGORY A. LEMAIRE  
and  
RICHARD A. MEISCH**

ETHANOL MAINTAINED PERFORMANCE OF RATS UNDER  
INTERVAL SCHEDULES<sup>1</sup>

Patrick M. Beardsley, Gregory A. Lemaire, and Richard A. Meisch

Department of Psychiatry - University of Minnesota

<sup>1</sup>This research was supported by NIAAA grant 00299 and by a Research Scientist Development Award DA 00007, to Richard A. Meisch. The data for this report were collected while P.M. Beardsley was a NIDA Predoctoral Fellowship Awardee, DA 05111. P.M. Beardsley is now at the Addiction Research Foundation, Biobehavioral Research Division, 33 Russell Street, Toronto, Ontario M5S 2S1, Canada.

## Abstract

Dipper cups filled with an 8% (w/v) ethanol solution were presented to Long-Evans hooded rats according to either a multiple Extinction  $\underline{x}$  sec Fixed-Ratio 1 or a chain Differential-Reinforcement-of-Other-Behavior  $\underline{x}$  sec Fixed-Ratio 1 schedule of reinforcement. The scheduled value of the extinction and differential-reinforcement-of-other-behavior components was varied to manipulate minimum-interreinforcer interval. Minimum-interreinforcer intervals from 0 to 480 sec were tested in an ascending series followed by a descending, retest series. A water-control condition at a 0-sec duration followed the final 8% 0-sec retest condition. Increasing the minimum-interreinforcer interval reduced the number of ethanol presentations obtained. The number of ethanol presentations obtained was always less than the maximum number obtainable permitted by the value of the minimum-interreinforcer interval. Group mean presentations during the retest condition usually exceeded presentations during the corresponding test condition. Water presentations were infrequent and less than 8% ethanol presentations obtained during similar 0-sec conditions.

Key words: Ethanol, minimum-interreinforcer interval, chain DRO FR schedule, mult EXT FR schedule, lever press, rats

Ratio and interval schedules of reinforcement are the two fundamental methods of arranging deliveries of positive reinforcers (Ferster & Skinner, 1957). In recent reviews Johanson (1978) and Spealman and Goldberg (1978) noted that although drug self-administration by animals under ratio schedules of reinforcement has been studied extensively, little attention has been given to interval schedules of drug reinforcement. When interval schedules have been used to arrange drug deliveries, the drugs have usually been delivered via the intravenous or intramuscular routes. Only a few studies involving interval reinforcement schedules have delivered drugs orally.

Interval reinforcement schedules have characteristics advantageous to the study of drugs as reinforcers. For example, they can be used to space drug-taking opportunities. Previous studies with human subjects who had oral drug use histories have demonstrated that the minimum-interreinforcer interval imposed by interval reinforcement schedules can be a critical determinant of oral drug self-administration. Gottheil and associates (Gottheil, Corbett, Grassberger, & Cornelison, 1972; Gottheil, Murphy, Skoloda, & Corbett, 1972) found that 2/3 of the alcoholics on a closed hospital ward either abstained from drinking or eventually stopped drinking ethanol when drinks were spaced by a minimum interval of 60 min. Bigelow, Griffiths, and Liebson (1975) found that incrementing the minimum-interreinforcer interval for ethanol reduced the percentage of available drinks consumed by alcoholics. These researchers also found reductions in pentobarbital and diazepam oral self-administration with increments in the interval separating drug taking opportunities (Griffiths, Bigelow, & Liebson, 1976). Research with rats has also demonstrated the potential importance of the

minimum-interreinforcer interval. Anderson and Thompson (1974) examined rats' 8% (w/v) ethanol drinking with fixed-interval schedules (FI) ranging from 0 to 240 sec. These investigators found that increasing the fixed-interval duration resulted in reductions of ethanol intake. Additionally, they found that the pattern of responding for ethanol was characterized by a pause after an ethanol delivery followed by a progressively higher rate of responding until the next delivery. This type of response pattern is similar to fixed-interval response patterns obtained with non-drug reinforcers (Ferster & Skinner, 1957).

The purpose of the present experiment was to further examine the effects of minimum-interreinforcer interval imposed by interval reinforcement schedules on performance maintained by 8% (w/v) ethanol. The number of interreinforcement responses can be a controlling variable of subsequent behavior (Crossman, Heaps, Nunes, & Alferink, 1974). In the Anderson and Thompson (1974) FI-schedule study the number of interreinforcement responses varied widely and may have acted along with the minimum-interreinforcer interval to control ethanol-maintained performance. Because minimum inter-reinforcer interval, per se, was the independent variable of interest in the present study, types of interval reinforcement schedules were used which were expected to minimize interreinforcement response occurrence. This experiment is the first in a series which examine temporal and response constraints on oral ethanol self-administration.

## Method

### Subjects

The subjects were ten experimentally naive male Long-Evans descent hooded rats (Blue Spruce Farms, Altamont, N.Y.) approximately 120 days old at the beginning of the study. The rats were assorted into five pairs based on their similarity in free-feeding body weight. One member from each pair, selected randomly, was then assigned to the T-Group. The remaining rats composed the V-Group. The rats were maintained at 80% of their free-feeding body weights and were individually housed in a continuously illuminated room regulated at 24<sup>o</sup> C. Water was always available in the rats' home cages except during the initial training period as noted below.

### Apparatus

Five identical sound-attenuated commercial operant-conditioning chambers (Lehigh Valley Electronics) were equipped with two levers and a solenoid driven liquid dipper. The levers were symmetrically centered on the front panel and were separated by an inactivated food magazine. An opening in the panel was located to the right of the magazine. The dipper cup was situated within this opening. Three colored jewel lights were located above each lever. A 4.76 W white light was located 3.2 cm above the hole in the panel where the dipper was located. A 2.80 W house light was centered at the top of the front panel. The speaker of a Sonalert (Sonalert, 2900 Hz Mallory and Co.) was located immediately below the house light. Reinforced lever presses resulted in the refilling of the dipper cup with .11 ml liquid. During refilling, the dipper cup was lowered into a reser-

voir and then returned to the up-available position. Simultaneous with the dipper cup refilling operation was a .8 sec sounding of the Sonalert and illumination of the white light above the dipper-panel opening. White masking noise was constantly present, and an exhaust fan provided ventilation.

Programming and data recording were automatically controlled by standard electromechanical equipment in an adjacent room. The temporal pattern of responses and dipper presentations was continuously recorded by a cumulative recorder and by a counter that printed out every 5 minutes.

### Procedure

Daily 3-hr experimental sessions were conducted throughout the experiment. All schedule requirements pertained to presses of the right lever. Presses of the left lever had no programmed consequence but were recorded. Initially, the rats were induced to lever press for water on a fixed-ratio 1 (FR 1) schedule of reinforcement by depriving them of water at their home cages and by feeding them their daily maintenance allotment of Purina Laboratory Chow in their operant chambers. Following two consecutive sessions of water responding, water bottles were restored to the home cages and access to 2, 4, and 8% (w/v) ethanol was made available for 2, 4, and 6 sessions, respectively, with daily maintenance food provided during experimental sessions. Subsequently, in-session feedings were discontinued, and food was given to the rats only in their home cages following each session. The rats were then treated differently depending upon their group membership. The T-Group rats were allowed access to 8% (w/v) ethanol on a multiple Extinction  $\underline{x}$  sec Fixed Ratio 1 (mult ext  $\underline{x}$  FR 1) schedule of reinforcement. During the EXT component, lever presses had no programmed con-

sequence and the dipper cup could not be refilled. During the FR 1 component, the dipper cup was refilled contingent upon a single lever press. Following a dipper delivery, the EXT component was reinstated. The jewel lights were lit during the EXT component and unlit during the FR 1 component. The illumination of the house light signalled the FR 1 component and was unlit with the onset of the EXT component (see the top frame of Figure 1 for an example of T-Group contingencies).

The V-Group rats were given access to 8% (w/v) ethanol on a chain Differential-Reinforcement-of-Other-Behavior  $\underline{x}$  sec FR 1 (chain DRO  $\underline{x}$  sec FR 1) schedule of reinforcement. During the DRO component the dipper cup could not be refilled and lever presses reset a clock which extended the DRO component by  $\underline{x}$  sec. During the FR 1 component the dipper cup was refilled contingent upon a single lever press. After an absence of lever pressing during the DRO component for  $\underline{x}$  sec, the FR 1 component was initiated. Following a dipper delivery during the FR 1 component, the DRO component was reinstated. The jewel lights were lit during the DRO component and unlit during the FR 1 component. The onset of the house light signalled the FR 1 component and was unlit with the onset of the DRO component (see the bottom frame of Figure 1 for an example of the V-Group contingencies). Different schedules of reinforcement were used with the T- and V-Groups to insure a constant interval between drinking opportunities (with the mult EXT  $\underline{x}$  sec FR 1 schedule in the T-Group) or to insure a constant interval without a lever press preceding drinking opportunities (with the chain DRO  $\underline{x}$  sec FR 1 schedule in the V-Group).

Tests at EXT and DRO component durations of 0, 7.5, 15, 30, 60, 120,



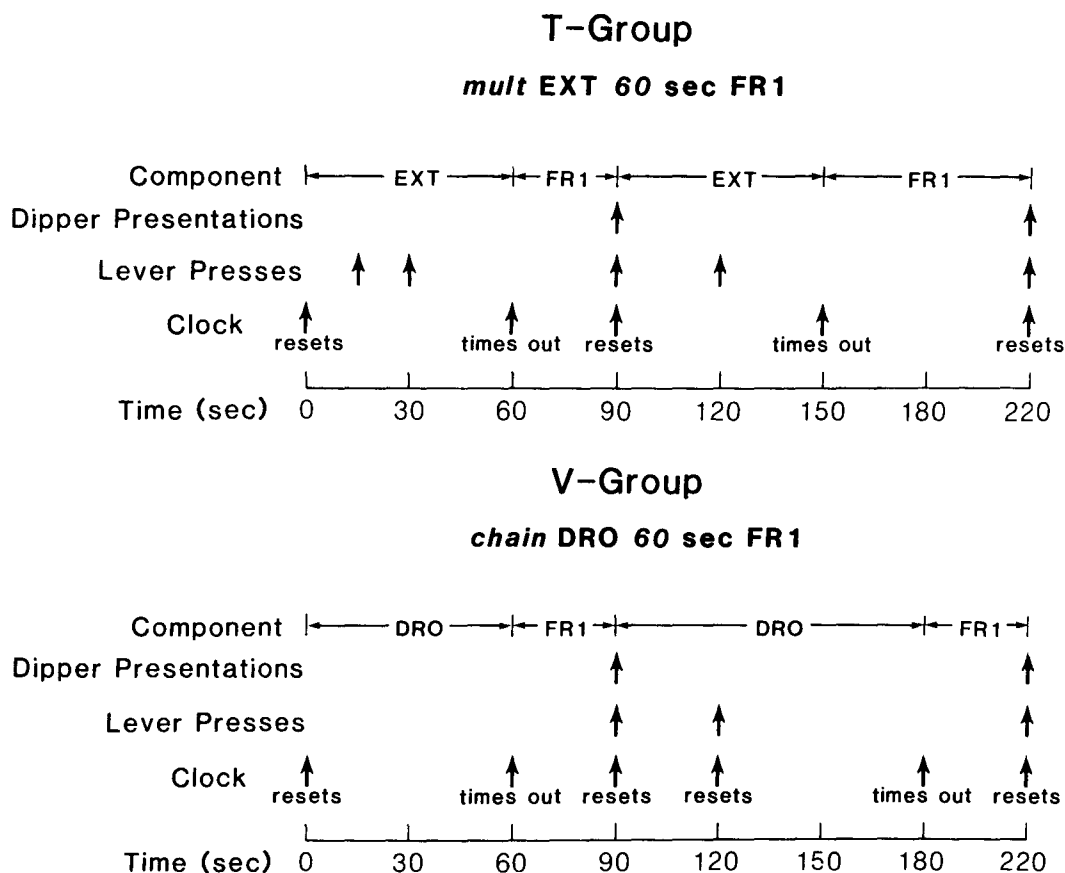


Figure 1. Examples of T-Group (upper frame) and V-Group (lower frame) contingencies during Experiment 1. Minimum-interreinforcer intervals were controlled by the duration of the EXT component (T-Group) or DRO component (V-Group). In these examples 60 sec was the scheduled minimum-interreinforcer interval. A single lever press during the FR 1 component refilled the dipper cup and initiated the next interreinforcer interval. Differential conditions were associated with each component. Note that the only difference in treatment between the groups was that lever presses during the EXT component had no programmed consequence, while lever presses during the DRO component caused the clock timing the DRO component to restart, extending the DRO interval by 60 sec.

240, and 480 sec were followed by retests at 240, 120, 60, 30, 15, 7.5, and 0 sec, in that order. If a rat obtained, on the average, 20 or fewer ethanol presentations at a particular duration, longer durations were not tested. This criterion was enforced to prevent extinction of ethanol responding which would have necessitated retraining during the test series. Rats T-1, T-2, V-1, and V-5 obtained 20 or fewer ethanol presentations at 240 sec and subsequently were not tested at 480 sec. Following completion of the 0-sec retest condition, water was made the available liquid at a duration of 0 sec. Excepting the 0-sec test condition, in which the rats were maintained for 10 consecutive stable sessions, changes from one condition to the next were made following five consecutive sessions in which there were no systematic increases or decreases in the number of dipper presentations.

The solutions, expressed in grams percent (w/v), were prepared using 95% (v/v) ethanol in tap water. The solutions were prepared at least 20 hr before use and were kept in stoppered flasks at room temperature. The volume consumed was measured at the end of each session by subtracting the volume remaining from the volume added to the reservoir, corrected for evaporation. Because the volume measured by this method was sometimes greater than the product of dipper-cup size (.11 ml) and the number of dipper presentations, this product was used for calculations of volume consumption.

## Results

Increasing the EXT (Figure 2 & Tables A-F) and DRO (Figure 3 & Tables G-L) component durations resulted in progressive decreases in the number of dipper presentations obtained. When exceptions to this relationship occurred, they usually occurred at the shorter durations. The mean number of dipper presentations for the T-Group decreased from 100.0 and 100.9 per session for the test and retest conditions at 0 sec, to 22.9 per session at 240 sec. The mean number of dipper presentations obtained by the three T-Group rats tested at 480 sec and retested at 240 sec was 15.5 and 26.9 per session, respectively. The mean dipper presentations for the V-Group decreased from 105.0 and 136.5 per session for the test and retest conditions at 0 sec, to 22.1 per session at 240 sec. The mean number of ethanol deliveries obtained by the three V-Group rats tested at 480 sec and retested at 240 sec was 14.5 and 27.5 per session, respectively. Group mean number of presentations obtained during the retest conditions usually exceeded the number obtained during the corresponding test conditions. In 5 of 7 comparisons for the T-Group, and in 7 of 7 comparisons for the V-Group, retest means exceeded test means. When water was made available at 0 sec, presentations were infrequent and fewer in number than those obtained with 8% ethanol.

The number of dipper presentations obtained was not determined by the maximum number of possible dipper presentations imposed by the value of the EXT and DRO components. Figures 4 (T-Group) and 5 (V-Group) show the percent of possible dipper presentations obtained at each duration for the test and retest conditions. Subjects never obtained all of the possible

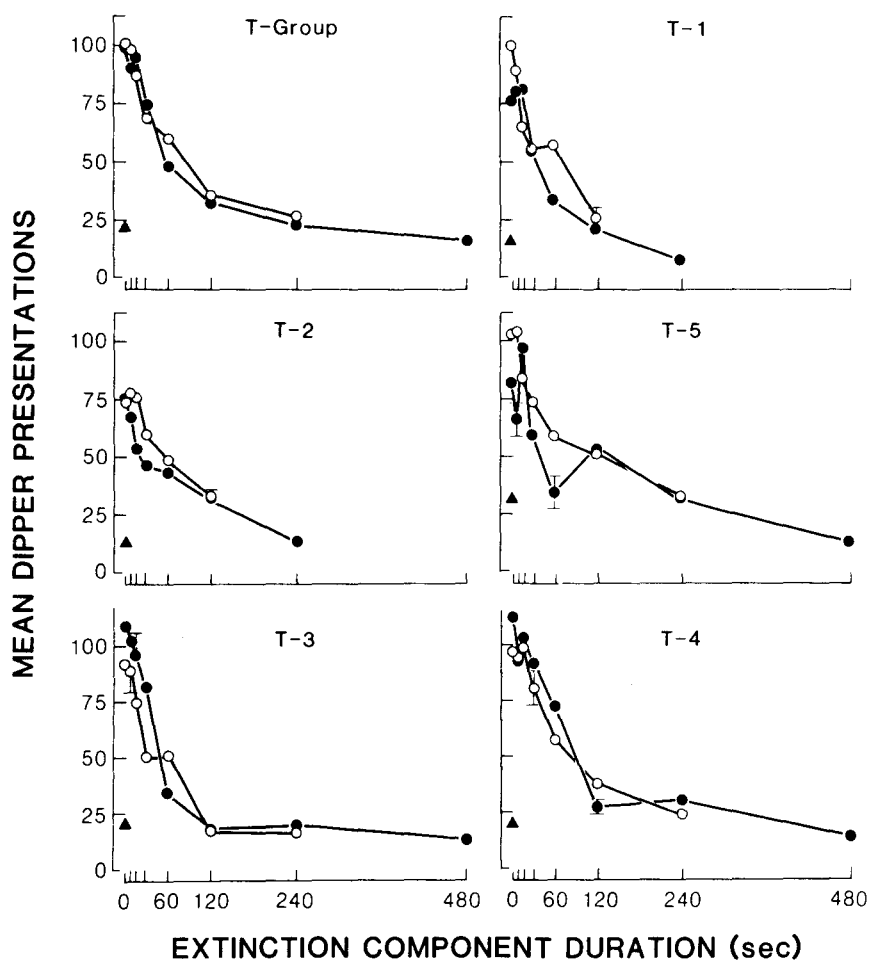


Figure 2. Mean dipper presentations obtained by the T-Group and individual T-rats as a function of EXT component duration. Filled circles: ascending, 8% ethanol test values. Unfilled circles: descending, 8% ethanol retest values. Filled triangles: water control values. Excepting for the 0-sec 8% test value, each point within individual subject frames represents the mean of five consecutive sessions. Brackets indicate the standard errors of the mean. Brackets are plotted only for standard errors that exceeded 10% of the mean. Absence of a data point indicates that the rat failed to meet criterion performance during a preceding condition and was not subsequently tested at longer intervals. The 0-sec 8% test value represents the mean of 10 consecutive sessions. Points in the group graph represent the mean of available subject means (N=5; except for 480 sec, N=3).

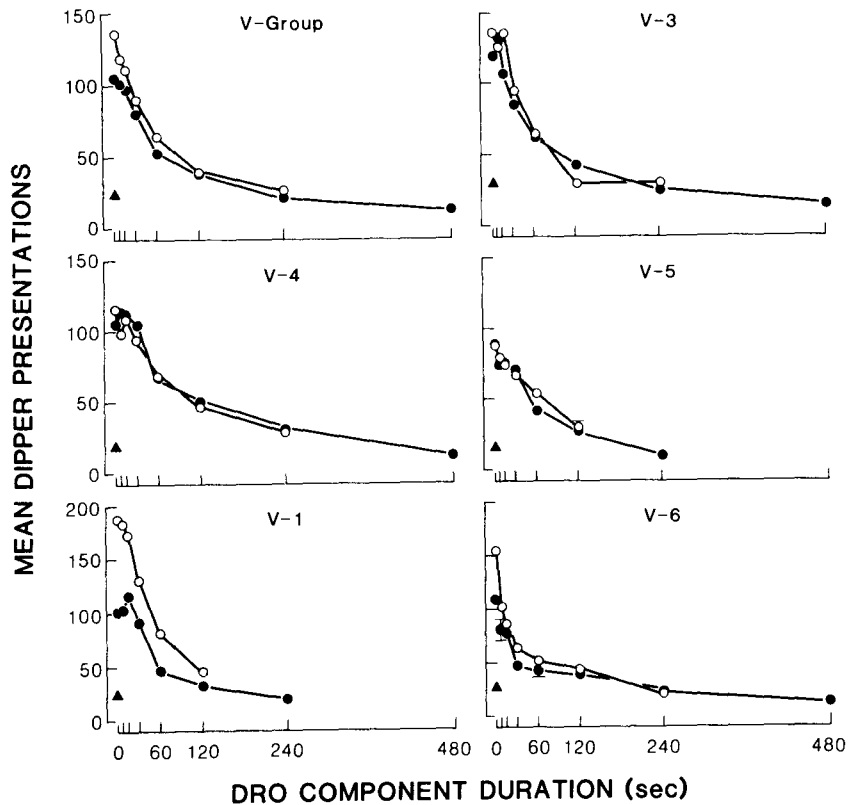


Figure 3. Mean dipper presentations obtained by the V-Group and individual V-rats as a function of DRO component duration. Filled circles: ascending, 8% ethanol test values. Unfilled circles: descending, 8% ethanol retest values. Filled triangles: water control values. Excepting for the 0-sec 8% test value, each point within individual subject frames represents the mean of five consecutive sessions. Brackets indicate the standard errors of the mean. Brackets are plotted only for standard errors that exceeded 10% of the mean. Absence of a data point indicates that the rat failed to meet criterion performance during a preceding condition and was not subsequently tested at longer intervals. The 0-sec 8% test value represents the mean of 10 consecutive sessions. Points in the group graph represent the mean of available subject means (N=5; except for 480 sec, N=3).

dipper presentations available at any duration. The mean percent of possible dipper presentations obtained between 7.5 and 240 sec increased with increasing duration for both the T- and V- rats. However, two of the three T-rats (T-4 and T-5) and one of the three V-rats (V-4) tested at 480 sec showed decreases in the percent of possible dipper presentations obtained between 240 and 480 sec.

Figures 6 (T-Group) and 7 (V-Group) show that ethanol intake (mean mg ethanol/kg body weight/3-hr session) decreased with increasing EXT and DRO durations (see also Tables A-L). V-Group ethanol intake was higher than T-Group intake at most durations tested.

The mean number of lever presses emitted per dipper presentation did not systematically vary with DRO component duration (Figure 9 & Tables G-L). The V-Group mean number of lever presses per presentation was close to unity during most conditions, and never exceeded 2.0 per presentation. However, for the T-Group the mean number of lever presses per dipper presentation first increased then decreased between EXT values of 0 and 240 sec (see Figure 8 & Tables A-F). Nevertheless, mean T-Group response output never exceeded 3.0 responses per presentation. For both groups, mean responses per presentation were usually less during the retest phase than the test phase at identical durations. In 33 possible comparisons between the test and retest phases across the T-rats (3 rats x 7 conditions each + 2 rats x 6 conditions each) 27 comparisons had higher response per presentation means during the test phase, 5 were higher during the retest phase, and, in one case, they were identical. In similar comparisons across the V-rats, 25 of 33 comparisons showed more responses per presentation during the test phase, and in one comparison they were equal.

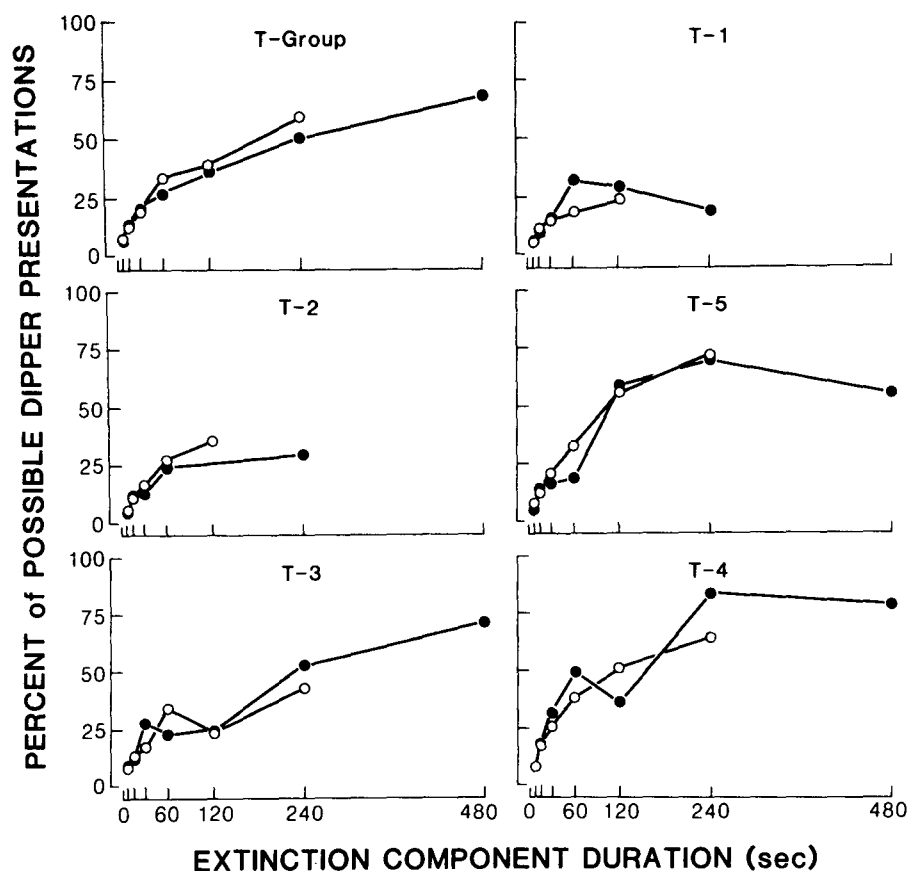


Figure 4. Percent of possible dipper presentations obtained by the T-Group and individual T-rats as a function of EXT component duration. Filled circles: ascending, 8% ethanol test values. Unfilled circles: descending, 8% ethanol retest values. Each point was determined by dividing the actually obtained mean number of dipper presentations by the maximum number potentially obtainable within a 3-hr session and then multiplying this quotient by 100. Absence of a data point indicates that the rat failed to meet criterion performance during a preceding condition and was not subsequently tested at longer intervals.

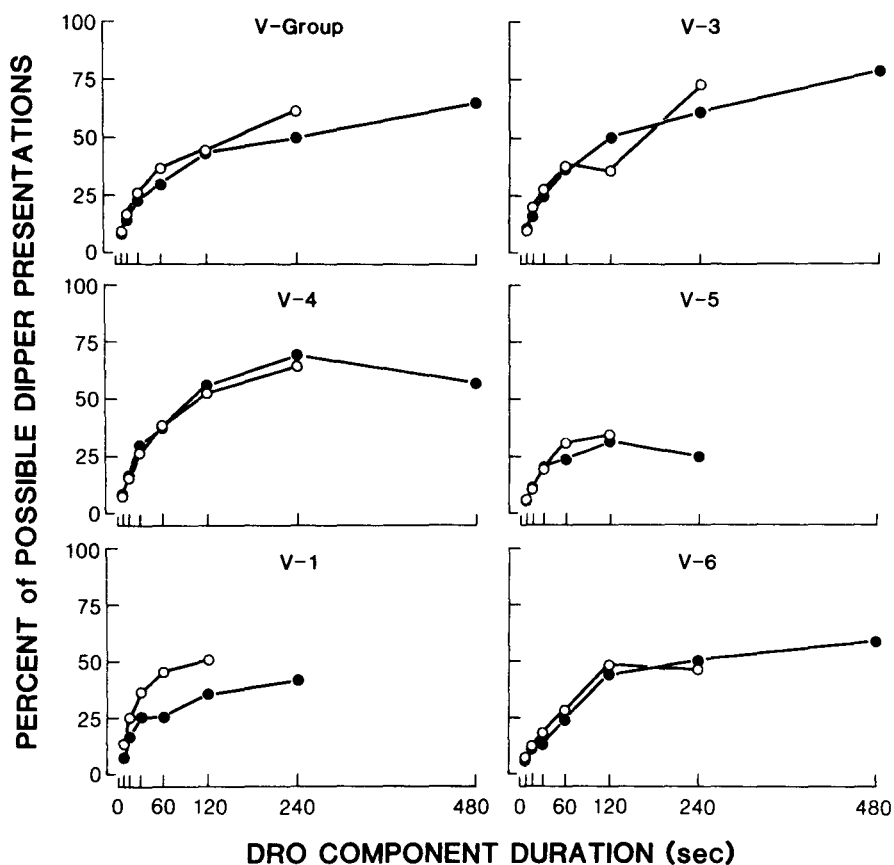


Figure 5. Percent of possible dipper presentations obtained by the V-Group and individual V-rats as a function of DRO component duration. Filled circles: ascending, 8% ethanol test values. Unfilled circles: descending, 8% ethanol retest values. Each point was determined by dividing the actually obtained mean number of dipper presentations by the maximum number potentially obtainable within a 3-hr session and then multiplying this quotient by 100. Absence of a data point indicates that the rat failed to meet criterion performance during a preceding condition and was not subsequently tested at longer intervals.



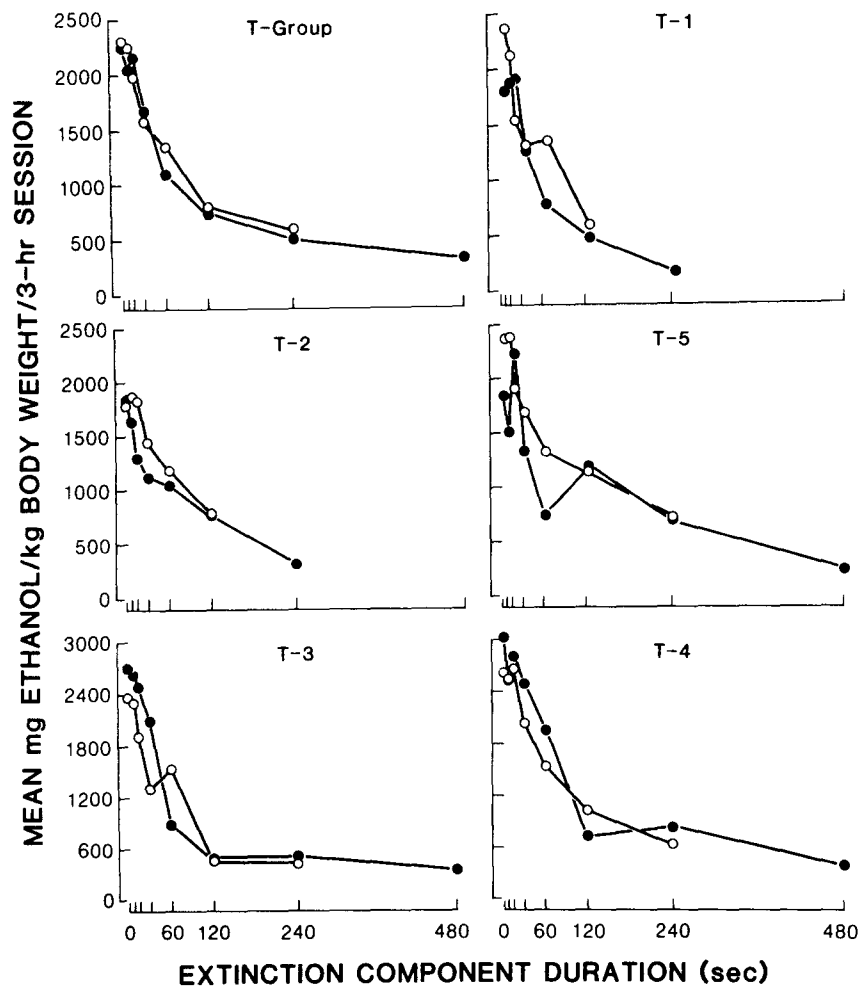


Figure 6. Mean ethanol intake (mean mg ethanol/kg body weight/3-hr session) of the T-Group and individual T-rats as a function of EXT component duration. Filled circles: ascending, 8% ethanol test values. Unfilled circles: descending, 8% ethanol retest values. Excepting for the 0-sec 8% test value, each point within individual subject frames represents the mean of 5 consecutive sessions. Absence of a data point indicates that the rat failed to meet criterion performance during a preceding condition and was not subsequently tested at longer intervals. The 0-sec 8% test value represents the mean of 10 consecutive sessions. Points in the group graph represent the mean of all available rat means.

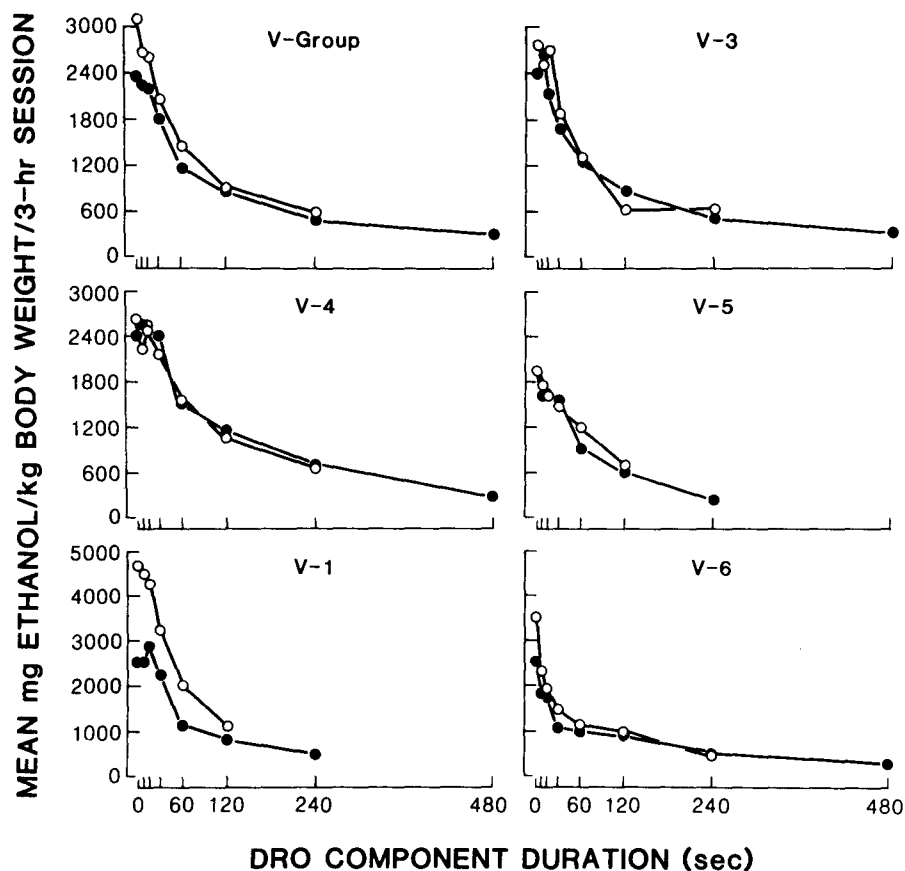


Figure 7. Mean ethanol intake (mean mg ethanol/kg body weight/3-hr session) of the V-Group and individual V-rats as a function of DRO component duration. Filled circles: ascending, 8% ethanol test values. Unfilled circles: descending, 8% ethanol retest values. Excepting for the 0-sec 8% test value, each point within individual subject frames represents the mean of 5 consecutive sessions. Absence of a data point indicates that the rat failed to meet criterion performance during a preceding condition and was not subsequently tested at longer intervals. The 0-sec 8% test value represents the mean of 10 consecutive sessions. Points in the group graph represents the mean of all available rat means.

Sample cumulative records at each condition for V-6 (Figure 10) show that ethanol presentations occurred in bursts, with the largest burst occurring at the beginning of each session. Unreinforced ethanol responses (lever presses occurring during the DRO components) were infrequent. When water was available at a schedule duration of 0 sec, few dipper presentations occurred.

### Discussion

Increases in minimum-interreinforcer interval resulted in decreases in both ethanol deliveries and ethanol intake. An inverse relationship between minimum-interreinforcer interval and ethanol intake has been similarly found with humans (Bigelow et al., 1975) and with Sprague-Dawley rats (Anderson and Thompson, 1974). The present data systematically extends this relationship to include additional schedules of reinforcement (mult EXT  $\underline{x}$  sec FR 1 and chain DRO  $\underline{x}$  sec FR 1), a different strain of rat (Long-Evans Hooded rats), different dipper cup size (.11 ml per delivery), and different session length (3 hr).

The decreases in ethanol deliveries that occurred with increases in minimum-interreinforcer interval were not due to the rats obtaining the maximum number of deliveries permitted at a particular condition (Figures 4 and 5). There are at least three variables which could account for the decreases in ethanol deliveries. One variable could have operated through response-rate altering effects that follow ethanol absorption. At session onset with short minimum-interreinforcer intervals lever pressing was so rapid that significant absorption of ethanol could not have occurred between deliveries. Drug absorption can modulate subsequent drug intake by

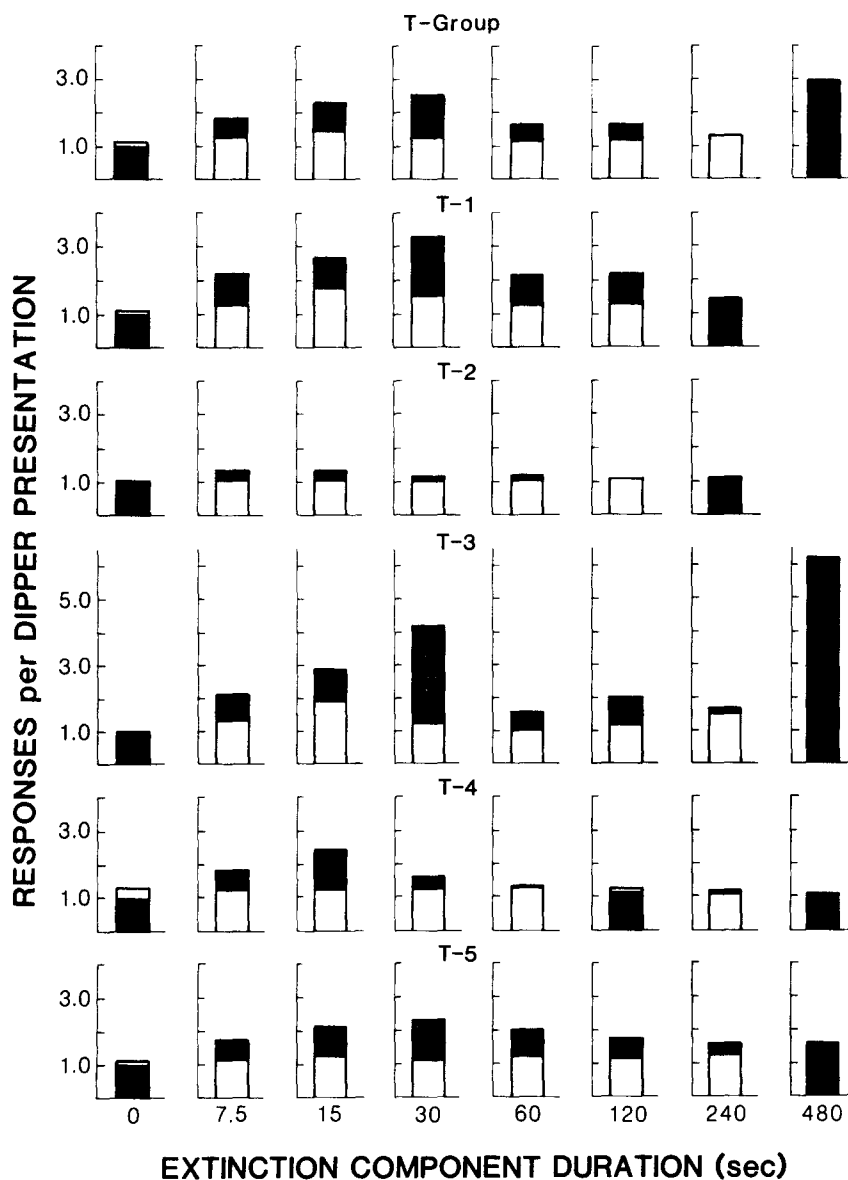


Figure 8. Mean number of lever presses per dipper presentation emitted by the T-Group and individual T-rats as a function of EXT component duration. Filled bars: ascending, 8% test condition. Unfilled bars: descending, 8% ethanol retest condition. Each value was determined by dividing the mean number of lever presses by the mean number of dipper presentations obtained at each condition. Absence of a bar indicates that the rat failed to meet criterion performance during a preceding condition and was not subsequently tested at longer intervals.

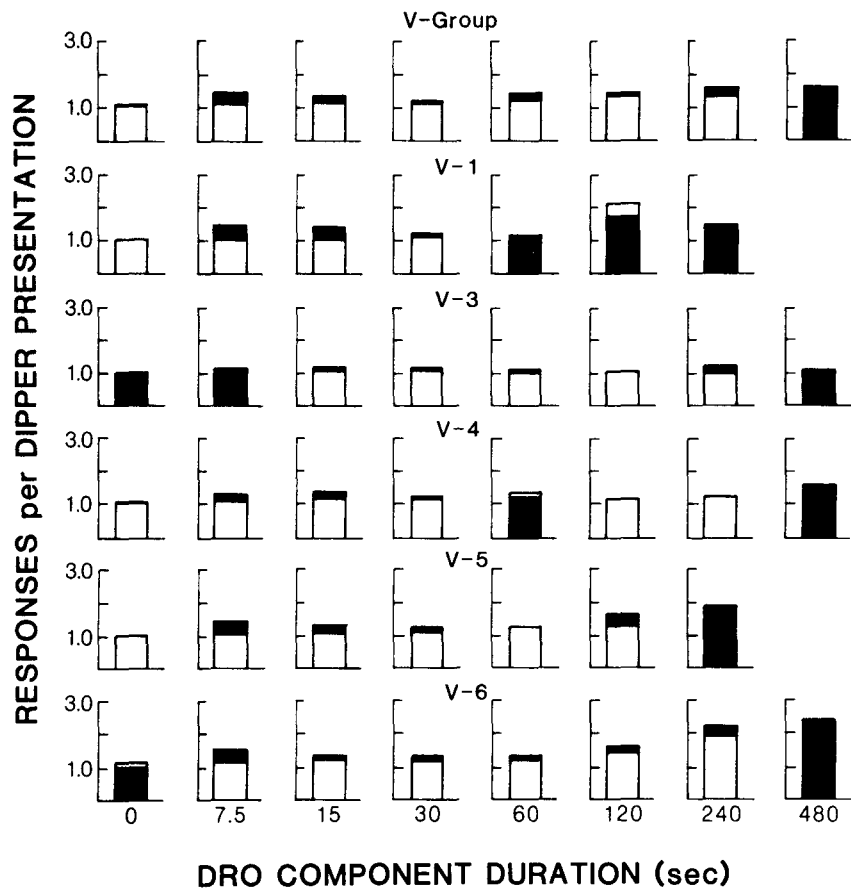


Figure 9. Mean number of lever presses per dipper presentation emitted by the V-Group and individual V-rats as a function of DRO component duration. Filled bars: ascending, 8% test condition. Unfilled bars: descending, 8% ethanol retest condition. Each value was determined by dividing the mean number of lever presses by the mean number of dipper presentations obtained at each condition. Absence of a bar indicates that the rat failed to meet criterion performance during a preceding condition and was not subsequently tested at longer intervals.

## V-6

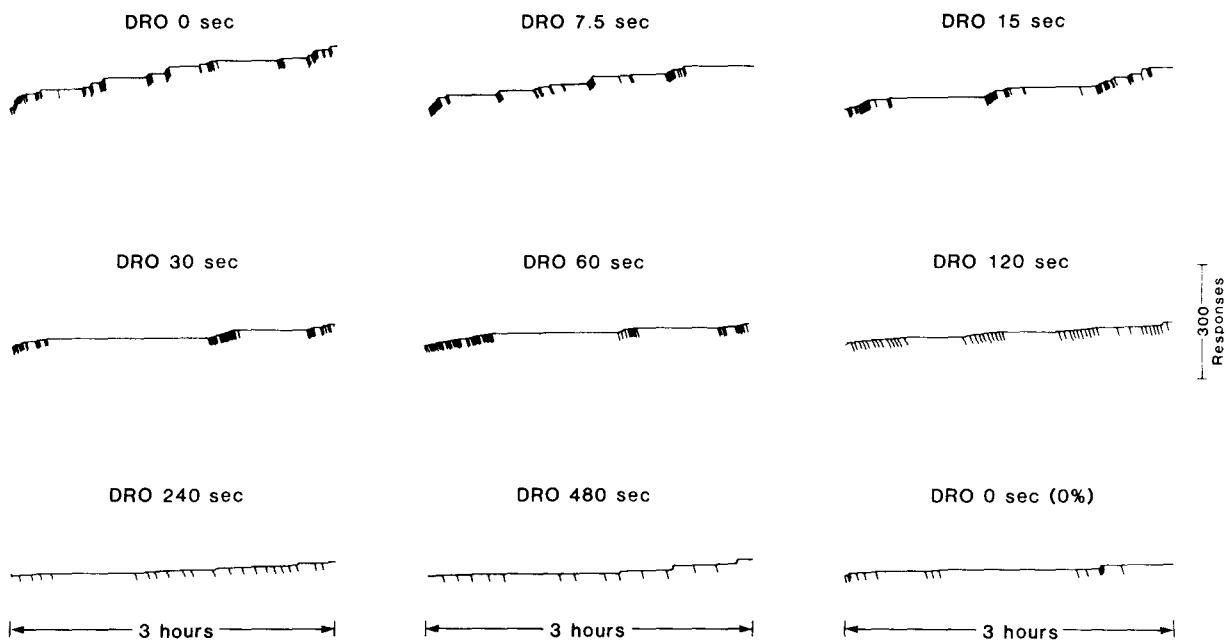


Figure 10. Sample cumulative records of V-6 at each DRO component duration tested with 8% ethanol available and from the water control condition. Vertical steps in the pen indicate lever presses. Pen pips represent dipper presentations. Records from V-6 were selected because its mean number of dipper presentations were, overall, closest to the group mean number.

nonspecifically suppressing subsequent drug responding (see Pickens, Meisch, & Thompson, 1978; Thompson & Schuster, 1968). At longer minimum-interreinforcer intervals sufficient ethanol absorption could occur to suppress subsequent drug responding. The rats may have decreased their ethanol intake at long minimum-interreinforcer intervals because of the control exerted by previously absorbed ethanol.

Two additional variables which may have influenced lever pressing were the number of interreinforcement responses and the interreinforcement interval. The number of interreinforcement responses (Crossman, Heaps, Nunes, & Alferink, 1974) and interreinforcement interval (Neuringer & Schneider, 1968) have been demonstrated to be controlling variables in schedules involving non-drug reinforcers. Fewer than an average of two responses for the V-Group, and three responses for the T-Group were emitted per ethanol delivery across all conditions. Because so few responses were emitted per delivery it is unlikely that the number of interreinforcement responses could have been the dominant controlling variable affecting the number of obtained deliveries. If the interreinforcement interval was a major controlling variable (which seems likely) the mechanism by which it operated was not isolated in the present experiment. For example, time-out periods can have punisher-like effects (e.g., McMillan, 1967). Perhaps long interreinforcement intervals function in a manner similar to time-out periods and lever pressing is suppressed via a punishment mechanism. Or, because ethanol drinking could not occur in continuous bouts (the typical pattern of drinking on less intermittent reinforcement schedules) ethanol may be weakened as a reinforcer. Further research is needed to ascertain the relative importance of each variable and the mechanisms through which they act

to decrease ethanol deliveries.

Marcucella (1974) studied food-reinforced performance of rats with signalled differential-reinforcement-of-low-rate schedules (signalled DRL schedules). A signalled DRL schedule is functionally equivalent to a chain DRO FR 1 schedule with which the V-Group rats were tested. Marcucella (1974) found that increases in DRL duration between 5 and 240 sec resulted in systematic decreases in the proportion of unreinforced responses to total responses. In the present experiment increases in the DRL (i.e., DRO) duration resulted in unsystematic variations in the number of responses per dipper presentation. Since the proportion of unreinforced responses to total responses and the number of total responses per reinforcer delivery must necessarily covary, Marcucella's (1974) findings and the results of the V-Group do not agree. There are a number of procedural differences between the studies that possibly could account for this discrepancy. For example, Marcucella (1974) primarily used a between-subjects design and terminated each session after 150 food deliveries, whereas the present experiment used a within-subject design and terminated each session after 3 hours duration, regardless of the number of dipper presentations obtained. The results of the V-Group are more compatible with results obtained by Richardson and Loughhead (1974) who studied food-reinforced performance of rats with unsignalled DRL schedules in a within-subjects design using sessions of fixed duration. Similar to the results of the V-Group, these investigators found unsystematic variations in the number of responses per reinforcer delivery with increases in DRL duration (between 1 and 7 min). Additionally, they found that responses averaged less than 3 per food delivery (across a range of DRL values from 1 to 7 min) which is similar to the V-



Group's average of less than 2 responses per dipper presentation (across a range of DRL values from 0 to 480 sec).

Up through minimum-interreinforcer intervals of 60 sec most subjects consumed ethanol in amounts exceeding 300 mg/kg body weight/hr, their rate of metabolizing ethanol (Wallgren and Barry, 1970). At minimum-interreinforcer intervals exceeding 60 sec, ethanol metabolism usually exceeded ethanol consumption. On days when ethanol consumption greatly exceeded metabolic rate, gross locomotor ataxia was not readily apparent. However, the rats did show evidence of sedation and relaxed muscle tonicity on days of high ethanol consumption.

In the FI study of Anderson and Thompson (1974) estimates of ethanol intake (mg ethanol consumed/kg body weight/session) were not provided. However, estimates can be derived by using Figure 6 from Anderson and Thompson (1974) to obtain the mean volumes of ethanol consumed which can then be converted to intake expressions based on the weights of the individual rats. Estimates of ethanol intake from Anderson and Thompson (1974) can be compared with the average ethanol intake of all T- and V- rats during the test condition of Experiment 1. Higher ethanol intakes were obtained by Anderson and Thompson's (1974) rats when compared at identical minimum-interreinforcer intervals (0, 60, 120, and 240 sec). The higher ethanol intakes obtained in the Anderson and Thompson (1974) study cannot strictly be accounted for by their longer session duration (5 hr). Adjusting ethanol intake estimates from Anderson and Thompson (1974) by reducing them by 2/5 (i.e., compensating for their 2-hr longer sessions) still yielded higher intakes in 3 of the 4 comparisons. The differences in ethanol intake per session between the two studies ranged from 171.0 to 1009.6 mg ethanol

consumed/kg body weight. Differences in ethanol intake might be accounted for by a number of factors including differences in strain of rat, dipper-cup size, and schedule of reinforcement used.

In 12 of 15 possible comparisons (8 test + 7 retest conditions) the V-Group had higher mean ethanol intakes (mg ethanol consumed/kg body weight/session) than the T-Group. The V-Group had 11.9% higher ethanol intake than the T-Group averaged across all minimum interreinforcer intervals. The higher ethanol intake by the V-Group is not explainable by aberrantly high-drinking individual V-rats for the variance within both groups was similar (V-Group  $\bar{X}$  S.E.M. = 89.4; T-Group  $\bar{X}$  S.E.M. = 89.7). A possible determinant of the difference in ethanol intake is the schedule of reinforcement. Both schedules of reinforcement used for the T- and V-Groups formally specified an identical series of minimum-interreinforcer intervals. However, the chain DRO  $\underline{x}$  sec FR 1 schedule used for the V-Group additionally required the absence of lever pressing for a minimum interval prior to a reinforced response. Because lever presses during the DRO component further extended the DRO component, the functional interval of time during which ethanol drinking could not occur was potentially longer for the V-Group. Because the V-Group's schedule of reinforcement provided for potentially longer intervals of time during which ethanol drinking could not occur, it would be predicted that the V-rats would drink less than the T-rats. However, the V-rats actually drank more than the T-rats. Perhaps the schedules of reinforcement generated different response outputs by the two groups. If the T-Group had emitted more lever presses per ethanol delivery than the V-Group it might be expected that this higher functional response requirement would lead to fewer obtained deliveries (Meisch &

Thompson, 1973). However, the schedules of reinforcement generated only slight differences in response output by the two groups. On the average, 1.59 and 1.29 lever presses per ethanol delivery were emitted by the T- and V-Groups, respectively. It seems unlikely that this slight difference in response output could account for differences in ethanol intake. Other potential differences in the two groups' behavior which might account for differences in ethanol intake were not recorded. For instance, behaviors other than lever pressing were not recorded during the interreinforcer interval, and such behavior can influence scheduled-reinforced behavior (Levitsky & Collier, 1968). Future research ascertaining the importance of interreinforcer behavior on subsequent ethanol responding could be valuable in suggesting new mechanisms through which ethanol drinking could be controlled.

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## APPENDIX

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TABLE A

Mean dipper presentations of 8% (w/v) ethanol, mean lever presses, and mean ethanol intake (mean mg ethanol/kg body weight) per 3-hr session of the T-Group tested in a mult EXT x sec FR 1 schedule during Experiment 1.

EXT Component Duration (sec)	Dipper Presentations		Lever Presses		Ethanol Intake	
	Test	Retest	Test	Retest	Test	Retest
0	100.0 (6.02)	100.9 (4.75)	101.9 (5.83)	113.5 (5.61)	2256.5 (127.2)	2319.0 (111.0)
7.5	89.7 (6.39)	98.3 (3.74)	169.1 (13.9)	120.7 (7.57)	2048.4 (146.1)	2259.6 (106.5)
15	94.2 (5.58)	86.6 (5.24)	223.4 (19.6)	123.4 (8.44)	2155.0 (130.7)	1983.0 (111.0)
30	73.7 (5.76)	68.2 (5.15)	188.9 (13.6)	83.8 (6.77)	1674.2 (131.8)	1571.2 (118.9)
60	47.8 (3.61)	59.0 (3.62)	72.6 (6.61)	69.3 (4.69)	1090.2 (82.2)	1357.4 (83.5)
120	32.3 (2.18)	35.1 (2.68)	50.6 (5.30)	40.8 (3.82)	744.3 (58.6)	813.8 (63.2)

(Table A continued  
on following page)

TABLE A (continued)

240	22.9 (1.45)	26.9 <sup>a</sup> (1.40)	31.0 (2.93)	33.1 <sup>a</sup> (2.15)	522.5 (33.2)	605.6 <sup>a</sup> (30.4)
480	15.5 <sup>a</sup> (0.88)	-- --	48.5 <sup>a</sup> (19.1)	-- --	345.3 <sup>a</sup> (10.9)	-- --

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Note: Group means were calculated by averaging the available subjects' means. N = 5 unless otherwise noted. Numbers in parentheses indicate the mean S.E.M.

<sup>a</sup>N = 3.

TABLE B

Mean dipper presentations of 8% (w/v) ethanol, mean lever presses, and mean ethanol intake (mean mg ethanol/kg body weight) per 3-hr session of T-1 tested in a mult EXT x sec FR 1 schedule during Experiment 1.

EXT Component Duration (sec)	Dipper Presentations		Lever Presses		Ethanol Intake	
	Test	Retest	Test	Retest	Test	Retest
0	76.6 (2.23)	100.8 (6.81)	77.1 (2.24)	114.8 (8.69)	1828.8 (53.0)	2416.2 (165.6)
7.5	80.4 (2.71)	89.8 (3.15)	177.0 (12.4)	115.4 (4.59)	1913.8 (59.6)	2161.7 (77.4)
15	81.2 (3.40)	65.4 (3.49)	216.8 (14.4)	117.4 (9.89)	1944.6 (86.9)	1566.8 (85.7)
30	54.6 (2.56)	56.6 (3.40)	179.8 (23.9)	88.2 (7.68)	1295.4 (61.1)	1348.4 (80.2)
60	33.8 (1.02)	57.8 (2.70)	73.2 (5.88)	73.6 (4.96)	809.2 (25.3)	1387.0 (66.8)
120	21.6 (1.26)	26.4 (4.13)	46.6 (6.45)	33.4 (5.45)	516.7 (30.8)	632.3 (99.1)

(Table B continued  
on following page)

TABLE B (continued)

240	8.8 (0.65)	-- --	12.4 (2.16)	-- --	211.4 (15.6)	-- --
480	-- --	-- --	-- --	-- --	-- --	-- --

---

Note: N = 5 except for the 0 sec test condition: N = 10.  
Numbers in parentheses indicate the S.E.M.

TABLE C

Mean dipper presentations of 8% (w/v) ethanol, mean lever presses, and mean ethanol intake (mean mg ethanol/kg body weight) per 3-hr session of T-2 tested in a mult EXT x sec FR 1 schedule during Experiment 1.

EXT Component Duration (sec)	Dipper Presentations		Lever Presses		Ethanol Intake	
	Test	Retest	Test	Retest	Test	Retest
0	75.4 (4.32)	73.6 (2.20)	75.6 (4.10)	73.6 (1.96)	1825.8 (103.1)	1795.2 (54.7)
7.5	67.0 (4.08)	77.6 (2.80)	86.2 (4.87)	80.2 (3.84)	1630.5 (103.2)	1872.8 (73.7)
15	53.2 (1.24)	75.8 (2.72)	69.2 (3.81)	77.0 (2.88)	1296.5 (34.3)	1832.4 (65.0)
30	46.2 (1.52)	59.6 (3.15)	50.6 (1.72)	60.0 (6.24)	1121.1 (40.9)	1451.9 (80.6)
60	43.0 (3.71)	48.6 (3.72)	48.6 (3.71)	49.2 (3.69)	1042.2 (94.9)	1184.4 (89.1)
120	32.0 (1.28)	32.2 (3.38)	33.6 (0.87)	32.4 (2.84)	771.2 (34.1)	748.9 (82.2)

(Table C continued  
on following page)

TABLE C (continued)

240	13.2 (0.55)	-- --	14.0 (0.55)	-- --	321.7 (12.8)	-- --
480	-- --	-- --	-- --	-- --	-- --	-- --

---

Note: N = 5 except for the 0 sec test condition: N = 10.  
Numbers in parentheses indicate the S.E.M.

TABLE D

Mean dipper presentations of 8% (w/v) ethanol, mean lever presses, and mean ethanol intake (mean mg ethanol/kg body weight) per 3-hr session of T-3 tested in a mult EXT x sec FR 1 schedule during Experiment 1.

EXT Component Duration (sec)	Dipper Presentations		Lever Presses		Ethanol Intake	
	<u>Test</u>	<u>Retest</u>	<u>Test</u>	<u>Retest</u>	<u>Test</u>	<u>Retest</u>
0	130.8 (11.6)	110.2 (6.44)	133.5 (10.7)	110.8 (5.58)	2712.7 (207.2)	2366.8 (140.0)
7.5	122.6 (8.93)	107.0 (7.82)	260.2 (24.7)	144.0 (17.7)	2631.1 (190.1)	2294.1 (171.3)
15	115.0 (8.74)	89.2 (9.42)	319.6 (28.9)	166.4 (15.9)	2477.4 (191.6)	1910.2 (202.7)
30	97.8 (9.86)	60.4 (4.18)	399.2 (15.6)	72.6 (4.64)	2095.2 (211.2)	1301.5 (90.3)
60	41.0 (3.43)	61.0 (2.45)	63.8 (6.85)	67.6 (4.34)	880.2 (74.3)	1312.7 (54.5)
120	22.0 (1.58)	21.0 (1.73)	43.2 (9.04)	25.4 (2.42)	477.8 (71.2)	452.3 (37.5)

(Table D continued  
on following page)

TABLE D (continued)

240	23.4 (1.82)	19.2 (1.82)	37.8 (5.09)	29.0 (2.74)	506.4 (41.0)	411.9 (38.1)
480	16.0 (0.79)	-- --	105.8 (54.7)	-- --	344.7 (16.9)	-- --

---

Note: N = 5 except for the 0 sec test condition: N = 10.  
Numbers in parentheses indicate the S.E.M.



TABLE E

Mean dipper presentations of 8% (w/v) ethanol, mean lever presses, and mean ethanol intake (mean mg ethanol/kg body weight) per 3-hr session of T-4 tested in a mult EXT x sec FR 1 schedule during Experiment 1.

EXT Component Duration (sec)	Dipper Presentations		Lever Presses		Ethanol Intake	
	<u>Test</u>	<u>Retest</u>	<u>Test</u>	<u>Retest</u>	<u>Test</u>	<u>Retest</u>
0	135.7 (5.70)	117.0 (4.51)	138.4 (5.41)	153.6 (6.34)	3049.6 (130.7)	2628.5 (106.8)
7.5	112.6 (8.87)	113.8 (1.82)	209.2 (15.6)	143.2 (4.47)	2535.9 (201.4)	2563.9 (40.9)
15	124.6 (8.38)	119.2 (6.31)	304.2 (27.5)	152.6 (10.0)	2813.3 (191.2)	2674.6 (142.1)
30	111.0 (9.73)	90.8 (9.12)	177.6 (13.3)	116.8 (9.82)	2502.4 (224.9)	2042.7 (205.8)
60	87.4 (3.09)	68.8 (4.35)	115.8 (7.41)	86.4 (5.54)	1965.0 (69.6)	1544.2 (91.6)
120	33.0 (3.87)	45.6 (2.33)	38.4 (5.07)	55.8 (5.76)	740.8 (87.2)	1030.2 (54.0)

(Table E continued  
on following page)

TABLE E (continued)

240	37.4 (2.25)	29.0 (1.46)	42.0 (1.92)	29.8 (0.97)	844.0 (51.6)	652.3 (32.4)
480	17.8 (0.55)	-- --	19.4 (0.24)	-- --	400.0 (12.6)	-- --

---

Note: N = 5 except for the 0 sec test condition: N = 10.  
Numbers in parentheses indicate the S.E.M.

TABLE F

Mean dipper presentations of 8% (w/v) ethanol, mean lever presses, and mean ethanol intake (mean mg ethanol/kg body weight) per 3-hr session of T-5 tested in a mult EXT x sec FR 1 schedule during Experiment 1.

EXT Component Duration (sec)	Dipper Presentations		Lever Presses		Ethanol Intake	
	<u>Test</u>	<u>Retest</u>	<u>Test</u>	<u>Retest</u>	<u>Test</u>	<u>Retest</u>
0	81.4 (6.29)	102.8 (3.80)	85.0 (6.64)	114.8 (5.46)	1865.7 (142.0)	2388.2 (87.7)
7.5	65.8 (7.35)	103.4 (3.11)	113.0 (12.0)	120.6 (7.23)	1530.9 (176.1)	2405.7 (69.4)
15	97.0 (6.14)	83.4 (4.28)	207.2 (23.4)	103.4 (3.49)	2243.3 (149.5)	1931.4 (60.2)
30	59.0 (5.12)	73.4 (5.88)	137.2 (13.5)	81.4 (5.45)	1356.5 (120.9)	1711.6 (137.6)
60	33.6 (6.78)	58.6 (4.86)	61.6 (9.21)	69.8 (4.93)	773.0 (159.3)	1358.6 (115.6)
120	52.8 (2.92)	50.2 (1.85)	91.2 (5.07)	57.2 (2.65)	1214.8 (69.5)	1169.3 (43.3)

(Table F continued  
on following page)

TABLE F (continued)

240	31.6 (1.96)	32.4 (0.91)	49.0 (5.01)	40.6 (2.75)	729.1 (45.0)	752.7 (20.8)
480	12.6 (1.30)	-- --	20.2 (2.40)	-- --	291.1 (30.3)	-- --

---

Note: N = 5 except for the 0 sec test condition: N = 10.  
Numbers in parentheses indicate the S.E.M.

TABLE G

Mean dipper presentations of 8% (w/v) ethanol, mean lever presses, and mean ethanol intake (mean mg ethanol/kg body weight) per 3-hr session of the V-Group tested in a chain DRO  $\bar{x}$  sec FR 1 schedule during Experiment 1.

DRO Component Duration (sec)	Dipper Presentations		Lever Presses		Ethanol Intake	
	Test	Retest	Test	Retest	Test	Retest
0	105.0 (5.25)	136.5 (6.72)	108.9 (5.74)	141.8 (6.71)	2356.6 (119.9)	3112.6 (134.9)
7.5	101.2 (6.34)	118.4 (4.99)	136.4 (9.19)	129.0 (6.42)	2247.5 (143.3)	2668.9 (114.2)
15	97.7 (3.27)	111.6 (5.74)	129.7 (7.23)	125.9 (9.89)	2197.6 (74.1)	2615.2 (108.3)
30	80.2 (3.99)	90.4 (5.00)	99.0 (5.64)	100.9 (6.46)	1798.7 (88.4)	2050.5 (108.9)
60	52.6 (2.86)	64.7 (4.20)	63.0 (7.11)	78.2 (6.71)	1170.5 (64.5)	1460.5 (100.4)
120	38.8 (2.20)	39.5 (3.26)	55.0 (6.66)	56.5 (6.49)	867.9 (48.4)	905.8 (67.9)

(Table G continued  
on following page)

TABLE G (continued)

240	22.1 (1.78)	27.5 <sup>a</sup> (2.37)	34.5 (4.98)	36.5 <sup>a</sup> (3.83)	494.7 (39.3)	599.0 <sup>a</sup> (51.4)
480	14.5 <sup>a</sup> (0.79)	-- --	24.1 <sup>a</sup> (2.77)	-- --	315.4 <sup>a</sup> (17.0)	-- --

---

Note: Group means were calculated by averaging the available subjects' means. N = 5 unless otherwise noted. Numbers in parentheses indicate the mean S.E.M.

<sup>a</sup>N = 3.

TABLE H

Mean dipper presentations of 8% (w/v) ethanol, mean lever presses, and mean ethanol intake (mean mg ethanol/kg body weight) per 3-hr session of V-1 tested in a chain DRO  $\bar{x}$  sec FR 1 schedule during Experiment 1.

DRO Component Duration (sec)	Dipper Presentations		Lever Presses		Ethanol Intake	
	Test	Retest	Test	Retest	Test	Retest
0	101.3 (4.09)	187.4 (11.0)	106.5 (4.92)	187.8 (11.2)	2508.2 (104.8)	4680.3 (278.6)
7.5	103.4 (6.61)	183.4 (4.92)	149.2 (6.55)	189.4 (5.73)	2543.7 (158.1)	4500.4 (141.4)
15	115.4 (2.84)	172.8 (5.46)	166.2 (3.23)	183.8 (6.27)	2872.3 (75.0)	4296.3 (140.5)
30	90.2 (4.32)	130.0 (2.55)	111.2 (6.89)	142.6 (2.39)	2240.0 (108.5)	3226.2 (61.5)
60	45.8 (3.27)	80.8 (3.78)	54.6 (8.27)	95.4 (7.00)	1132.0 (80.1)	2003.8 (91.9)
120	32.2 (1.52)	45.0 (4.02)	57.8 (7.59)	94.0 (17.2)	808.8 (38.6)	1121.7 (99.3)

(Table H continued  
on following page)

TABLE H (continued)

240	18.8 (0.96)	-- --	28.4 (3.78)	-- --	464.6 (23.3)	-- --
480	-- --	-- --	-- --	-- --	-- --	-- --

---

Note: N = 5 except for the 0 sec test condition: N = 10.  
Numbers in parentheses indicate the S.E.M.



TABLE I

Mean dipper presentations of 8% (w/v) ethanol, mean lever presses, and mean ethanol intake (mean mg ethanol/kg body weight) per 3-hr session of V-3 tested in a chain DRO  $\underline{x}$  sec FR 1 schedule during Experiment 1.

DRO Component Duration (sec)	Dipper Presentations		Lever Presses		Ethanol Intake	
	Test	Retest	Test	Retest	Test	Retest
0	120.9 (6.47)	137.4 (7.52)	121.0 (6.43)	138.6 (7.62)	2407.9 (130.1)	2790.0 (118.0)
7.5	134.0 (6.55)	127.6 (6.09)	149.2 (6.55)	148.0 (8.27)	2657.0 (129.7)	2532.9 (123.9)
15	108.2 (6.30)	136.6 (9.50)	124.0 (4.40)	148.6 (11.2)	2157.2 (125.9)	2722.9 (187.0)
30	86.8 (4.64)	96.4 (9.01)	100.8 (4.51)	102.4 (10.4)	1707.8 (90.0)	1906.8 (177.5)
60	64.2 (3.81)	67.0 (5.86)	70.8 (4.26)	70.4 (7.08)	1274.2 (75.9)	1331.5 (118.5)
120	44.4 (3.51)	32.0 (2.15)	48.0 (4.53)	34.2 (2.46)	874.6 (69.6)	634.1 (44.8)

(Table I continued  
on following page)

TABLE I (continued)

240	27.2 (3.49)	32.6 (3.49)	34.6 (6.09)	34.4 (3.68)	540.2 (70.2)	652.9 (70.6)
480	17.6 (0.76)	-- --	19.8 (0.89)	-- --	352.4 (14.6)	-- --

---

Note: N = 5 except for the 0 sec test condition: N = 10.  
Numbers in parentheses indicate the S.E.M.

TABLE J

Mean dipper presentations of 8% (w/v) ethanol, mean lever presses, and mean ethanol intake (mean mg ethanol/kg body weight) per 3-hr session of V-4 tested in a chain DRO  $\bar{x}$  sec FR 1 schedule during Experiment 1.

DRO Component Duration (sec)	Dipper Presentations		Lever Presses		Ethanol Intake	
	Test	Retest	Test	Retest	Test	Retest
0	104.7 (4.74)	115.4 (5.51)	110.1 (4.47)	115.4 (5.51)	2399.9 (110.3)	2630.2 (119.8)
7.5	113.2 (4.04)	98.4 (3.85)	147.4 (7.02)	104.0 (4.62)	2565.6 (97.3)	2236.8 (80.9)
15	111.8 (3.11)	108.4 (4.83)	153.6 (18.8)	126.2 (7.59)	2542.9 (78.0)	2480.7 (102.8)
30	104.8 (5.12)	94.2 (7.90)	133.2 (5.52)	110.6 (11.4)	2400.9 (111.3)	2161.5 (179.2)
60	67.0 (2.18)	68.2 (6.60)	85.0 (6.79)	94.4 (11.4)	1523.7 (50.7)	1561.2 (155.9)
120	50.0 (1.97)	47.2 (2.22)	60.2 (6.44)	52.6 (2.88)	1146.0 (46.2)	1076.6 (50.3)

(Table J continued  
on following page)

TABLE J (continued)

240	31.0 (1.17)	29.0 (2.09)	39.2 (4.16)	35.6 (3.48)	709.0 (27.6)	664.0 (48.1)
480	12.8 (0.65)	-- --	20.6 (1.89)	-- --	292.4 (14.6)	-- --

---

Note: N = 5 except for the 0 sec test condition: N = 10.  
Numbers in parentheses indicate the S.E.M.

TABLE K

Mean dipper presentations of 8% (w/v) ethanol, mean lever presses, and mean ethanol intake (mean mg ethanol/kg body weight) per 3-hr session of V-5 tested in a chain DRO  $\underline{x}$  sec FR 1 schedule during Experiment 1.

DRO Component Duration (sec)	Dipper Presentations		Lever Presses		Ethanol Intake	
	Test	Retest	Test	Retest	Test	Retest
0	89.7 (4.07)	89.2 (4.72)	89.8 (4.13)	89.2 (3.05)	1961.2 (93.4)	1954.2 (71.9)
7.5	75.0 (5.06)	80.6 (4.01)	110.4 (7.13)	83.0 (4.26)	1626.0 (111.8)	1762.7 (87.8)
15	76.6 (2.41)	75.2 (0.74)	100.4 (2.71)	64.6 (15.6)	1670.7 (49.8)	1646.4 (21.7)
30	71.8 (3.07)	67.8 (2.88)	87.4 (5.57)	74.6 (3.82)	1564.6 (71.0)	1489.4 (63.8)
60	42.2 (0.55)	55.0 (2.62)	53.0 (1.84)	69.0 (4.14)	921.5 (11.1)	1207.8 (58.6)
120	28.0 (1.77)	30.4 (5.01)	45.0 (3.22)	40.2 (3.56)	611.9 (38.3)	711.1 (76.6)

(Table K continued  
on following page)

TABLE K (continued)

240	11.2 (1.67)	-- --	20.0 (2.03)	-- --	243.8 (36.8)	-- --
480	-- --	-- --	-- --	-- --	-- --	-- --

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Note: N = 5 except for the 0 sec test condition: N = 10.  
Numbers in parentheses indicate the S.E.M.

TABLE L

Mean dipper presentations of 8% (w/v) ethanol, mean lever presses, and mean ethanol intake (mean mg ethanol/kg body weight) per 3-hr session of V-6 tested in a chain DR0  $\bar{x}$  sec FR 1 schedule during Experiment 1.

DR0 Component Duration (sec)	Dipper Presentations		Lever Presses		Ethanol Intake	
	Test	Retest	Test	Retest	Test	Retest
0	108.5 (6.88)	154.0 (4.26)	117.0 (8.73)	178.2 (6.15)	2505.6 (161.1)	3508.2 (86.0)
7.5	80.6 (9.44)	102.2 (6.07)	126.0 (18.7)	120.8 (9.21)	1845.0 (219.6)	2311.9 (137.2)
15	76.4 (1.68)	85.2 (3.60)	104.4 (7.02)	106.2 (8.78)	1744.8 (41.6)	1929.8 (89.6)
30	47.4 (2.78)	63.8 (2.68)	62.6 (5.72)	74.4 (4.28)	1080.2 (61.1)	1468.4 (62.6)
60	43.6 (4.49)	50.6 (3.05)	51.4 (14.4)	61.6 (3.95)	1001.2 (104.5)	1148.4 (67.3)
120	39.4 (2.25)	43.0 (2.92)	64.0 (11.5)	61.6 (6.35)	898.0 (49.3)	985.5 (68.3)

(Table L continued  
on following page)

TABLE L (continued)

240	22.4 (1.68)	21.0 (1.54)	50.2 (8.84)	39.6 (4.32)	515.7 (38.6)	480.1 (35.6)
480	13.2 (0.96)	-- --	31.8 (5.54)	-- --	301.5 (21.7)	-- --

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Note: N = 5 except for the 0 sec test condition: N = 10.  
Numbers in parentheses indicate the S.E.M.