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## A Precision Drinking Device with a Micrometric Capillary Valve Flow Control for Rats

by

PATRICK M. BEARDSLEY

and

RICHARD A. MEISCH

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Patrick M. Beardsley[2] and Richard A. Meisch[3]

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ABSTRACT

An inexpensive system for detecting tongue licking and for delivering liquids to rats is described. The ability of the system to dispense volumes less than .012 ml was tested in three experiments with three different liquids. In each experiment, liquids were dispensed following the completion of a heterogenous chain schedule of reinforcement in which depressions of a lever were required before tongue licking produced liquid delivery. The system utilized a closed reservoir to minimize evaporation and a micrometric capillary valve to control volume of fluid dispensed.

In Experiment 1, three male, Long-Evans descent hooded rats drank water dispensed by the system at lowest, highest, and midmost valve settings. The volume of water delivered increased logarithmically from .0027 ml to .012 ml across valve settings. There was little variation in the volumes delivered at a particular valve setting either across sessions or amongst rats. In Experiment 2, two male, Sprague-Dawley rats were tested with 5.0 μg/ml etonitazene HCl or water as the available liquid. Both rats obtained more deliveries of 5.0 μg/ml etonitazene than water. Intakes of etonitazene were similar to previous intakes obtained with the same rats, identical concentration, and session duration using a dipper delivery system. In Experiment 3, one male, Long-Evans descent hooded rat was tested with 8% w/v ethanol or water available. More ethanol deliveries than water were obtained. Intakes of ethanol were somewhat less than intakes previously obtained with the same rat, identical session duration, and concentration using a dipper delivery system.

The present liquid delivery system provided several advantages over dipper delivery systems. First, it allowed quick and easy control of the volume delivered. Secondly, it minimized evaporation. Thirdly, the drinking device, along with the heterogenous chain schedule of reinforcement, insured that liquid was delivered only when oral contact was made with it.

Common methods of delivering liquids to rats include the presentation of filled dipper cups and the delivery of droplets through drinking spouts controlled by electronic drinkometers. Delivering liquids by refilling dipper cups has certain disadvantages. The amount delivered can only be varied by exchanging different sizes of dipper cups. Machining a dipper cup for each of many volumes is laborious and expensive. Secondly, a reservoir is needed which, because it must be partially opened for dipper refilling, allows evaporation. Thirdly, substantial evaporation can occur from the dipper cup itself, which could lead to imprecise measurements of volume consumed. Finally, and most importantly, there is no assurance that the animal contacts and drinks liquid upon each dipper presentation. This can be particularly problematic when an animal is under a drug's influence. Electronic drinkometer-equipped systems have been designed which eliminate most of the problems associated with dipper cup delivery systems (e.g., Hulse, 1960; Justesen, Levinson, & Daley, 1967; Lal & Zabik, 1972). However, when previous drinkometer-equipped systems have gained precision and offered ease in controlling a range of small volumes (less than .05 ml), they have done so at considerable expense, for instance, by employing costly syringe pumps (e.g., Hulse, 1960).

The present drinking system was designed to eliminate the problems associated with dipper cup delivery systems and to precisely deliver a range of small volumes of liquids at an inexpensive construction cost. Its use was tested under conditions in which three different volumes of water, and the drugs etonitazene HCl and ethanol, were delivered following completion of a heterogenous chain schedule of reinforcement (Kelleher, 1966).

Apparatus

The drinking device is shown in Figure 1. A vertically supported Becton-Dickinson H575-G 35 cc glass syringe serves as a reservoir. Weight on the syringe plunger is supplied by a 61.26 g, hollowed, plexiglass cylinder, 7 3/16 in. (18.26 cm) long with a 1 7/32 in. (3.10 cm) diameter. The syringe is fitted with a screw-type Luer-Lok stopcock (Scientific Products #3154) to enable removal without spillage. Polypropylene tubing [5/16 in. (7.94 mm) O.D./.035 in. (.889 mm) wall] and an elbow tube-to-tube connector (Cole-Parmer #6383-20) connects the syringe to the intake side of a micrometric capillary valve (Cole-Parmer #3235). The output side of the micrometric capillary valve is connected to the intake port of a liquid solenoid valve (Gould #21381-24VDC). The ports of the liquid solenoid valve are fitted with brass hose barbs [1/8 in. (3.18 mm) I.D.]. Polypropylene tubing is pressed over both hose barbs. The tubing is then extended into union, tube-to-tube connectors (Cole-Parmer #6381-20) connecting the output side of the micrometric capillary valve to the input port of the liquid solenoid valve, and, on the other side, connecting a 3 9/16 in (9.05 cm) long, hollowed, glass rod [5/16 in. (8mm) O.D./.07 in. (1.75 mm) I.D.] to the output port. The glass rod extends 1 3/32 in. (2.78 cm) into the operant chamber and is secured to the intelligence panel and supported by a 27/32 in. (2.14 cm) plastic sleeve. The tip of the glass rod located in the operant chamber is smoothed and tapered.

A 4 14/32 in. (11.27 cm) long, stainless steel tube [.0655 in. (1.66 mm) O.D./.0415 in. (1.05 mm) I.D.] runs through the glass rod and into a copper clip which is press-fitted into the inside walls of the brass hose

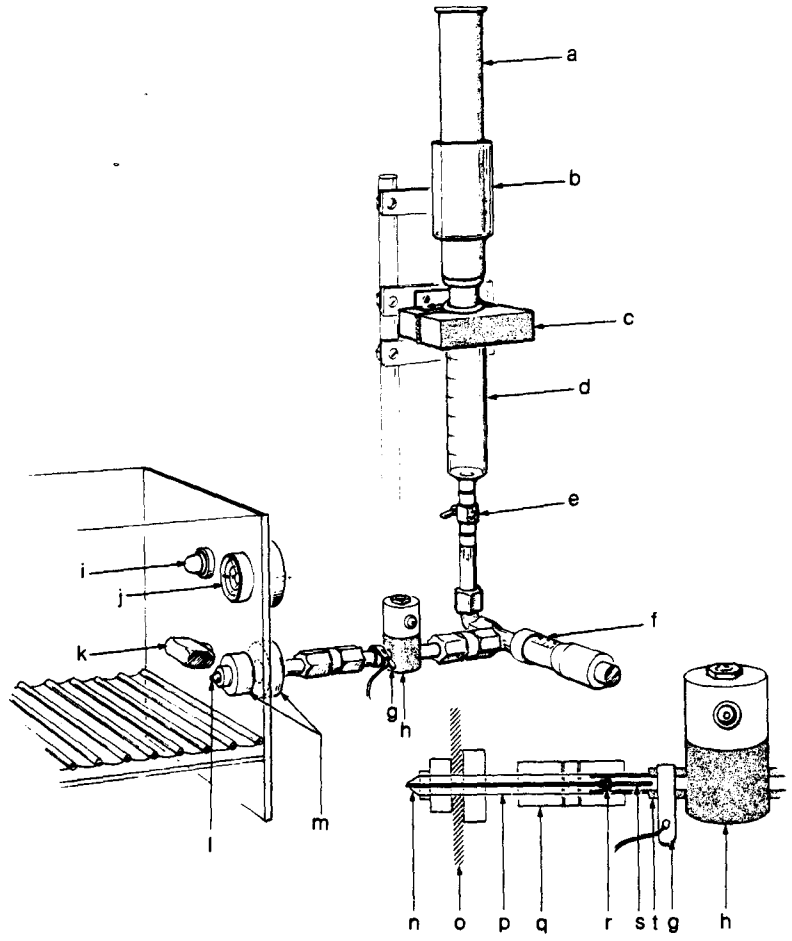


Figure 1. Drinking device and internal construction from the solenoid to the drinking spout (inset). (a) plexiglass cylinder; (b) cylinder guide; (c) syringe support stand; (d) 35 cc syringe; (e) stopcock; (f) micrometric capillary valve; (g) contact clip; (h) liquid solenoid valve; (i) white, jewelled lamp; (j) sonalert; (k) response lever; (l) spout; (m) plastic sleeve; (n) bevelled spout tip; (o) intelligence panel; (p) glass rod; (q) tube-to-tube connector; (r) copper clip; (s) stainless steel tube; (t) hose barb.

barb at the output port of the liquid solenoid valve. The stainless steel tube is cemented by epoxy to the inside walls of the glass rod, and is flush with the exposed tip of the rod. The lower bevel of the glass rod's tip is cut out 1/16 in. (1.59 mm) vertically by 1/32 in. (.79 mm) horizontally. A 1/16 in. (1.59 mm) wide by 3/16 in. (4.76 mm) long copper strip is passed through the glass rod's lower bevel, under, and in contact with the stainless steel tubing until one end is flush with the exposed end of the stainless steel tubing. Electrical contact thus extends from the copper strip at the lower bevel of the glass rod, through the stainless steel tubing, into the brass hose barb at the output port of the liquid solenoid valve (see Figure 2, insert). A wire, clipped to the brass hose barb at the output port of the liquid solenoid valve, serves as the input line to a Coulbourn Instruments S26-01 Contact Input module. The contact input module employs a maximum 1 μA sense current and has a resistance threshold of 2 meg ohm. When programmed, tongue contacts of the exposed copper strip at the glass rod's lower bevel result in a 40 msec delivery of liquid with a latency of 6 to 10 msec following tongue contact. Costs for the micrometric capillary valve, syringe-reservoir, liquid solenoid valve, stopcock valve, and all tubing connectors total less than $85.00. Additional costs for the glass and stainless steel rods and raw materials for the syringe holder and syringe weight brought construction costs (less operant chamber and programming equipment) to between $100 and $125.

The operant chamber itself is 11 in. (27.94 cm) long by 7 1/2 in. (19.05 cm) wide by 6 in. (15.24 cm) in height. On the left side of the

intelligence panel, a lever is mounted 1 1/2 in. (3.81 cm) above the floor, and 2 3/4 in. (6.99 cm) directly above the lever a 1.12 W white-jewelled lamp is positioned. The drinking spout (the tip of the glass rod) emerges 1 1/2 in. (3.81 cm) above the floor, 1 7/8 in. (4.76 cm) to the right of the lever. The speaker of a sonalert (Mallory #S6628-24VDC) is positioned 2 3/4 in. (6.99 cm) directly above the drinking spout. A 4.76 W house light is centered on top of the operant chamber's Plexiglass cover 3 in. (7.62 cm) from the chamber's back panel. The operant chamber and drinking device are enclosed in a ventilated, sound-attenuating, plastic ice chest.

## Experiment 1. Water as the available liquid

The purpose of Experiment 1 was to determine the range of volumes of water that could be controlled by the valve. Valve settings of .2, 1.0, and 1.8 were chosen for testing for they included the practical limits of the valve's control (settings of 0 and 2.0 completely opened and closed the valve) while being spaced maximally apart from one another. Three rats, experimentally naive, were tested twice at each valve setting.

### METHODS

Subjects. Three adult, male, Long-Evans descent hooded rats (Blu-Spruce Farms), approximately 2 yr old at the beginning of the study, were tested during daily 1 hr experimental sessions.

Procedure. The rats were allowed access to water during experimental sessions and for a .5 hr period following each experimental session in

their home cages. During sessions, the white house light was continually lit and water deliveries were available on a heterogenous chain Fixed Ratio 1 (lever press) Fixed Ratio 1 (20) (spout contact) schedule of reinforcement; a single lever press allowed 20 reinforced spout contacts [i.e., chain FR 1 FR 1 (20)]. The onset of the white-jewelled lamp signalled the first component of the chain, in which one lever press was necessary to initiate the second component. The offset of the white--jewelled lamp and the sounding of the sonalert signalled the second component of the chain, during which spout contacts resulted in water deliveries. Following the 20th reinforced spout contact the sonalert extinguished and the white-jewelled lamp was again lit. Neither spout contacts during the first component nor lever presses during the second component had programmed consequences. This particular schedule was employed because it required a typically used, quantifiable instrumental response (lever press) to be emitted prior to gaining access to liquid. Although a lick response could have been used alone as the required instrumental response, lick responding is often atypical of other instrumental behavior (Justesen et al., 1967) and bears respondent-like properties (Miller & De Bold, 1965; Patten & Deaux, 1966). Use alone of the licking response without a lever press requirement would have thus made the data less comparable with other research employing instrumental response requirements.

Volume of liquid consumed was determined by changes in weight of the syringe reservoir. That is, prior to each session, the syringe reservoir, filled with liquid, was weighed on a Mettler Platform Balance (PL 1200) and

then reweighed immediately after each session. The change in weight, converted into a volume measure based on the relative density of water at laboratory temperatures, was then used as the measure of volume consumed.

Following acquisition of lever press-spout contact behavior, settings on the micrometric capillary valve of 1.8, 1.0 and .2 were tested with each rat in the following order: 1.8, 1.0, .2, 1.0, 1.8, .2. Decreases in the valve setting result in increases of the valve opening. During the retest condition at valve setting .2, rat L-10 sickened and died; consequently, its data at this condition were excluded from the following report. Changes in one valve setting to the next were made following 5 consecutive stable sessions as determined by visual inspection of the data.

## RESULTS

Figure 2 shows the mean milliters of water per delivery for each rat at each valve setting for the test and retest conditions. At each individual valve setting, similar volumes of water were delivered for each rat during both the test and retest conditions.

Figure 3 shows group mean volumes per delivery at each valve setting (N = 30; 3 rats X 5 sessions each X 2 conditions, i.e., test and retest conditions, each). The mean volumes of water per delivery increased from .0027 ml at valve setting 1.8 to .006 ml at valve setting 1.0 to .012 ml at valve setting .2. As can be seen from Figure 3 there was a logarithmic increase in the volume delivered with decrements in the valve setting. The range of each group mean was small, and in no case did the range at a valve setting overlap with ranges of any other valve setting.

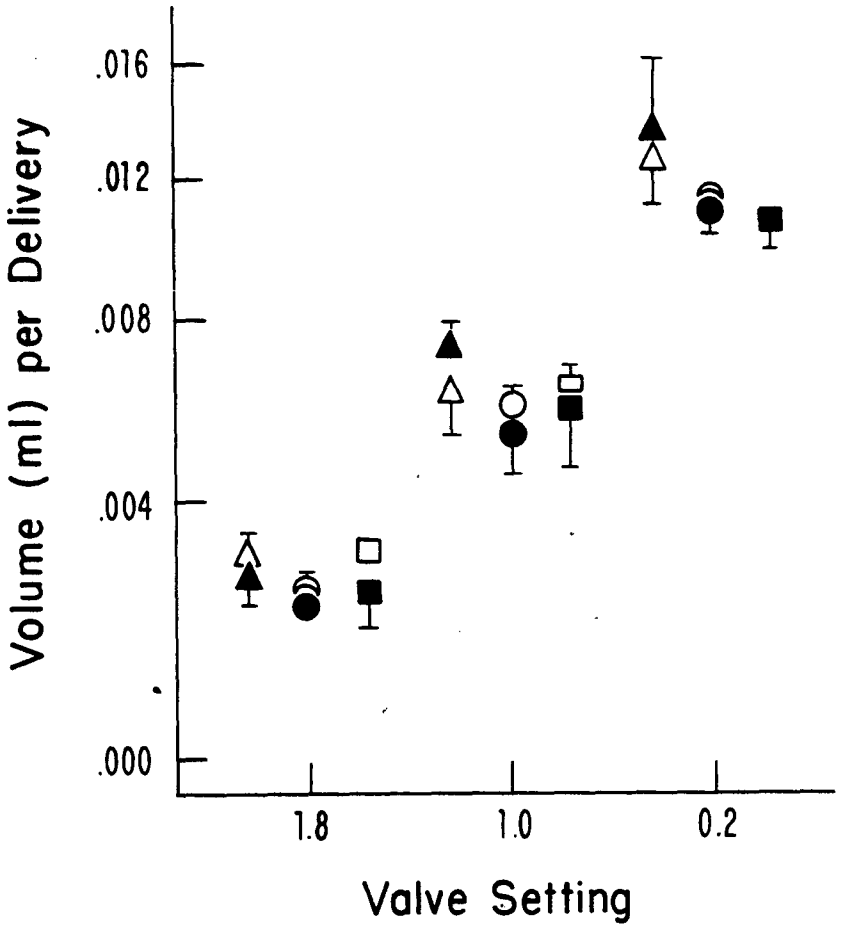


Figure 2. Mean ml of water per delivery for each rat at each valve setting for the test and retest conditions. Filled symbols: test conditions. Unfilled symbols: retest conditions. Triangles, circles, squares: rats L-5, L-8, L-10, respectively. Each symbol represents the mean of 5 consecutive session values at a particular valve setting; each session value being a mean of the volume of water delivered per delivery during that session. Brackets indicate the range of the means used to compute each point. Where no brackets appear, the range of the means fell within the enclosed symbol. Note that decreases in the valve setting result in increases in the valve opening, (i.e., at valve setting 0.0, valve is completely open; at valve setting 2.0, valve is completely closed).

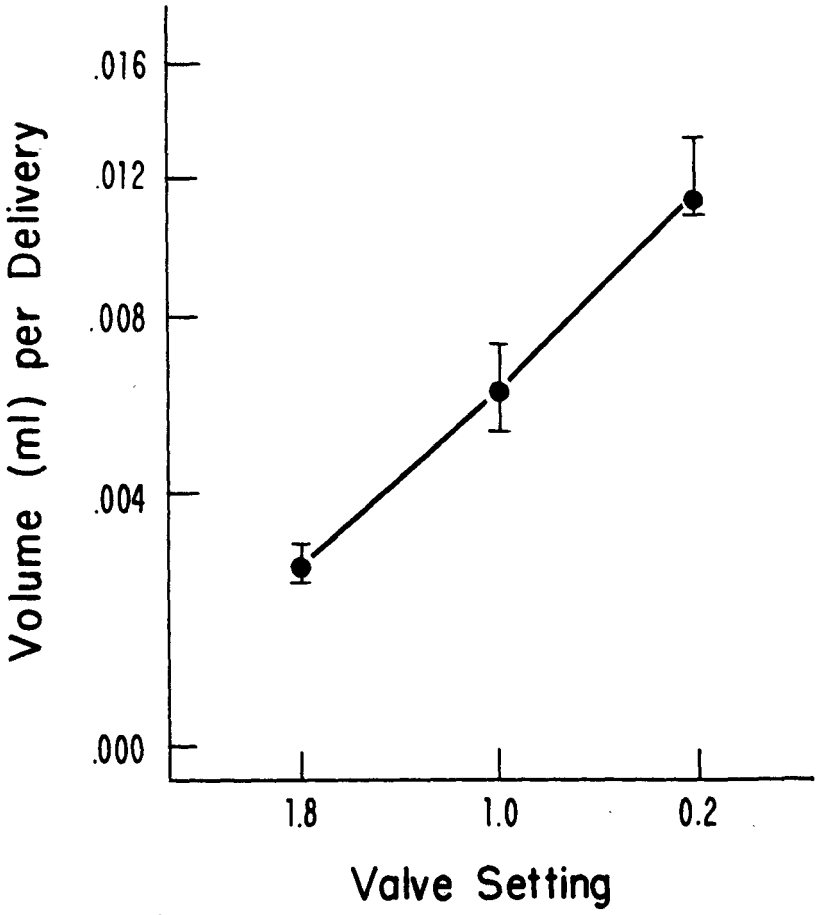


Figure 3. Group means of ml of water per delivery at each valve setting. Each symbol is the mean of 6 means (the means of each of 3 rats X 2 conditions, i.e., test and retest conditions, each). Brackets indicate the range of the individual rat means for each determination.

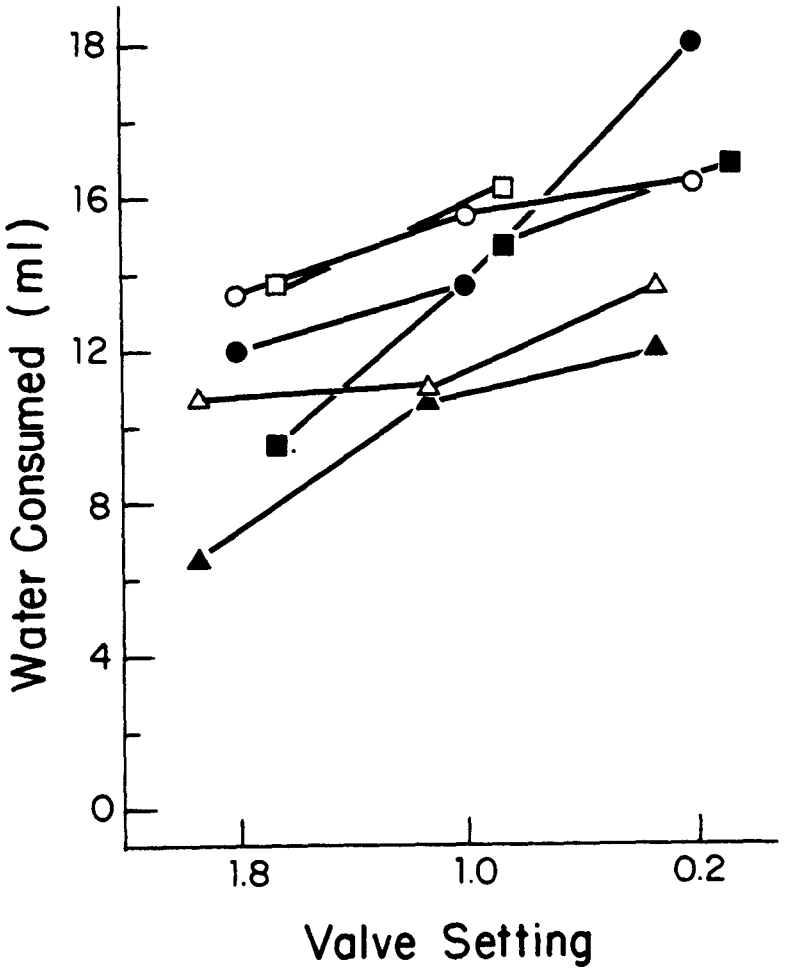


Figure 4. Mean ml of water consumed per session for each rat at each valve setting. Filled symbols: test condition. Unfilled symbols: retest condition. Triangles, circles, squares: rats L-5, L-8, L-10, respectively. Each symbol represents the mean of 5 consecutive session values.

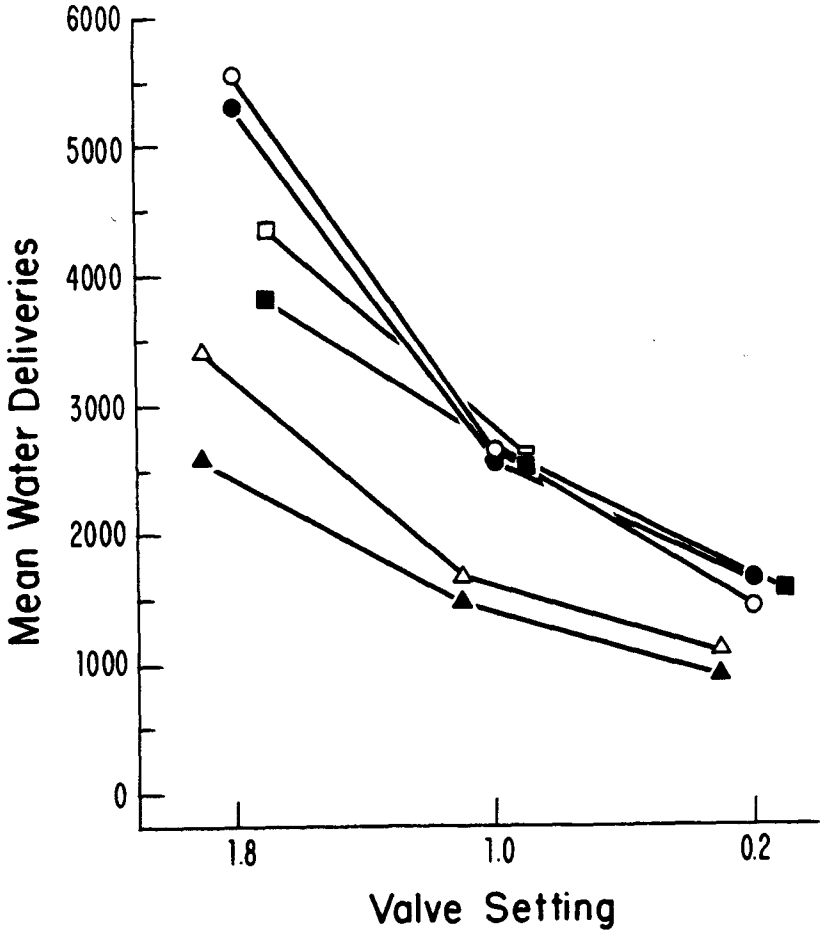


Figure 5. Mean water deliveries obtained by each rat at each valve setting for the test and retest conditions. Filled symbols: test condition. Unfilled symbols: retest condition. Triangles, circles, squares: rats L-5, L-8, L-10, respectively. Each symbol represents the mean of 5 consecutive sessions.

Figure 4 shows that with decrements in the valve setting there were increments in the volume of water drunk per session. This was true for each rat during both the test and retest conditions. Also, Figure 4 shows that in 7 of 8 possible comparisons, more water was drunk during the retest than the test condition at each valve setting (again, note there was no completed retest condition for rat L-10 at valve setting .2). Combining test and retest conditions (N = 30; 3 rats X 2 conditions X 5 sessions each) group mean water consumption increased from 10.99 ml, to 13.63 ml, to 15.38 ml per session with respective decrements in the valve setting from 1.8 to 1.0 to .2.

Figure 5 shows the mean liquid deliveries for each rat at each valve setting for the test and retest conditions. The number of liquid deliveries decreased with increases in the valve opening. Although there were sizeable differences in the number of liquid deliveries among the rats at valve setting 1.8, these differences decreased at lower valve settings.

## Experiment 2. Etonitazene HCl or water as the available liquid

The purpose of Experiment 2 was to test whether etonitazene HCl would serve as a reinforcer for rats which had histories of drinking etonitazene in dipper delivery systems. Additionally, etonitazene intakes obtained in Experiment 2 were to be compared with intakes determined previously using dipper delivery systems. Two rats with etonitazene drinking histories were tested with either 5.0 μg/ml etonitazene HCl or water available with the valve at setting .2.

## METHODS

Subjects. Two adult, male, Sprague-Dawley descent rats (Bio-Lab Corporation) approximately 1 yr old at the beginning of the study, were tested during daily, 2 hr experimental sessions.

Procedure. For both rats, 5.0 µg/ml etonitazene HCl had been previously established as a positive reinforcer. In another operant conditioning chamber the rats had lever pressed for, and drank from, dipper cups filled with etonitazene or water (Beardsley and Meisch, unpublished data). The rats were maintained at 70% of their free feeding body weight by placing limited amounts of Purina Laboratory Chow in their home cages immediately following each experimental session. The rats had unlimited access to water between sessions in their home cages except as described below for rat B-3.

At the start of the present study, rat C-10 was allowed access to 5.0 µg/ml etonitazene on a heterogenous chain Fixed Ratio 1 (lever press) Fixed Ratio 1 (20) (spout contact) Limited Hold 10 sec schedule of reinforcement in which a single lever press allowed spout contacts to be reinforced for 10 sec or for 20 deliveries, whichever came first [i.e., chain FR 1 and FR 1 (20) LH 10 sec]. Gradually, the lever press requirement during the first component was increased to FR 4. Then 5.0 µg/ml etonitazene, water, and 5.0 µg/ml etonitazene (retest) were made available during experimental sessions. Changes in the availability of liquids were made following 5 consecutive sessions of stable responding as determined by visual inspection of the data.

Rat B-3, at the start of the present study, was water deprived in the home cage and was allowed access to water only during experimental sessions in the operant chamber on a heterogenous chain FR 1 FR 1 (20) schedule of reinforcement. After acquisition of the lever press and spout contact responses, water was restored at the home cage, and 5.0 μg/ml etonitazene was made available in the operant chamber. The first component lever press requirement was gradually increased to FR 8 and a limited hold value of 30 sec was imposed during the final component, [i.e., a heterogenous chain FR 8 FR 1 (20) LH 30 sec schedule]. Similarly to rat C-10, 5.0 μg/ml etonitazene, water and 5.0 μg/ml etonitazene (retest) were then made available. Stimulus conditions during the present study were identical to those in Experiment 1 except that the white-jewelled lamp flickered at 10 times per sec during the first component on days when etonitazene was the available liquid.

Etonitazene solutions were prepared approximately 20 hr prior to each drug session using deionized water and etonitazene HCl. When water was the available liquid, deionized water was used. The micrometric capillary valve was set at setting .2 throughout all conditions for both rats. Volume consumptions were determined as in Experiment 1.

## RESULTS

Both rats obtained more deliveries of 5.0 μg/ml etonitazene than of water (upper panel of Figure 6 and Table 1). On the average, fewer than 60 water deliveries per session were obtained by either rat although both averaged more than 300 deliveries of 5.0 μg/ml etonitazene. Similarly,

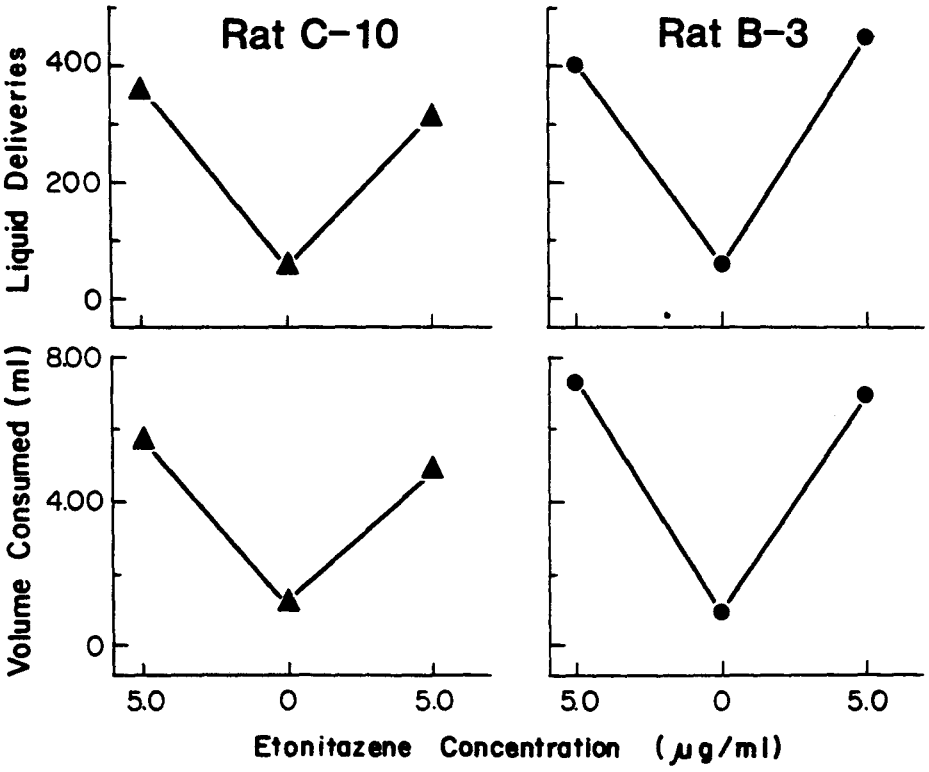


Figure 6. Mean deliveries (upper panel) and mean volume consumed (lower panel) of 5.0 µg/ml etonitazene and water for rats L-10 (triangles) and B-3 (circles). Each symbol is the mean of 5 consecutive sessions.

Table 1

Mean number of deliveries, volume consumed, and volume per delivery of 5.0 µg/ml etonitazene (Etz.) or water, and intake of Etz. (µg/kg body weight/hr).

| Rat | Liquid | Mean Deliveries | Mean ml Consumed | Mean ml/Delivery | Mean µg/ kg Body Weight/hr |
|---|---|---|---|---|---|
| | 5.0 µg/ml Etz. (test) | 355.0 | 5.68 | .016 | 31.8 |
| C-10 | 0.0 µg/ml Etz. (water) | 54.2 | 1.15 | .018* | ---- |
| | 5.0 µg/ml Etz. (retest) | 314.2 | 4.81 | .015 | 27.0 |
| | 5.0 µg/ml Etz. (test) | 396.0 | 7.31 | .018 | 60.7 |
| B-3 | 0.0 µg/ml Etz. (water) | 56.8 | .90 | .017 | ---- |
| | 5.0 µg/ml Etz. (retest) | 451.4 | 6.99 | .016 | 58.1 |

*N = 4; i.e., 1 session had 0 deliveries and 0 volume consumed.

more 5.0 µg/ml etonitazene HCl was drunk than water by both rats (lower panel of Figure 6 and Table 1). Rat C-10 drank more than 4.8 ml and rat B-3 drank more than 6.9 ml of 5.0 µg/ml etonitazene HCl; both drank less than 1.2 ml of the vehicle, water. The higher drug than vehicle intake indicates that etonitazene was serving as a positive reinforcer (cf. Meisch & Stark, 1977).

Table 1 presents the mean liquid deliveries, volume consumed, volume per liquid delivery, and intake of etonitazene HCl per kg body weight per hr for each rat and condition. Rat B-3's etonitazene intake was nearly twice that of C-10's during both the test and retest conditions; rat B-3 averaged 60.7 and 58.1 µg/kg body weight/hr during the test and retest conditions, respectively.

Table 1 also shows that the mean volume of liquid delivered per delivery ranged from .015 to .018 ml across all conditions. The volume per delivery did not vary as a function of liquid (i.e., drug vs. water). Also, the volume per delivery did not consistently vary within the range of the mean liquid deliveries presented in Table 1; that is, about the same volume per delivery was calculated across sessions averaging between 54 and 451 deliveries.

Figure 7 presents sample cumulative records for both rats from each condition. When water was the available liquid there was little drinking, few unreinforced spout contacts (first component contacts), or nonessential lever presses (lever presses not initiating the second component of the chain schedule) occurred. However, with 5.0 µg/ml etonitazene available a different pattern emerged for both rats. There was much more drinking.

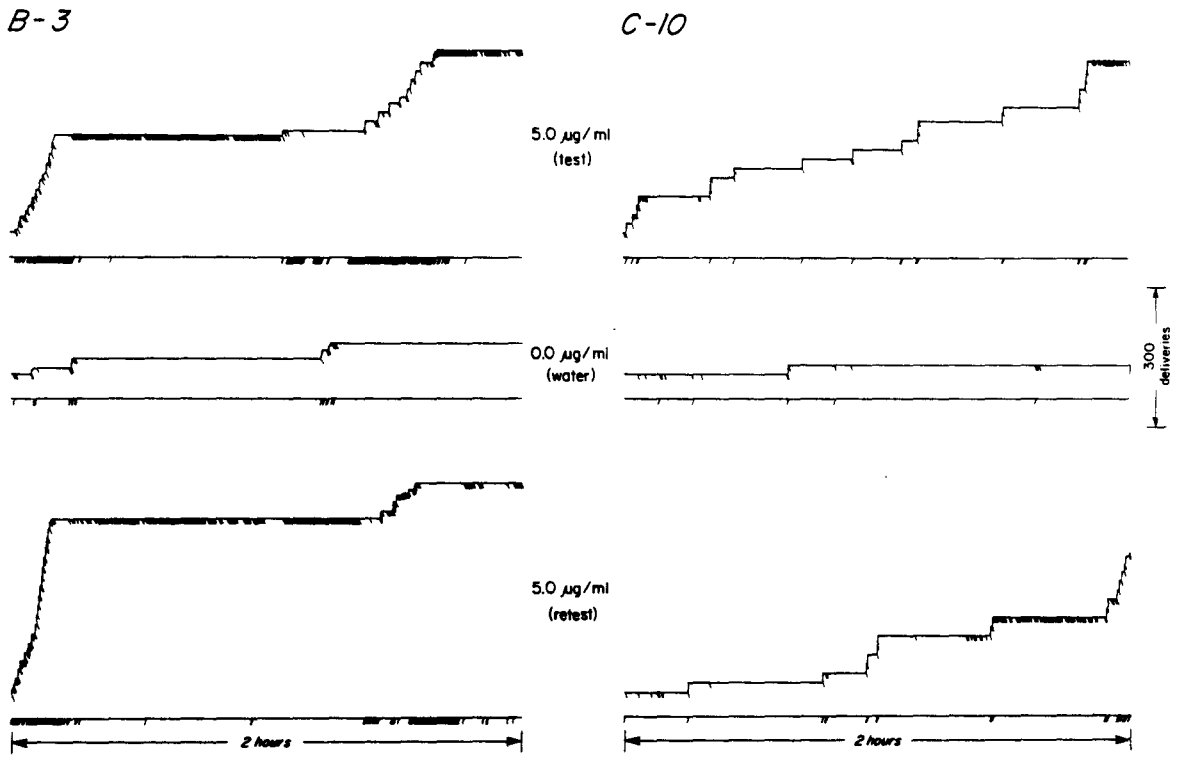


Figure 7. Cumulative records of the performance of rats B-3 and C-10 during the 5.0 µg/ml etonitazene test and retest conditions and during the water condition. Each record was selected on the basis of representing the number of liquid deliveries closest to the mean for its respective condition. Event pen pips represent lever presses. Increments in the stepping pen indicate reinforced spout contacts. Stepping pen pips indicate unreinforced spout contacts.

Also, many more unreinforced spout contacts occurred. The increase in unreinforced spout contacts was especially pronounced with B-3; bouts of hundreds of unreinforced spout contacts occurred after an initial bout of drinking. These unreinforced spout contacts were followed by bouts of nonessential lever presses before etonitazene drinking resumed.

Intakes of etonitazene in the present study were similar to previous etonitazene intakes obtained with the same two rats, identical etonitazene concentration, and equal session durations when a dipper delivery system was used (Beardsley and Meisch, unpublished data). Rat C-10 averaged 31.7 µg/kg body weight/hr in the dipper delivery system and 29.4 µg/kg body weight/hr in the present system (mean of test and retest values; ie., N = 10; 2 conditions X 5 sessions each). Rat B-3 averaged 76.1 µg/kg body weight/hr in the dipper delivery system and 59.4 µg/kg body weight/hr in the present system. These similarities in intake persisted despite differences in schedule of availability, age of rats, and experimental chamber used.

## Experiment 3. Ethanol or water as the available liquid

The purposes of Experiment 3 were similar to those of Experiment 2 except ethanol rather than etonitazene was the available drug. Experiment 3 tested whether ethanol would serve as a reinforcer using the present liquid delivery system for a rat which had an ethanol drinking history in a dipper delivery system. Additionally, ethanol intake obtained in Experiment 3 was to be compared with intake determined previously using a dipper delivery system. A rat for which ethanol had previously served as a

reinforcer was tested with 8% w/v ethanol or water with the valve at setting .2.

## METHODS

Subjects. One adult male, Long Evans descent hooded rat (Blu-Spruce Farms), approximately 2 yr old at the beginning of the study was tested during daily 3 hr experimental sessions. The rat had an extensive history of lever pressing for, and drinking from, dipper cups filled with ethanol solutions ranging from 2 to 32% w/v during a previous study (Beardsley, Lemaire, and Meisch, in preparation).

Procedure. The rat was maintained at 80% of its free feeding body weight by placing limited amounts of Purina Laboratory Chow in its home cage immediately following each experimental session. The rat had unlimited access to water between experimental sessions in its home cage.

At the beginning of the study, rat T-2 was allowed access to 8% w/v ethanol on a heterogenous chain Fixed Ratio 1 (lever press) Fixed Ratio 1 (20) (spout contact) schedule of reinforcement [i.e., chain FR 1 FR 1 (20)]. During the first experimental session, the rat acquired the lever press-spout contact response chain without explicit shaping. Gradually, over the next 44 sessions, the fixed-ratio lever press requirement was increased to FR 16. The rat was then tested on a chain FR 16 FR 1 (20) schedule with 8% w/v ethanol, water, and 8% w/v ethanol (retest) available. Changes from the availability of one liquid to the next were made following 5 consecutive sessions of stable responding as determined by visual inspec-

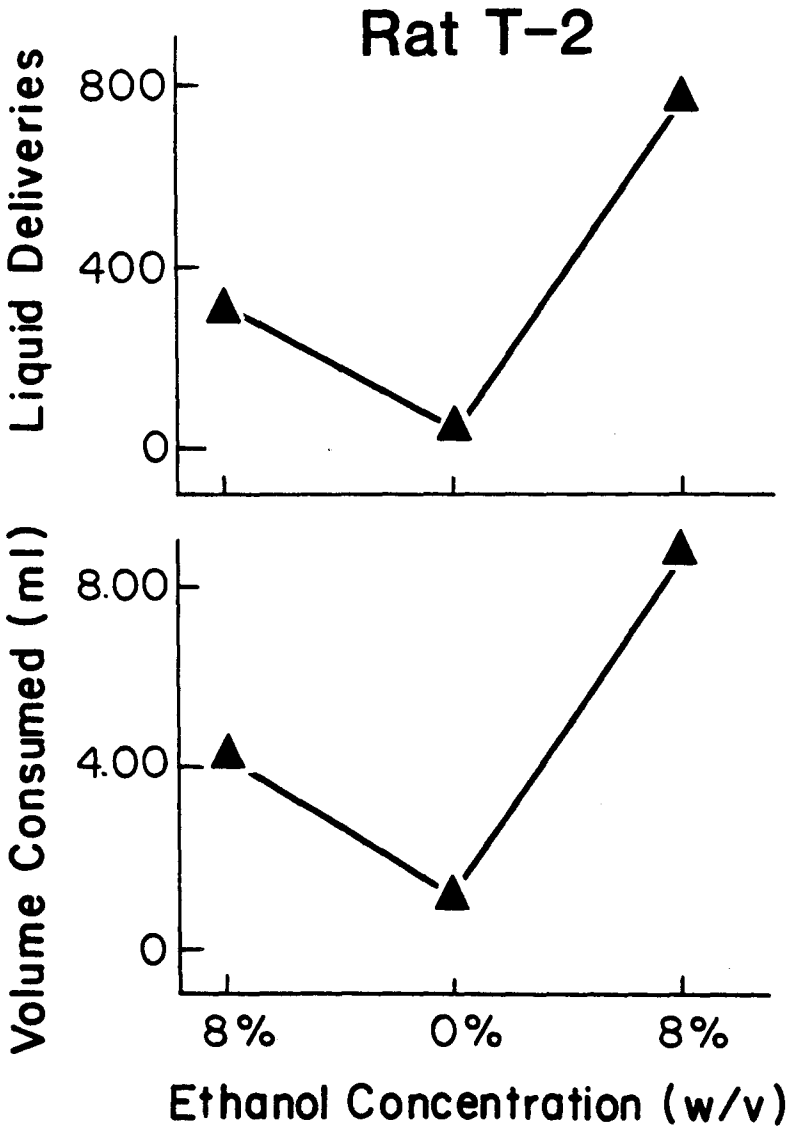


Figure 8. Mean deliveries (upper panel) and volume consumed (lower panel) of 8% w/v ethanol and water for rat T-2. Each symbol is the mean of 5 consecutive session values.

Table 2

Mean number of deliveries, volume consumed, and volume per delivery of 8% w/v ethanol or water, and intake of ethanol (g/kg body weight/hr) for rat T-2.

| Liquid | Mean Deliveries | Mean ml Consumed | Mean ml/Delivery | Mean g/ kg Body Weight/hr |
|---|---|---|---|---|
| 8% w/v ethanol (test) | 308 | 4.31 | .014 | .314 |
| 0% w/v ethanol (water) | 56 | 1.23 | .024* | ---- |
| 8% w/v ethanol (retest) | 765 | 8.76 | .012 | .638 |

*See text

tion of the data. Stimulus conditions during each component of the chain schedule of reinforcement were identical to those prevailing in Experiment 2 except the white-jewelled lamp flickered at 10 times per second during the first component when 8% w/v ethanol was present.

Ethanol solutions were prepared at least 20 hr prior to each session using 95% ethanol and deionized water. When water was the available liquid, deionized water was used. The micrometric capillary valve was at setting .2 throughout the entire study. Volume consumptions were determined as in the previous studies.

## RESULTS

Rat T-2 obtained more deliveries of 8% w/v ethanol than water (upper panel of Figure 8 and Table 2). The rat obtained a mean of 308 and 765 deliveries of 8% w/v during the initial test and retest ethanol periods, respectively, but averaged only 56 deliveries of water. Similarly, greater volumes of 8% w/v ethanol were drunk than water (lower panel of Figure 8 and Table 2). Less than an average of 1.24 ml of water was drunk; however, during the ethanol test and retest periods, an average of 4.31 and 8.77 ml was drunk, respectively. The greater ethanol than vehicle (water) intake suggests that ethanol was functioning as a positive reinforcer (Meisch & Thompson, 1974).

Table 2 shows the mean liquid deliveries, volume consumed, volume per delivery and intake of ethanol per kg body weight per hr during all conditions. The mean volume per liquid delivery was highest with the lowest mean number of deliveries (for water at 56 deliveries) and lowest with the

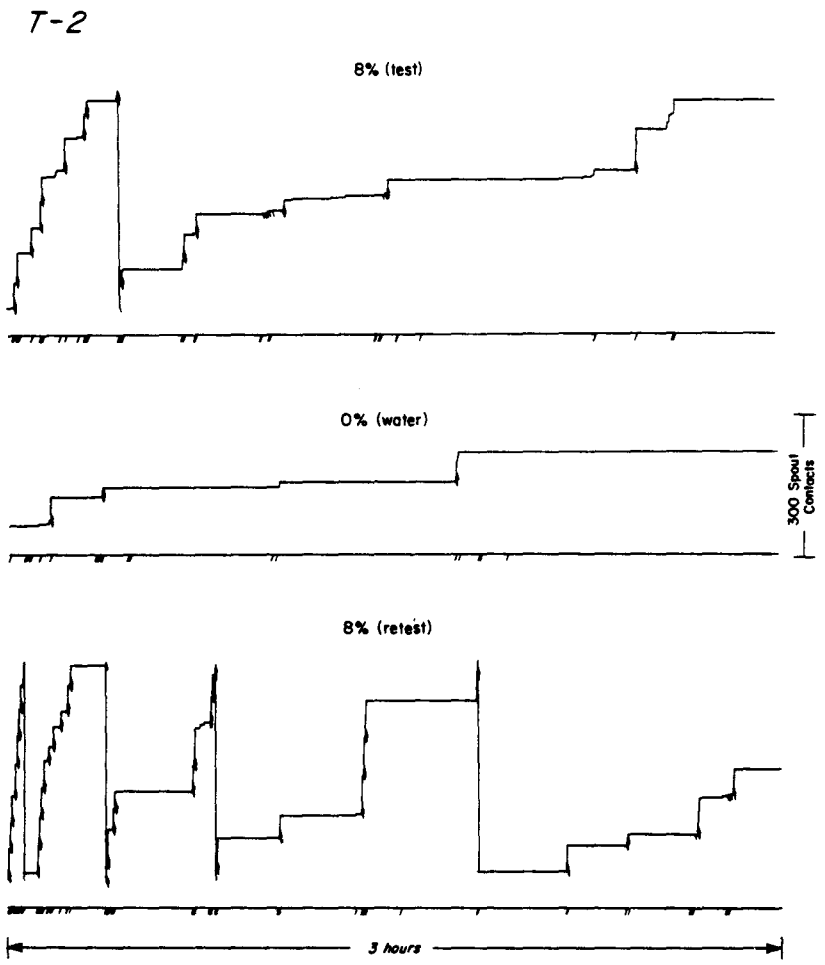


Figure 9. Cumulative records of the performance of rat T-2 during the 8% w/v ethanol test and retest conditions and during the water condition. Each record was selected on the basis of representing the number of liquid deliveries closest to the mean for its respective condition. Increments in the stepping pen indicate spout contacts. Stepping pen pips indicate reinforced spout contacts.

highest mean number of deliveries [for 8% w/v ethanol (retest) at 765 deliveries]. The high volume per delivery determination obtained when water was present (0.24 ml per delivery) was, in part, accounted for by one session in which the individually calculated volume per delivery of .035 ml was obtained. During this session the fewest number of deliveries (i.e., 20 deliveries) occurred of the 5 sessions used to determine the mean value for the water-available condition.

Figure 9 presents sample cumulative records for both 8% w/v ethanol tests and for water. When 8% w/v ethanol was available, many reinforced spout contacts occurred. The greatest number of reinforced spout contacts occurred in the first third of the session. When there were unreinforced spout contacts, they usually immediately followed a bout of reinforced spout contacts. Few reinforced or unreinforced spout contacts occurred when water was the available liquid.

Intake of ethanol for rat T-2 in the present study was dissimilar to previous intake determined using a dipper delivery system (Beardsley, Lemaire, and Meisch, in preparation). When tested in the dipper delivery system during sessions of identical duration and ethanol concentration as used in the present study, rat T-2's ethanol intake was .751 g/kg body weight/hr. In the present study, rat T-2's ethanol intake was .476 g/kg body weight/hr (mean of test and retest values; i.e., N = 10; 2 conditions X 5 sessions each). However, it should be noted that ethanol intake during the retest condition of the present study was .638 g/kg body weight/hr which was over twice that of the test condition (.314 g/kg body weight/hr).

Reasons for the difference in results between the test and retest conditions are unknown.

## DISCUSSION

The present drinking system provided several advantages over dipper delivery systems and did so at a relatively inexpensive cost. First, it allowed quick and easy control of the volume delivered between .0027 and .012 ml (Experiment 1). Presumably the range of liquid delivered could be further expanded by manipulating the duration of delivery from that used in the present study (40 msec) or by adding weight to the hollowed, plexiglass cylinder used to depress the syringe plunger.

Secondly, evaporation was minimized by the use of a closed reservoir. Utilization of completely closed reservoirs in dipper delivery systems are precluded by the necessity of dipper cup refilling operations.

Thirdly, and most importantly, the drinking device, in conjunction with the heterogenous chain schedule of reinforcement, insured that liquid was delivered only when oral contact was made with it. The assurance of oral contact with dispensed liquid is particularly important in research involving the oral self-administration of drugs. For instance, in previous research (Beardsley and Meisch, unpublished data) it was observed that rats, orally self-administering 5.0 μg/ml etonitazene, would complete fixed-ratio lever press requirements repeatedly for dipper presentations of the drug yet would not drink the presented liquid. This repeated occurrence of not drinking available drug followed periods in which some etonitazene had been drunk which suggested the influence of a drug effect.

The present drinking device, as programmed, prevented dispensing of liquids unless there was tongue contact on the drinking spout, and it enabled recording of tongue contacts when liquid was not available.

REFERENCES

Hulse, S. H. A precision liquid feeding system controlled by licking behavior. Journal of the Experimental Analysis of Behavior, 1960, 3, 1-3.

Justesen, D. R., Levinson, D. M., & Daley, M. A modification of the Hulse lickerandum: Preliminary studies and suggested applications. Psychonomic Science, 1967, 7, 111-112.

Lal, H., & Zabik, J. P. Operant ingestion (oral) of ethanol: Effects of behavioral contingencies, disulfiram pretreatment and morphine dependence. In J. M. Singh & H. Lal (Eds.), Drug Addiction: Experimental Pharmacology (Vol. 1). New York: Futura Publishing Co., Inc., 1972.

Keleher, R. T., & Gollub, L. R. A review of positive conditioned reinforcement. Journal of the Experimental Analysis of Behavior, 1962, 5, 543-597.

Meisch, R. A., & Stark, L. J. Establishment of etonitazene as a reinforcer for rats by use of schedule-induced drinking. Pharmacology, Biochemistry and Behavior, 1977, 7, 195-203.

Meisch, R. A., & Thompson, T. Rapid establishment of ethanol as a reinforcer for rats. Psychopharmacologia, 1974, 37, 311-321.

Miller, N. A., & De Bold, R. C. Classically conditioned tongue-licking and operant bar pressing recorded simultaneously in the rat. Journal of Comparative and Physiological Psychology, 1965, 59, 109-111.

Patten, R. L, & Deaux, E. B. Classical conditioning and the licking response in rats. Psychonomic Science, 1966, 4, 21-22.