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Ethanol-Reinforced Responding and Intake as a Function of Volume per Reinforcement[1]

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HENNINGFIELD, J. E. AND R. A. MEISCH. *Ethanol-reinforced responding and intake as a function of volume per reinforcement.* PHARMAC. BIOCHEM. BEHAV. 3(3) 437–441, 1975.– Number of ethanol reinforcements obtained and ethanol intake (mg/100 g body weight/hr) of 3 food-deprived rats were measured over a range of dipper volumes during daily 1 hr sessions. The rats had free access to water in their home cages between sessions. Ethanol concentration was 8 percent (W/V); each response was reinforced. As the volume per reinforcement increased, ethanol intake tended to increase, while the number of reinforcements obtained decreased systematically. Responding was maintained by 8 percent (W/V) ethanol but not by water.

Rats Ethanol drinking Ethanol reinforcement Volume per reinforcement Ethanol intake Magnitude of reinforcement

RESPONSE rate varies inversely with the amount of food reinforcement per response when each response is reinforced [8,9] and when every tenth response is reinforced [1]. Additionally, the quantity (g) of food obtained increases with the amount of reinforcement per response [1,8]. Similar relationships have been found when drugs serve as reinforcers via the intravenous route: Over a range of doses, response rate under fixed ratios of 10 or less is inversely related to dose, while intake (mg/kg/hr) of some drugs increases with dose [2, 3, 9, 10, 11, 12, 13]. In several studies that have employed a liquid dipper mechanisms, the amount (mg) of ethanol per reinforcement has been varied by manipulating the concentration and by holding dipper volume constant [4, 5, 6, 7]. As the ethanol concentration was increased from 2 to 32 percent (W/V), the number of reinforcements first increased and then decreased at the higher concentrations [4,5]. However, these changes in number of reinforcements as a function of ethanol concentration cannot be attributed solely to variations in the amount of ethanol, for different concentrations probably have different taste properties. In the present study, the amount of ethanol per reinforcement was manipulated by holding the concentrations constant at 8 percent (W/V) and by varying the volume per reinforcement. Orderly relationships were obtained between dipper volume and number of reinforcements, quantity consumed, and time course of lever pressing.

METHOD

Animals

Three male albino Sprague-Dawley rats, about 150 days old at the beginning of the experiment, were individually housed in a constantly illuminated room with the temperature maintained at 24°C. They were maintained at 80 percent of their free-feeding weights; under these conditions the rats weighed: 360 g, R-22; 362 g, R-24; 424 g, R-29. Water was always available in the rats' home cages, except for 5 days during training (see *Procedure* below).

Apparatus

A sound-attenuated commercial operant conditioning chamber (LVE, No. 1417) was equipped with two levers and a solenoid-driven liquid dipper (LVE, No. 1351). Lights located above the levers provided general illumination. A 4 W clear light was located 3.2 cm above the hole in the panel where the dipper was when in the up position. The dipper cup (0.034 ml in volume during training) was constantly available, i.e., in the up position, except during the 0.8 sec refilling operation when it was lowered into the reservoir. Each press on the right-hand lever resulted in a refilling operation, during which a Sonalert sounded and the light above the dipper was turned off. White masking noise was constantly present, and an exhaust fan provided ventilation.

Programming and data recording were automatically

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controlled by standard electromechanical equipment in an adjacent room. The temporal pattern of the responses and reinforcements was continuously recorded by a cumulative recorder and a counter which printed out every 2 min.

The ethanol concentrations, expressed in grams percent, were prepared using 95 percent (V/V) ethanol in tap water. For example, the 8 percent solution was made by adding 10.6 ml of ethanol to a volumetric flask with sufficient tap water to make a total volume of 100 ml. 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.

Procedure

Establishment of lever pressing for water. Water bottles were removed from the rats' home cages and to further increase the probability of drinking, the daily feedings of Purina Laboratory Chow were placed in a wire food hopper in the operant chamber. During the first daily 6 hr session, dipper presentations occurred on a 1 min variable-time schedule. After the rats learned to drink from the dipper, the variable-time liquid presentations were discontinued, and the rats were manually shaped to lever press. After the rats learned to lever press, 3 more sessions were conducted before the water bottles were restored to the home cages.

Establishment of ethanol as a reinforcer. In-session feedings of Purina Chow continued for a series of 14 daily 6 hr sessions. During the first 5 sessions water was the available liquid, then 2 percent ethanol for 2 sessions, 4 percent ethanol for 3 sessions, and 8 percent ethanol for 4 sessions. The in-session feedings were then discontinued, and the food was given to the rats only in their home cages following each session. Five sessions were run at 8 percent; then, the session length was decreased to 1 hr, and 5 more sessions at 8 percent were run. Finally, 7 sessions were run at 0 percent (water), and then 8 percent ethanol was reintroduced. Immediately after the 5 ethanol sessions following the water phase, the dipper volume was changed from 0.034 ml to 0.274 ml, and the volume manipulations were begun.

Volume manipulations. Volume of 8 percent (W/V) ethanol per reinforcement was manipulated by use of 5 logarithmically decreasing dipper cup volumes that were presented in the following order: 0.274, 0.137, 0.068, 0.034 and 0.017 ml. Following completion of the series of sessions at 0.017 ml, the 0.274 ml dipper was reinstated for two of the rats R-22 and R-24. Each dipper volume was present for at least 10 consecutive sessions, and a change in dipper volumes was not made until lever pressing appeared stable. Stability was subsequently checked by comparing the mean of the first 5 of 10 consecutive sessions with the mean of the second 5 sessions. The lower mean divided by the higher mean provided a stability ratio, and the median

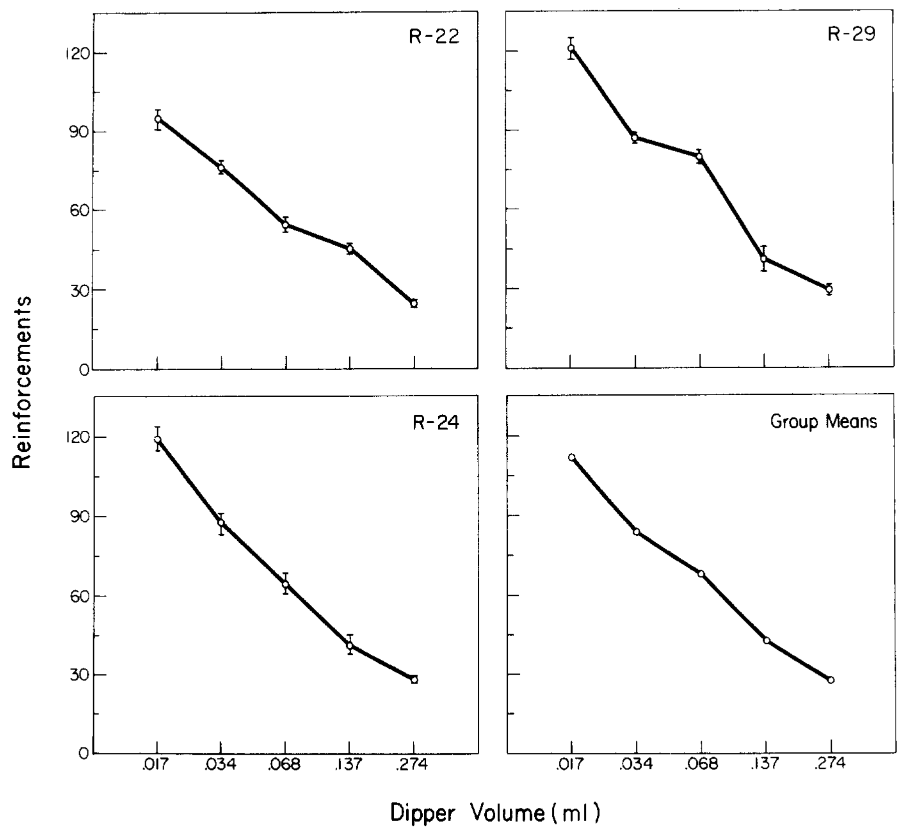

FIG. 1. Ethanol reinforcements per 1 hr session as a function of volume per reinforcement. Abscissa: dipper volume in ml, logarithmic scale; ordinate: number of ethanol reinforcements per 1 hr session. Each point indicates the mean value of the last 10 sessions at a dipper volume, except for the points in the lower right-hand panel, where each point represents the mean value of 30 sessions (3 rats × 10 sessions). Vertical lines indicate the standard error of the mean.

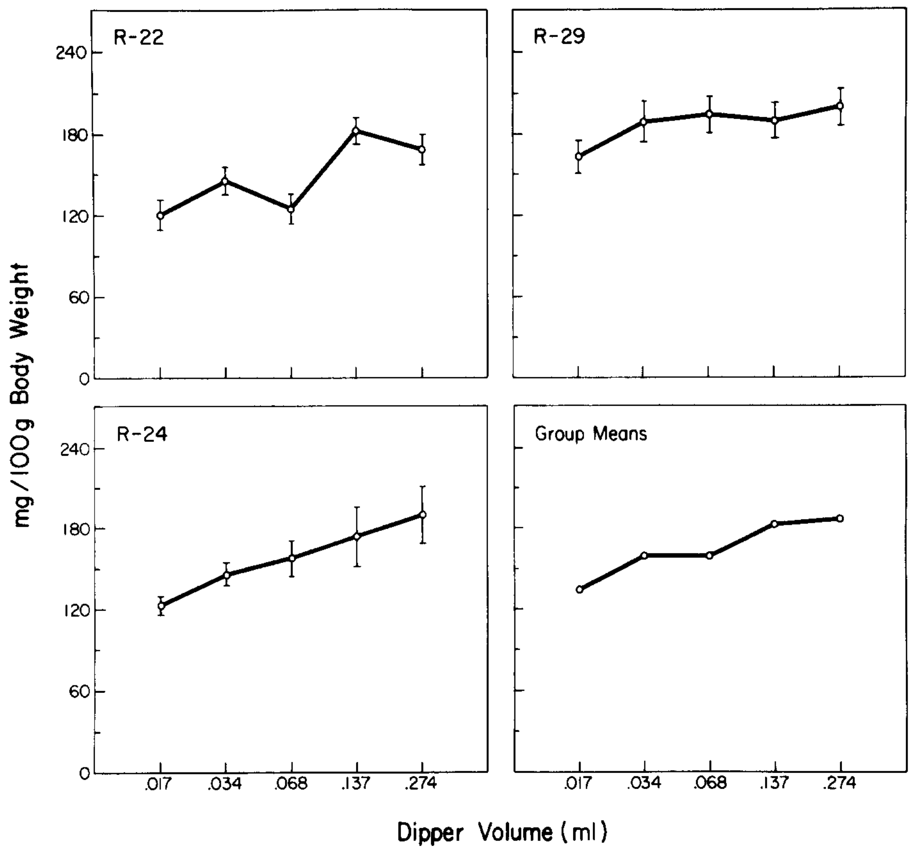

FIG. 2. Ethanol intake (mg/100 g body weight) per 1 hr session as a function of volume per reinforcement. Abscissa: dipper volume in ml, logarithmic scale; ordinate: quantity of ethanol consumed in mg per 100 g of body weight. Each point indicates the mean value of the last 10 sessions at a dipper volume, except for the points in the lower right-hand panel, where each point represents the mean value of 30 sessions (3 rats X 10 sessions). Vertical lines indicate the standard error of the mean.

value for these 15 ratios (3 rats x 5 dipper volumes) was 0.94. In 6 of the 15 comparisons the mean of the first 5 sessions was the lower mean.

RESULTS

When water was substituted for 8 percent ethanol, lever pressing declined more than 85 percent. Reintroduction of 8 percent ethanol resulted in a prompt return to intake levels reached prior to the water sessions. These results indicate that ethanol was serving as a reinforcer.

Figure 1 shows that as the volume per reinforcement increased, the number of reinforcements obtained per 1 hr session decreased. The results were orderly: In every case increases in dipper size resulted in decreases in the number of reinforcements, and the results for the individual rats and the results for the group were very similar (Fig. 1). When rats were shifted to a new dipper volume, performance usually stabilized quickly. At each dipper volume rats R-22, R-24, and R-29 were run a median number of 12, 14 and 12 sessions, respectively. Following completion of the series of sessions with the 0.017 ml dipper, the 0.274 ml dipper was reinstated for two of the rats, R-22 and R-24, so that comparisons of intake could be made before and after dipper volume was varied. Mean numbers of reinforcements obtained for rats R-22 and R-24, respectively, initially were 24.5 and 28.5, and on retest were 23.7 and 32.0. These data suggest that the systematic changes in ethanol-reinforced responding, occuring when volume per reinforcement was manipulated, were not due to nonspecific shifts in liquid intake over time.

Figure 2 shows that as the dipper size was increased there was a somewhat variable trend towards increasing amount (mg per 100 g of body weight) consumed. The points plotted in Fig. 2 are not directly related to the product of the dipper volume multiplied by the number of reinforcements obtained. This lack of correspondence may be due to the fact that the volume actually presented to the rat was not equal to the machined volume of the dipper. That is, as the dipper volume decreased, the proportion of liquid added by surface tension increased. The machined and actually presented volumes for each dipper size were, respectively: 0.017, 0.06; 0.034, 0.09; 0.068, 0.12; 0.137, 0.19; and 0.274, 0.31 ml.

Figure 3 shows the temporal distribution of reinforcements, and Fig. 4 presents representative cumulative re-

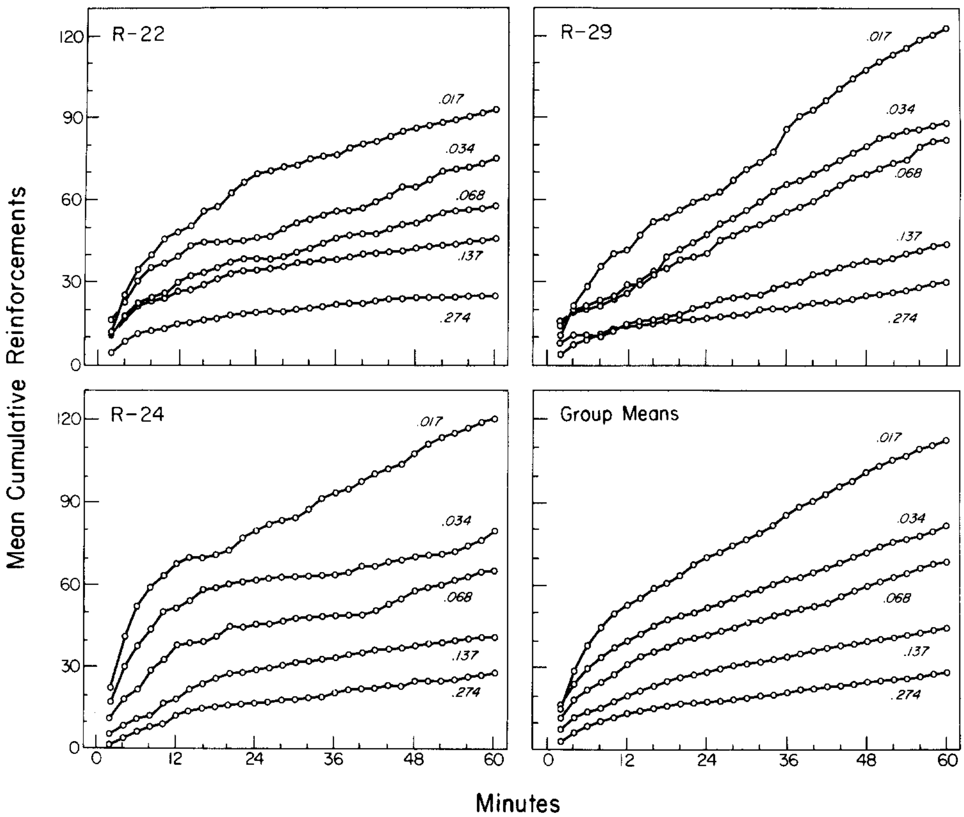

FIG. 3. Mean cumulative reinforcements over 1 hr sessions for each dipper volume. Each point is based on observations from 10 sessions, except for the points in the lower right-hand panel, where each point is based on observations from 30 sessions (3 rats X 10 sessions).

cords. Reinforcements occurred most frequently at the beginning of the session (Fig. 3). As the dipper volume was decreased, the rats' responding became more evenly distributed over the session (Fig. 3). Lever pressing, when it occurred, was often in bursts (Fig. 4).

DISCUSSION

Increasing the amount of ethanol delivered per reinforcement produced increases in the quantity of ethanol consumed and decreases in the number of reinforcements obtained. These relationships are similar to those that have been found in many studies of intravenous drug reinforcement [2, 3, 9, 10, 11, 12, 13]. The data are consistent with results obtained with food-deprived rats when the amount of ethanol per reinforcement was varied by altering the ethanol concentration [4, 5, 6]. When the concentration was increased from 4 to 8 to 16 to 32 percent (W/V), the number of reinforcements decreased while the quantity consumed increased [4,5]. However, at 2 percent (W/V) the number of reinforcements was less than at 4 percent (W/V), and in a pilot study using Rat R-29, responding was not maintained with a dipper volume of 0.005 ml. Responding is diminished or not maintained when the amount of ethanol per reinforcement is decreased below a certain point. These results obtained with different dipper volumes extend the range of conditions under which ethanol serves as a reinforcer.

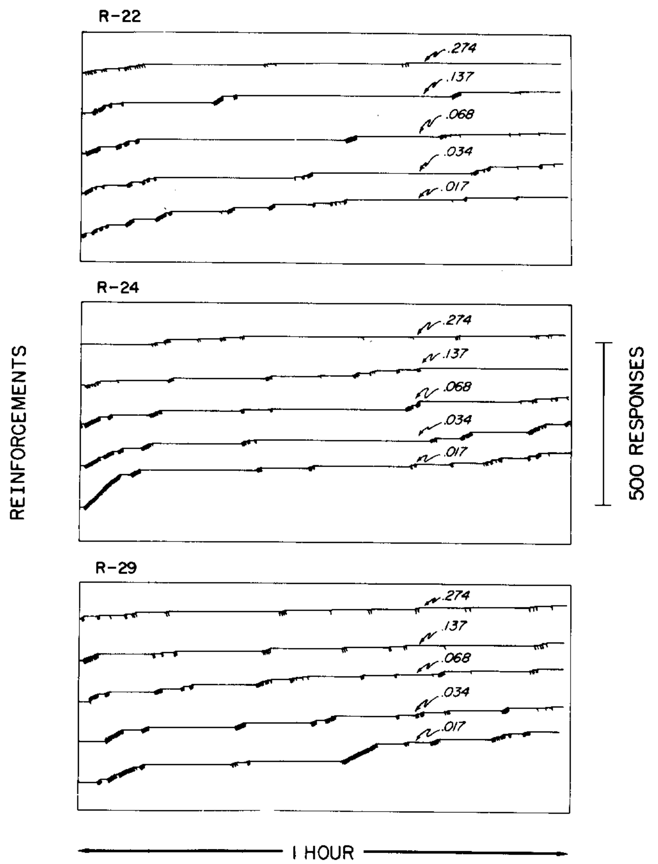

FIG. 4. Representative cumulative records for each rat at each dipper volume. Numbers above each record indicate the dipper volume in ml. Each record for each rat was selected on the basis of being closest to the mean value at a particular dipper volume. Time is indicated along the abscissa, and responses are cumulated along the ordinate. Thus, the slope of the line represents the rate of responding. Slash marks indicate dipper presentations of 8 percent ethanol.

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