Reports from the Research Laboratories
of the
Department of Psychiatry
University of Minnesota

Ethanol Intake in Food-Deprived and Food-Satiated Rats:
Effects of Ethanol Concentration and Alternate Positions of Water and Ethanol
by
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August 28, 1975
Abstract

Water and ethanol solutions were concurrently available on a continuous reinforcement schedule to two male albino rats under conditions of food deprivation and food satiation. The rats were run during daily 1-hr sessions in an operant-conditioning chamber equipped with two levers and two liquid dippers. During both food deprivation and food satiation at each concentration (8, 16, and 32% w/v), the number of ethanol reinforcements exceeded the number of water reinforcements. Also, water reinforcements were low in number and did not vary with ethanol concentration or feeding condition. During the food-deprived phase, as the ethanol concentration was increased the number of ethanol reinforcements decreased and the quantity consumed (mg/100 g of body weight/hr) increased. However, during the food-satiated phase the number of ethanol reinforcements was greatest at 16%, and the quantity consumed was also greatest at 16%. The number of ethanol reinforcements at 8% was less during the food-satiated phase than the food-deprived phase, but at 16 and 32% the differences in ethanol reinforcements were diminished. During both food conditions and at all concentrations, the highest rate of responding occurred at the beginning of the session.

Key Words: Ethanol - Water-Ethanol Choice - Concurrent Schedule - Food-deprived - Food-satiated - Rats
Lester and Freed (1972) have argued that food-deprived rats consume ethanol for its caloric value and not for its pharmacological properties. Since it is unlikely that human alcohol dependence is maintained by caloric need, they have argued that the use of food-deprived rats in the study of ethanol drinking is "meaningless." If, however, rats which are food and water satiated self-administer ethanol in a similar pattern as when food-deprived, then it seems likely that they do so for reasons other than to satisfy hunger or thirst. Meisch and Thompson (1974) have shown that food-satiated rats will consume ethanol concentrations of 2, 4, 8, 16, and 32% (w/v) in excess of water control values. The water control values were obtained during phases preceding and following presentations of the ethanol concentrations. Unfortunately, their procedure did not allow a control for general liquid increase simultaneous with ethanol availability. Myers (1961a, 1961b; Myers and Carey, 1961) made water and food concurrently available with ethanol. The presentation of each liquid was contingent upon a lever press of a different lever. Although controlling for possible general liquid increases by making water simultaneously available with ethanol, the rats used in the Myers' studies were both liquid and food deprived. Meisch and Beardsley (1974, 1975) used a procedure similar to Myers' in that water and ethanol were concurrently available to food-deprived rats contingent upon lever pressing. They also alternated the side positions of ethanol and water daily and thus controlled for possible side biases. The present study uses the same procedure employed by Meisch and Beardsley (1974, 1975) and systematically extends the previous findings by using food-satiated rats.

The purpose of this study was to compare ethanol intake in food-deprived and food-satiated rats under conditions of concurrent access to water. The quantity (mg) of ethanol consumed and the time course of intake were
measured under both food conditions. Additionally, the intake of 8% (w/v) ethanol was examined during the transition phase from the food-deprived to the food-satiated state.

Method

Subjects. Two naive male albino Sprague-Dawley rats were individually housed in a constantly illuminated room with the temperature maintained at 24° C. Rat Z-2 was approximately 300 days old and rat KK-3 about 120 days old at the beginning of the experiment. Free-feeding weights were calculated for each rat by taking their mean weight for 10 consecutive days during which Purina Laboratory Chow was constantly available in their home cages. At 80% of their free-feeding weights, at which the rats were maintained during their food-deprived condition, rat Z-2 weighed 494 g and rat KK-3 weighed 407 g. Water was always available in the rats' home cages except for 5 days during initial training (see Procedure below).

Apparatus. A sound-attenuated commercial operant-conditioning chamber (LVE, #1414) was equipped with two levers and two solenoid-driven liquid dippers (LVE, #1351). The levers and liquid dippers were symmetrically centered on the front panel with the dippers placed lateral to the levers. Three colored jewel lights located above each lever provided general illumination. A 4.76-W white light was located 3.2 cm above the hole in the panel where the dipper cup was located when in the up-available position. Each lever press produced 4-sec access to a dipper cup containing 0.12 ml of liquid. Simultaneous with the 4-sec dipper cup presentation was the sounding of a tone (Sonalert, 2900 Hz, Mallory & Co.) and the illumination of the light above the dipper-panel opening. Liquid was contained in partially covered reservoirs to minimize evaporation. White masking noise was constantly present, and an exhaust fan provided ventilation.
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PR-75-4

1This research was supported by U.S. Public Health Service grant AA00299.

2NIDA Research Scientist Development Awardee, DA00007.
Programming and data recording were automatically 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 (w/v), were prepared using 95% (v/v) ethanol in tap water. For example, the 8% 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 hrs 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. Evaporation corrections were determined for each concentration by measuring the volume lost from a second reservoir which, during experimental sessions, was placed adjacent to the reservoir used with the liquid dipper.

Procedure. Table 1 summarizes the phases of the procedure for establishing concurrent performance maintained by water and ethanol-reinforced lever pressing.

Establishment of Lever Pressing for Water. To induce drinking in the operant-conditioning chamber, water bottles were removed from the rats' home cages. Daily feedings of Purina Laboratory Chow, which maintained the rats at 80% of their free-feeding weight, were placed in wire food hoppers in the operant-conditioning chambers to further induce drinking. During the first 6-hr session, right-side dipper presentations of water occurred noncontingently on a 1-minute variable time (1-min VT) schedule of reinforcement. During the second and third 6-hr sessions, the 1-min VT schedule was discontinued and right-side dipper presentations of water were used to
Table 1. Sequence of training and experimental phases

<table>
<thead>
<tr>
<th>Phases</th>
<th>Home Cage</th>
<th>Operant Chamber</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Food</td>
<td>Left side</td>
</tr>
<tr>
<td>Establishment of lever-pressing for water</td>
<td>a</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td></td>
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<td></td>
<td>c</td>
<td></td>
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<tr>
<td>Establishment of ethanol as a reinforcer</td>
<td>e</td>
<td>0%</td>
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<td></td>
<td></td>
<td>2%</td>
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<td>4%</td>
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<td></td>
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<td>8%</td>
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<td></td>
<td></td>
<td>8%</td>
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<tr>
<td>Establishment of concurrent performance</td>
<td>a</td>
<td>-</td>
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<tr>
<td></td>
<td></td>
<td>Alternation of 8% &amp; E</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alternation of 8% &amp; E</td>
</tr>
<tr>
<td>Experimental phase</td>
<td></td>
<td>Alternation of 8% &amp; 0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alternation of 16% &amp; 0%</td>
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<td>Alternation of 32% &amp; 0%</td>
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<td></td>
<td></td>
<td>Alternation of 8% &amp; 0%</td>
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<td></td>
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<td>(Retest)</td>
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Table 1. Sequence of training and experimental phases
(continued)

<table>
<thead>
<tr>
<th>Phases</th>
<th>Home Cage</th>
<th>Operant Chamber</th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Food</td>
<td>Water</td>
<td>Left side</td>
<td>Right side</td>
<td>Food</td>
<td>Session duration</td>
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<tr>
<td>Transition phase</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Rat KK-3</td>
<td>+g</td>
<td>+</td>
<td>Alternation of 8% &amp; 0%</td>
<td>-</td>
<td>1 h</td>
<td>107</td>
</tr>
<tr>
<td>Rat Z-2</td>
<td>+h</td>
<td>+</td>
<td>Alternation of 8% &amp; 0%</td>
<td>-</td>
<td>1 h</td>
<td>79</td>
</tr>
<tr>
<td>Food-satiated</td>
<td>+g</td>
<td>+</td>
<td>Alternation of 8% &amp; 0%</td>
<td>-</td>
<td>1 h</td>
<td>≥ 10</td>
</tr>
<tr>
<td>experimental phase</td>
<td>+</td>
<td>+</td>
<td>Alternation of 16% &amp; 0%</td>
<td>-</td>
<td>1 h</td>
<td>≥ 10</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>+</td>
<td>Alternation of 32% &amp; 0%</td>
<td>-</td>
<td>1 h</td>
<td>≥ 10</td>
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<td></td>
<td>+</td>
<td>+</td>
<td>Alternation of 8% &amp; 0%</td>
<td>-</td>
<td>1 h</td>
<td>≥ 10</td>
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(Retest)

|                         |                      |                      |                      |                      |                      |                      |

a Absence of food
b Absence of water
c No consequences followed responses
d Sufficient food was provided to maintain rats at 80% of their free-feeding weights
e Free access to water
f Presentations of an empty dipper were produced by lever presses on the side not containing ethanol
g Free access to food
h Every second day its food allotment was increased by 2 g. These increases continued to the point where the rat had free access to food between sessions
shape responses on the right lever. After the rats learned to lever press, three more sessions were conducted before the water bottles were restored to the home cages.

Establishment of Ethanol as a Reinforcer. For the next 14 daily consecutive 6-hr sessions, enough food to maintain the rats at 80% of their free-feeding weight was provided in wire food hoppers in the operant-conditioning chamber. During the first five sessions, water was the available liquid at the right dipper, then 2% ethanol for two sessions, 4% ethanol for three sessions, and 8% ethanol for four sessions. In-session feedings were then discontinued and supplementary food was given to the rats after each session in their home cages. Sessions with 8% ethanol as the available liquid continued until five consecutive stable days of ethanol-reinforced responding occurred. During this phase, responses in the left-side lever had no consequences.

Establishment of Concurrent Performance. After 8% ethanol was established as a reinforcer at the right dipper, availability of 8% ethanol was shifted to the left dipper until the rats obtained an approximately equal number of ethanol reinforcements in a given session at the left dipper as they had in previous sessions at the right dipper. Thereafter, the position of 8% ethanol was alternated daily between the two dippers. Responding on the lever which was opposite the dipper containing ethanol produced presentations of an empty dipper. After 10 consecutive sessions of stable ethanol-reinforced lever pressing (five sessions on the left and five on the right), the session duration was reduced from 6-hr to 1-hr.

Food-deprived Phase. After daily alternating 8% ethanol between the sides for 10 consecutive 1-hr sessions, water was placed in the dipper reservoir opposite the one containing ethanol. Intake of ethanol concentra-
itions of 8, 16, 32, and 8% (retest), in that order, were studied during the concurrent availability of water. A change from one concentration to the next was made following 10 consecutive sessions in which there was no upward or downward trend in the number of reinforcements. Side positions of water and ethanol were alternated daily between the dippers except during the 8% retest series, in which 8% ethanol was held on the right side for two consecutive sessions and then on the left for two consecutive sessions; thereafter, liquid position again alternated daily between sides.

Transition Phase. Following 10 consecutive stable days of responding for 8% ethanol during the food-deprived 8% retest phase, the rats were returned to their free-feeding weights by two methods. During the first two days rat Z-2 was fed 2 g more than the mean amount of food (16 g) which maintained it at 80% of its free-feeding weight during the previous 10 days. Thereafter, the amount of food fed rat Z-2 following a session increased 2 g every second day, until uneaten food remained from a previous day's feeding in its home cage. Subsequently, it was allowed ad libitum access to food in its home cage. Rat KK-3 was given immediate ad libitum access to food in its home cage on the first day following completion of the food-deprived 8% retest condition. During this phase, 8% ethanol and water were shifted daily between dipper positions except for a few days for each rat when the positions of the liquids were maintained without alteration to induce higher ethanol consumption on a less preferred side. This phase was concluded when there was no consistent continued increase in the weights of the rats.

Food-satiated Phase. After the rats showed no further consistent increase in body weight, intake of ethanol concentrations of 8, 16, 32, and 8% (retest), in that order, were studied during concurrent water availability.
As during the food-deprived phase, a change from one concentration to the next was made following 10 consecutive sessions in which there was no consistent upward or downward trend in the number of ethanol reinforcements. Availability of water and ethanol was alternated daily between the dippers except during the 8% retest series in which 8% ethanol was again held constant on the right for two consecutive sessions and then on the left for two consecutive sessions. Subsequently, daily alternations in liquid positions were resumed.

Results

Food-deprived Phase. The left half of Figure 1 shows that the mean number of ethanol reinforcements exceeded the mean number of water reinforcements at each concentration regardless of the side of ethanol availability. There was no significant difference (i.e., p was always > 0.05, df = 8) between the mean number of ethanol reinforcements obtained on the two sides at any of the concentrations (t-test for the mean of two samples). The number of ethanol reinforcements during the 8% retest condition decreased by 8 and 15% on the left and right sides, respectively, for rat KK-3 compared to the number obtained during the initial 8% condition, and increased by 45 and 26% for the left and right sides, respectively, for rat Z-2. Also, during the 8% retest condition, both rats consistently responded on the side where ethanol was placed despite the fact that ethanol was held on the right side for two consecutive sessions and then on the left side for two consecutive sessions. This indicates that the rats did not merely learn to alternate between the sides from session to session, but discriminated the location of ethanol perhaps on the basis of odor (Meisch and Thompson, 1973). These results are consistent with those obtained in an earlier study (Meisch and Beardsley, 1975).
Figure 1. Ethanol and water reinforcements per 1-hr sessions as a function of ethanol concentration and position, left or right side. Left half of the figure shows reinforcements obtained during the food-deprived condition, while the right half shows reinforcements obtained during the food-satiated condition. Triangles: Reinforcements obtained on the left side; circles: Reinforcements on the right side. Filled symbols: Ethanol reinforcements; unfilled symbols: Water reinforcements. At 8%, where two points are plotted, the unconnected point is the retest value; occasionally, the retest point coincided with the original point, e.g., water reinforcements on the left side for rat Z-2. Brackets indicate the standard error of the mean. Where no brackets are visible the standard error of the mean fell within the area enclosed by the symbol. Each symbol represents the mean number of reinforcements obtained during five 1-hr sessions.
As the concentration of ethanol was increased, the number of reinforcements decreased (Fig. 1). However, the amount of the decrease was less than half of the number of reinforcements obtained at the next lower concentration. Since the volume consumed was proportional to the number of reinforcements, the quantity consumed (mg) increased with increasing concentrations (Fig. 2).

The highest rate of ethanol drinking occurred at the beginning of each session. Figure 3 shows that most ethanol reinforcements were acquired early in the session regardless of concentration; however, dipper presentations of water remained low in number and exhibited an even distribution throughout the session. Sample cumulative records (Fig. 4) show the close cluster of ethanol reinforcements near the beginning of the sessions for each concentration.

**Transition Phase.** Early in the transition phase between the food-deprived 8% retest condition and the food-satiated 8% condition, ethanol reinforcements greatly declined for both rats (Fig. 5 and 6). The slope of decline in ethanol reinforcements was greater for rat KK-3 which was abruptly food satiated. The amount of the reduction and the duration in the reduction of ethanol reinforcements were greater at the left dipper than the right dipper for both rats. By the end of the transition phase, ethanol reinforcements were greater than water reinforcements at both dippers for both rats. At the end of the transition phase, however, the number of 8% ethanol reinforcements was lower at the left dipper than at the right dipper. Also, the number of 8% ethanol reinforcements at either dipper was lower than the values of the food-deprived 8% retest condition. Dipper presentations of water were consistently low throughout the transition phase and showed no systematic variation with food satiation.
**Food-satiated Phase.** Figure 1 shows that during the food-satiated experimental phase mean ethanol reinforcements exceeded water reinforcements regardless of the concentration or side of ethanol availability. These results are similar to those obtained during the food-deprived phase. However, distinct differences between the two phases do appear in the number of ethanol but not water reinforcements obtained. The number of ethanol reinforcements during either of the 8% conditions (8% and 8% retest) at similar sides was less during the food-satiated than the food-deprived condition. However, the number of ethanol reinforcements at 16 and 32% at

![Graphs showing ethanol consumption](image)

**Figure 2.** Quantity (mg/100 g body weight/hr) of ethanol consumed per 1-hr session as a function of concentration. Left half of the figure shows consumption during food deprivation; right half shows consumption during food satiation. Triangles: Consumption on the left side; circles: Consumption on the right side. Each point is the mean value from five 1-hr sessions. Unconnected points represent values for the 8% retest condition.
Figure 3. Mean cumulative reinforcements over 1-hr sessions for each ethanol concentration. Each point is a mean based on observations from 5 sessions, except for those points at 0%, which are means from 20 sessions. Left half of the figure shows cumulative reinforcements obtained during food deprivation; right half shows cumulative reinforcements during food-satiation. Triangles indicate reinforcements obtained on the left side; circles indicate reinforcements obtained on the right side. Unfilled symbols represent cumulative ethanol reinforcements obtained during the 8% re-test condition.
similar sides during the two food conditions was not significantly different except for one of eight possible comparisons for the two rats (t-test for means of two samples, p < 0.05, df = 8). For rat KK-3 at 8, 16, and 8% (retest) significantly more reinforcements were obtained on the right than the left side (t-test for means of two samples, p < 0.05, df = 8) during the food-satiated phase. This side preference did not exist when the rat was food deprived.

![Figure 4](image)

**Figure 4.** Representative cumulative records at each concentration. Cumulative records on the left half of the figure were obtained during the food-deprived condition; those records on the right were taken during the food-satiated condition. Numbers on the left designate ethanol concentration. Time is indicated along the abscissa; responses are cumulated along the ordinate. Slash marks indicate dipper presentations. "Left" and "right" indicate at which lever the records were generated. Each record for each rat was selected on the basis of being closest to the mean value at a particular concentration.
Figure 5. The number of daily reinforcements for rat Z-2 during the transition phase following the last day of the 8% food-deprived retest condition and the first day of the 8% food-satiated condition. Triangles: Reinforcements obtained at the left dipper; circles: Reinforcements obtained at the right dipper. Filled symbols: Ethanol reinforcements; unfilled symbols: Water reinforcements. Unconnected symbols at the left side of the figure represent mean ethanol and water reinforcements obtained during the food-deprived 8% retest condition. Unconnected symbols on the right side of the figure represent mean ethanol and water reinforcements obtained during the 8% food-satiated condition. Brackets through the unconnected symbols indicate standard errors of the mean. Weight is specified along the abscissa for every tenth day following the final 8% food-deprived retest day.
Figure 6. The number of daily reinforcements for rat KK-3 during the transition phase following the last day of the 8% food-deprived retest condition and the first day of the 8% food-satiated condition. Triangles: Reinforcements obtained at the left dipper; circles: Reinforcements obtained at the right dipper. Filled symbols: Ethanol reinforcements; unfilled symbols: Water reinforcements. Unconnected symbols at the left side of the figure represent mean ethanol and water reinforcements obtained during the food-deprived 8% retest condition. Unconnected symbols on the right side of the figure represent mean ethanol and water reinforcements obtained during the 8% food-satiated condition. Brackets through the unconnected symbols indicate standard errors of the mean. Weight is specified along the abscissa for every tenth day following the final 8% food-deprived retest day.
Unlike the food-deprived phase where ethanol reinforcements decreased with increasing concentration, the number of ethanol reinforcements obtained during the food-satiated phase generally was greatest at 16% (Fig. 1). Similarly, the quantity (mg) of ethanol consumed was greatest at 16% (Fig. 2). These results are in contrast to increasing consumption with increasing concentration during the food-deprived phase (Fig. 2). At any one particular concentration the quantity (mg) of ethanol consumed per 100 g body weight was less during the food-satiated phase than during the food-deprived phase.

On retest at 8%, the number of ethanol reinforcements increased by 9% on the left and decreased by 23% on the right for rat KK-3. For rat Z-2, ethanol reinforcements increased by 5% on the left and decreased by 14% on the right relative to the number initially obtained at 8%. These data indicate that changes in responding at different concentrations were not due to non-specific trends in liquid reinforcements.

Figure 3 shows that the time course of ethanol self-administration was similar during both food phases. That is, most ethanol reinforcements were obtained early in the sessions, but water reinforcements were low in number and evenly distributed throughout the sessions. This grouping of ethanol reinforcements at the beginning of the session can be seen in the sample cumulative record in Figure 4.

Discussion

These data indicate that food-satiated rats with a past history of drinking ethanol when food-deprived will respond (lever press) for and consume ethanol concentrations as high as 32% (w/v) when water is concurrently available. Additionally, more ethanol than water is consumed, and more
lever pressing is maintained by ethanol than by water. The data also indicate that food-satiated rats will alternate daily between the two sides to obtain ethanol. Thus, intake of ethanol in food-satiated rats is due to properties of ethanol other than its liquid character.

Lester and Freed (1972) have suggested that food-deprived rats consume ethanol for its caloric value, and not for its pharmacological properties. However, in the present study, rats had unlimited access to food in their home cages during the food-satiated phase. Thus, it is unlikely that the caloric value of ethanol maintained ethanol intake. The evidence in the present study suggests that rats will consume substantial quantities of ethanol in the absence of food or liquid deprivation.

Under both food-deprived and food-satiated conditions, the rats' pattern of drinking was characterized by a high rate at the beginning of the session followed by prolonged pauses. This temporal pattern of ethanol drinking should produce maximum behavioral effects (Lester and Freed, 1973; Meisch and Thompson, 1974). However, the mean number of ethanol reinforcements obtained at a particular side was sometimes significantly different under the two food conditions. Of 8 possible comparisons of sides during the 8 and 8% (retest) condition (2 rats x 2 sides x 2 conditions), 7 showed a significantly greater number of ethanol reinforcements during the food-deprived condition (t-test for the means of two samples, p < 0.05, df = 8). At 16% under the two food conditions, there were no significant differences between sides in the number of ethanol reinforcements, and in only 1 of 4 possible comparisons was there a significant difference at 32%. Also, contrary to the results obtained during the food-deprived condition where ethanol reinforcements decreased with increasing concentration, the number of ethanol reinforcements during the food-satiated condition was greatest at
16%. In harmony with the number of reinforcements obtained, the quantity (mg) of ethanol consumed during the food-satiated phase was highest at 16%. This result is not consistent with those of a previous study (Meisch and Thompson, 1974) where under conditions of both food deprivation and satiation the quantity (mg) of ethanol consumed increased with increasing concentration. The reason for this discrepancy between the two studies is unknown.

While ethanol reinforcements obtained at a particular side may have differed during the two food conditions, the number of water reinforcements remained at a low, stable, equal rate throughout both conditions. Therefore, consumption of water in the operant-conditioning chamber was not affected by the different feeding procedures.

These data replicate previous results (Meisch and Beardsley, 1974, 1975) concerning self-administration of ethanol in food-deprived rats under conditions of concurrent water and ethanol availability. They also substantiate Meisch and Thompson's (1974) finding that ethanol will serve as a reinforcer for food-satiated rats. In addition, rats with ad libitum access to food in their home cages will consume ethanol in substantial volumes greater than concurrently available water. It is concluded that when there is concurrent access to water, intake of ethanol at concentrations of 8, 16, and 32% is not limited to conditions of food deprivation.
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