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Ethanol Reinforced Behavior Assessed with a Concurrent Schedule

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ROEHRS, T. A. AND H. H. SAMSON. *Ethanol reinforced behavior assessed with a concurrent schedule*. PHARMAC. BIOCHEM. BEHAV. 15(4) 539–544, 1981.—Oral ethanol (5% v/v) reinforced responding was studied in three rats using a concurrent fixed ratio (FR) schedule with water available at a second lever. First, concurrent (FR8 FR8) responding on both levers for water presentation was established. Then a concurrent (FR8 FR8) water-ethanol presentation schedule was introduced and a food ration was placed in the chamber at the beginning of the session. Within 12 sessions, ethanol responding developed and within-session feeding was discontinued. When stable concurrent water-ethanol performance was achieved, average ethanol responding was 11 times greater than water responding, even when ethanol availability switched from one lever to the other. During the one hour session, in some cases, sufficient ethanol was ingested to produce blood ethanol levels between 30 and 50 mg/100 ml. As the ethanol FR requirement was increased for four sessions each to FR10, 12, 14, 16, 18, 20, 40 and 50, rats continued to respond for ethanol, and in some rats, ethanol preference was maintained even when the ethanol FR was 50 while the water FR remained at 8.

Ethanol reinforced behavior Concurrent schedules Ethanol drinking Blood ethanol concentrations Rats

IN a series of studies, it was demonstrated that rats will press a lever to obtain access to a dipper filled with ethanol solutions in concentrations as high as 32% w/v [12, 13, 14]. To demonstrate that ethanol per se was maintaining responding, Meisch and Thompson [14] showed that the number of ethanol reinforced responses was greater than the number of water reinforced responses. These comparisons were made when water was available in either a previous session or during a two-hour period before the ethanol test, but at no time were both water and ethanol available simultaneously.

An alternative demonstration of ethanol as a reinforcer would be to show responding for ethanol when there is simultaneous access to water, the vehicle for ethanol. A concurrent schedule makes two or more schedules of reinforcement independently and simultaneously available. Responding to each of the two schedules has been used as a measure of choice and is considered a sensitive index of different conditions of reinforcement [5].

A study in rats used a concurrent schedule (CRF CRF) to assess water-reinforced and ethanol-reinforced responding [11]. Ethanol presentation maintained responding at all concentrations studied (8 to 32% w/v), but very few water-reinforced responses were ever made. While this would suggest that oral ethanol can function as a reinforcer and maintain behavior, the exact role of the concurrent schedule requires further assessment using increased behavioral requirements.

As has been shown for other reinforcers, ethanol reinforced behavior is subject to control by schedules of reinforcement. Studies using a single reinforcement schedule have demonstrated an orderly relation between number of ethanol reinforced responses and FR size [14], FI size [1], and dipper volumes [6]. All these studies were conducted without the presence of concurrent water presentation, the ethanol vehicle, associated with a second lever. It is not known whether simultaneous access to the ethanol vehicle will alter, for example, the relation between FR size and ethanol reinforced responding. There is evidence showing that the behavioral effect of a drug is altered when a second reinforcer is available [8]. It may be the case that the reinforcing effect of ethanol is altered in the presence of water, the vehicle for ethanol, depending on the schedule of availability. The present study used a concurrent schedule to assess the relation of ethanol reinforced responding to FR size when concurrent water presentation was available.

METHOD

Animals

Three naive, male Long Evans rats were gradually reduced to 80% of their free-feeding body weights (at 80% Rat 6 = 321 g, Rat 7 = 314 g, and Rat 8 = 309 g) and were maintained at that level during the water training phase of the experiment (Phase 1) by both restricting the daily food supply and allowing only 30 min access to water. During the ethanol testing phase of the experiment (Phase 2), the rats

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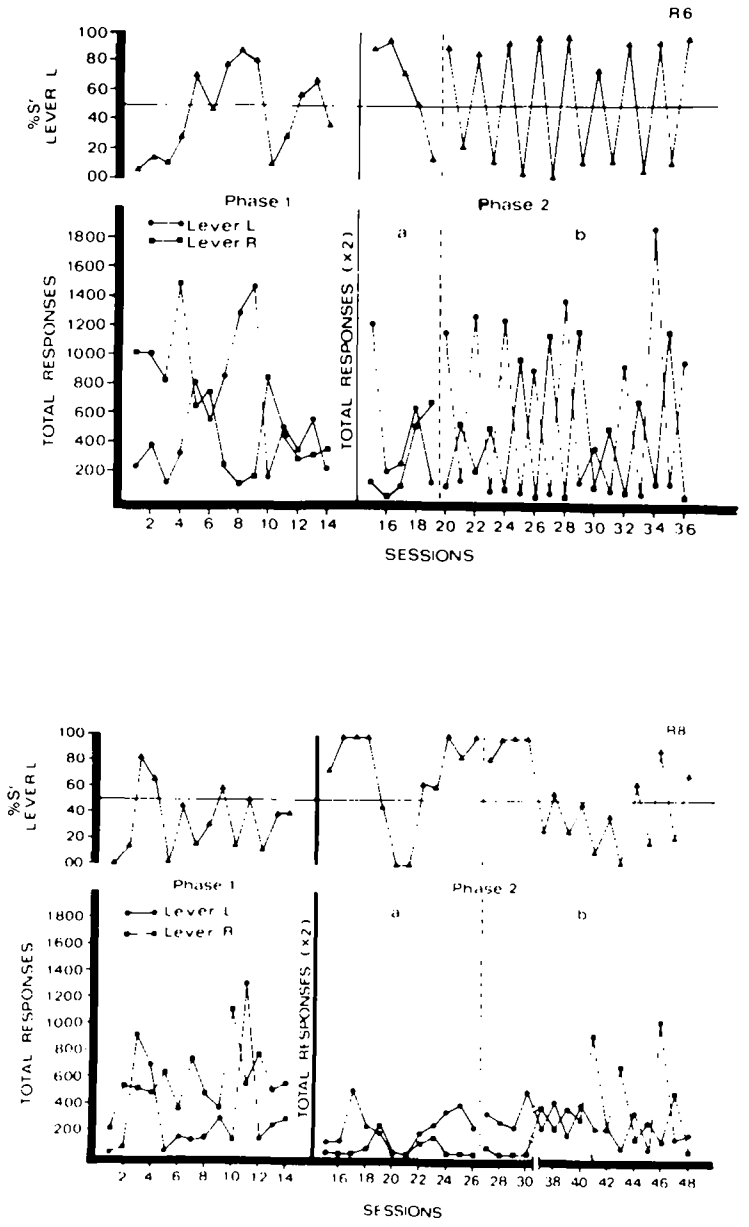


FIG. 1. Number of responses on each lever (lower panel) and percent of total dipper operations (S^r) on Lever L (upper panel) for Phase 1 (concurrent water-water presentation) and Phase 2 (concurrent water-ethanol presentation) of the experiment for rats 6 and 8. For both rats, ethanol was at Lever R in session 15 (first session of Phase 2) and alternated from Lever R to Lever L from session to session. Thus, on odd-numbered sessions, ethanol was on Lever R and on even-numbered sessions on Lever L.

had continuous access to water and were given daily food rations to maintain them at 80% of their initial ad lib body weights.

Apparatus

Daily sessions were conducted in operant conditioning chambers, 23×37×21 cm, placed in sound attenuated cubicles equipped with exhaust fans. At both ends of the front panel of the chamber, 5 cm from either side wall, was a 6 cm diameter opening through which 0.1 ml fluid was presented by a solenoid-operated dipper (Ralph Gebrands Company Model B-LH). When in the up position, the dippers were 3 cm above the chamber floor. Toward the center of the front panel, 3 cm from each of the dipper openings, was a lever (Hawley Training Devices, Inc.) positioned 4 cm above the chamber floor. Each lever was programmed to operate the adjacent dipper. A house lamp (1 W) illuminated the chamber during the session. Events were programmed and re-

TABLE 1

NUMBER OF RESPONSES, DIPPER OPERATIONS AND CHANGE IN VOLUME OF FLUID IN THE RESERVOIRS*

Rat (No.)		Number of responses	Number of dipper operations	Change in† volume
6	Water	41.0	5.0	0.75
	Ethanol	587.0	68.3	7.0
7	Water	38.0	4.0	0.25
	Ethanol	595.8	66.0	6.0
8	Water	47.0	6.0	0.75
	Ethanol	239.0	30.0	2.5
Mean	Water	42.0	5.0	0.6
	Ethanol	473.9	54.8	5.2

*Mean of 4 session on FR8 FR8 water-ethanol schedule.
†In ml corrected for fluid evaporation.

corded with standard electromechanical equipment. Digital counts and cumulative records (Scientific Prototype, Model 3-B) of the lever responses and dipper operations were collected.

Procedure

Initially, the rats were trained to press a single lever on a CRF schedule of 5 sec access to 0.1 ml water presented in a dipper. The reinforcement schedule was gradually increased to FR8. Then the rats were trained to press the second lever, singly available, on the FR8 reinforcement schedule of water presentation.

In Phase 1, both levers were placed in the chamber. During 60 min sessions, water presentation (0.1 ml for five sec) at either of the two dippers was available on a concurrent FR8 FR8 reinforcement schedule with a 3 sec changeover delay (COD 3 sec). The COD 3 sec was programmed so that a response on a lever initiated a 3 sec interval during which lever presses on the other lever had no consequence. To further establish the independence of the two levers (for a discussion of the problem of independence, see [5]), the FR requirement for the preferred lever was increased over successive sessions until the rat switched responding to the nonpreferred lever (remaining at FR8) so that a greater proportion of dipper presentations for the session were received at that lever. Rats were tested under these conditions until a criterion of two lever preference alternations from the larger ratio lever to the smaller ratio lever occurred.

Following Phase 1, the rats were given ad lib access to water in their home cage and maintained at 80% of body weights by daily food rationing. For 5 to 12 days, 5 g of their food ration was placed in the operant chamber at the beginning of each session (Phase 2a). During these sessions, water and 5% (v/v) ethanol in water were available, each associated with one of the levers according to a concurrent FR8 FR8 reinforcement schedule. From day to day, ethanol availability alternated from the left dipper to the right dipper. After the initial 5–12 daily sessions, within-session feeding was discontinued and the total food ration was placed in the home cage following the session (Phase 2b). Daily sessions of concurrent FR8 FR8 water and ethanol presentation were continued to 18–27 sessions.

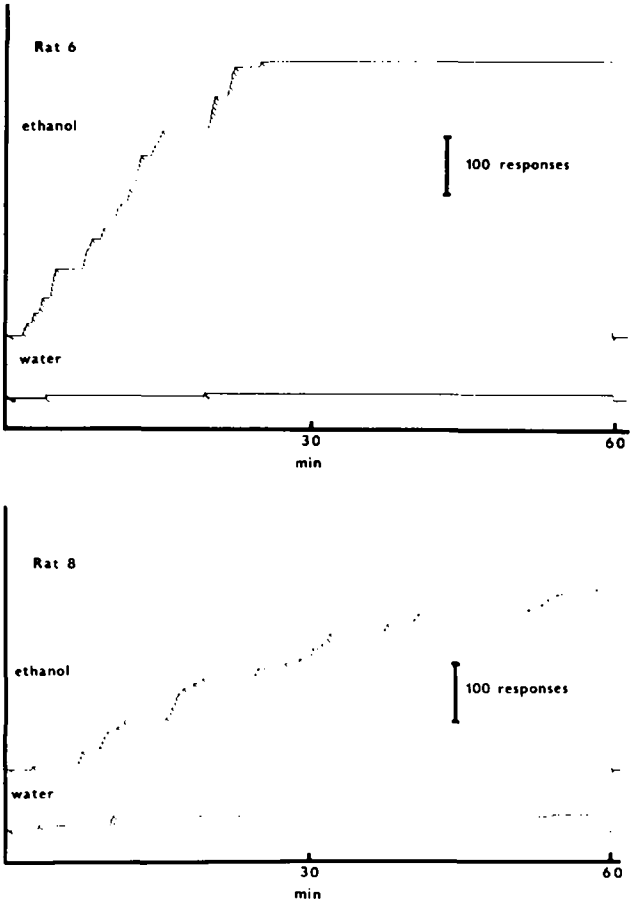


FIG. 2. Cumulative records of stable concurrent FR8 FR8 water-ethanol responding for rats 6 and 8.

When a stable, concurrent performance was established, the ethanol FR requirement was then increased for four daily sessions each to an FR10, 12, 14, 16, 18, 20, 40 and 50, while the FR for water presentation remained at 8. Following the FR manipulation, a concurrent FR8 FR8 water-ethanol schedule was reinstated for 20 daily sessions. When stable performance was again obtained, blood samples (100 μl) were taken from the tip of the tail 5 min after the session. Three days later, a second blood sample was taken 30 min after the session. Blood ethanol levels were determined by enzymatic method [3].

Water was then substituted for the ethanol presentation on the concurrent FR8 FR8 schedule for four daily sessions following which the concurrent FR8 FR8 water-ethanol schedule was again reinstated for 20 sessions.

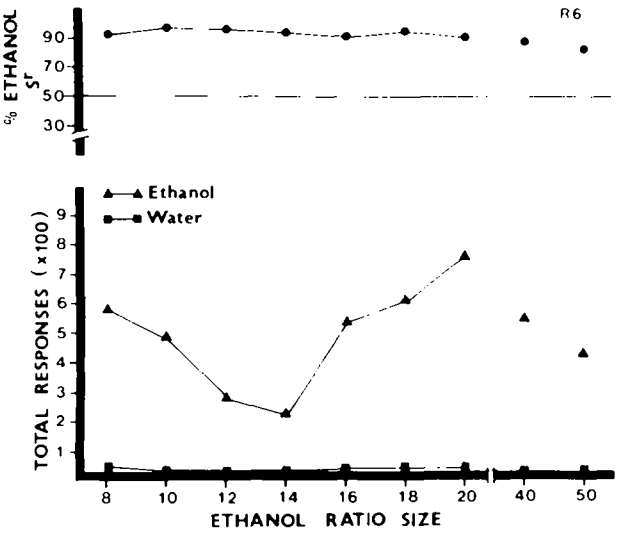
RESULTS

Figure 1 presents the number of lever presses on both levers and number of dipper operations at the left lever as a percentage of the total number of dipper operations during a session for rats 6 and 8 (rat 7 performed similarly to rat 6). During Phase 1 of the experiment when water was the available fluid at both dippers on the concurrent FR8 FR8 schedule, each rat initially showed a lever preference. As the FR on the preferred lever was increased over daily sessions, each rat switched to the nonpreferred lever which remained

TABLE 2
ETHANOL INTAKE AND BLOOD ETHANOL CONCENTRATIONS

Rat (No.)		Number of dipper operations	Volume* change	Blood† ethanol	Time post session of blood sample
6	Test day 1	58	6	46	5 min
	Test day 2	45	5	39	30 min
7	Test day 1	50	4	37	5 min
	Test day 2	55	7	24	30 min
8	Test day 1	9	1	0	5 min
	Test day 2	12	2	0	30 min

*Measured in ml and corrected for evaporation.
†mg/100 ml blood.



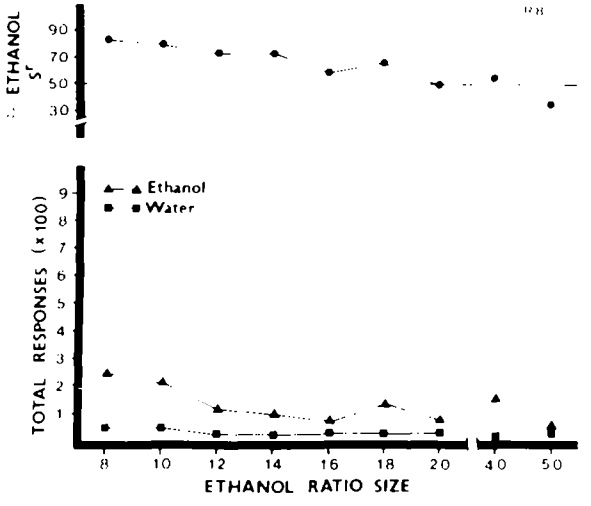


FIG. 3. Number of responses on lever associated with water and ethanol presentation (lower panel) and percent ethanol presentations (S^r) (upper panel) as a function of the fixed ratio size of the reinforcement schedule for rats 6 and 8.

at the FR8 and received a greater proportion of dipper presentations at that lever. For rats 6 and 7, the ratio increment required to modify lever preference was FR20 and for rat 8, FR16.

After 4 or 6 sessions of the concurrent FR8 FR8 water-ethanol schedule with an in-session food ration (Phase 2a), rats 6 and 7 began emitting more responses for ethanol than water (session 19 for rat 6 shown in Fig. 1). In-session feeding was then discontinued for these rats (Phase 2b) and responding continued at greater levels for ethanol than for water. Greater responding for ethanol was maintained as its availability switched daily from side to side (see Fig. 1). During Phase 2a, rat 8 showed a preference for the left lever due to a malfunction in the operation of the right lever. For this rat, in-session feeding was discontinued after 12 sessions, but responding on the left lever continued regardless of which fluid was available. To re-establish responding on both levers, the fixed-ratio on the left lever was increased to FR10 and then FR12. At FR12, rat 8 began to respond daily at greater levels for ethanol than for water, no longer showing a lever preference (session 37 shown in Fig. 1). Rat 7 developed a similar left lever preference during Phase 2b (over sessions 35–39) which was abolished by increasing the left lever ratio to FR10. In both of these rats, the ratios were gradually returned to FR8, so that over the last four sessions of Phase 2b all animals were consistently responding at greater levels for ethanol than for water on a concurrent FR8 FR8 schedule.

Table 1 presents the mean number of responses, dipper operations, and change in the reservoir fluid volume for water and ethanol during the last 4 days of the FR8 FR8 water-ethanol schedule. Fluid volume was measured before and after each session and corrected for evaporation during each session. Evaporation rate was calculated by averaging the change in volume during five sessions when no dipper operations were given. The animals averaged 54.8 ethanol dipper operations and 5.0 water dipper operations in the 60 min session. Since each dipper presented 0.1 ml fluid, the mean change in the volume of fluid from the beginning to the end of the session corresponded closely to the number of dipper presentations delivered (5.2 ml of ethanol and 0.6 ml of water).

Representative cumulative records of stable concurrent FR8 FR8 water-ethanol responding for rats 6 and 8 are presented in Fig. 2. In rats 6 and 7, the majority of ethanol responding and dipper operations occurred in the first 30 min of the 60 min session. In rat 8, ethanol responding and dipper operations were distributed across the 60 min session. Table 2 presents the ethanol intakes and blood ethanol concentrations for the three rats on each of the two test days. Rats 6 and 7 showed measurable amounts of ethanol in the blood, while for rat 8 no ethanol could be detected.

Figure 3 presents for rats 6 and 8 (rat 7 performed similarly to rat 6) both the number of ethanol dipper presentations as a percentage of the total number of presentations,

and the absolute number of lever presses for ethanol and water, as a function of the fixed ratio size of the ethanol schedule. Both rats 6 and 7 showed declines in responding at FR12 or 14 relative to FR8 performance levels. Thereafter, responding increased to maximum levels at FR18 and 20 before decreasing to FR8 levels at FR40 and 50. In rat 8, ethanol responding was relatively weak at FR8 and decreased to the water responding levels with increasing ratio size. At FR20, the percentage of ethanol presentations for rat 8 was 50 and remained so with subsequent ratio increases. On the other hand, the percentage of ethanol presentations never went below 50 for rat 6 and went below 50 only at FR40 for rat 7.

When the concurrent FR8 FR8 water-ethanol schedule was reinstated, ethanol responding returned gradually to the pre-FR manipulation levels. Mean number of ethanol responses was 457.5 resulting in 57.3 ethanol dipper presentations. This was similar to the original values reported in Table 1. Water was then substituted for the ethanol and within four sessions responding on either lever was at a minimum (10.8 and 17.4 responses per session). Following the reinstatement of the concurrent FR8 FR8 water-ethanol schedule, number of responses returned to a mean of 348.7 for ethanol and 14.0 for water.

DISCUSSION

The results of this study extend and clarify the earlier results of Meisch and associates [11, 12, 13, 14] showing operant responding can be maintained by the presentation of ethanol in a dipper. The present study demonstrated that ethanol will maintain responding when there is a simultaneous access to water available on a second schedule associated with a separate lever. That the two levers and schedules were functionally independent was seen when, with water available in both dippers, rats chose the schedule with the smaller fixed ratio. Further, during Phase 2, with the concurrent water-ethanol schedule, responding was not maintained exclusively by one of the two schedules, in that all rats responded on the water lever to receive a number of water presentations. When lever preferences developed, they were abolished by slightly increasing the fixed ratio on the preferred lever.

The blood ethanol determinations provided validity to the measures of fluid volume change and the number of ethanol presentations. The two rats with detectable levels of ethanol in their blood following the 60 min session received between 50 and 60 ethanol presentations (0.1 ml per presentation) with an associated reservoir volume reduction of 5 to 6 ml. Rat 8 showed no blood ethanol, while receiving a smaller number of dipper presentations and a volume change of only 2.5 ml. The two rats with detectable levels of ethanol in their blood also differed from rat 8 in the pattern of ethanol responding over the 60 min session. Rats 6 and 7 received the majority of their ethanol dipper presentations in the first 30 min of the session, while rat 8 distributed its ethanol reinforced responding across the 60 min session. It is known that blood ethanol level is a product of the volume of ethanol consumed and the time course of ethanol drinking [7], and these factors may account for the observed blood ethanols.

The results of the FR size manipulation in general confirm previous findings [14] using a single reinforcement schedule, a different ethanol concentration (8% w/v) and a different dipper size (0.25 ml). It was found that ethanol-reinforced responding was a bitonic function of FR size with the peak at FR16 or FR32 for two rats and FR64 for two other rats. For the two rats of the present study showing strong ethanol-maintained behavior, the peak was at FR18 and FR20. Interestingly, these two rats continued to show a preference for ethanol reinforcement even when the ethanol FR was 50 and water FR was 8. When water was available associated with both levers, these rats switched lever preference at FR20, illustrating the difference between water and ethanol maintained behavior under these conditions.

While many studies using several different procedures have produced considerably greater ethanol consumption than that achieved in the present study, these results demonstrate that ethanol is a relatively strong reinforcer which in small volumes (0.1 ml) will maintain a large amount of behavior when available concurrently with water. Most studies of oral, intragastric and intravenous ethanol self-administration, with one exception [14], have used limited behavioral requirements. The present study found ethanol maintained responding even under increased behavioral requirements. But which specific properties of ethanol (i.e. its gustatory, caloric, or central nervous system effects) contributed to its reinforcing effects are not clear from the present results. Studies using concurrent schedules with different behavioral requirements and comparing ethanol with other sapid solutions currently are being conducted to assess ethanol's reinforcing properties.

It has been well recognized that concurrent behaviors and other situational factors interact in human drug use. These important complex interactions have not been studied extensively in the analysis of the behavioral effects of drugs [10]. Much is known about the capacity of drugs to serve as response-contingent reinforcers and this information provides a basis for studies of greater complexity. Use of a concurrent schedule in assessing ethanol reinforced behavior provides such a complex behavioral interaction.

Recently, research interest has focused on the different capacity of stimulus events such as drugs to maintain behavior [2]. It is suggested that the behavior maintenance capacity of a drug reflects the efficacy of that drug as a reinforcer. One possible way to assess reinforcer efficacy is to examine a complex behavioral situation with two different classes of reinforcers available. Under conditions where two concurrent equally valued schedules produce two different reinforcing stimuli, a relative response rate measure may provide a useful index of the efficacy of a particular reinforcer. In the present study, ethanol reinforced responding could be assessed relative to total responding (i.e. ethanol responses plus water responses). As determined from Table 1, the ratio of ethanol responding to total responding is .93, .94 and .83 for rats 6, 7 and 8, respectively. By using this concept of efficacy as operationally defined by relative responding, examination of both the properties of the reinforcers and the schedules of presentation can be made. Similar ideas have been proposed by others as an assessment of drug reinforcing properties [4, 9, 15, 16].

To what extent concurrent schedules can be used to ascertain the reinforcing properties of ethanol remains for further experimentation, but the studies reported here suggest that this procedure could be extremely useful in the isolation of different factors involved in drug self-administration.

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