

Relative Responding on Concurrent Schedules: Indexing Ethanol's Reinforcing Efficacy

TIMOTHY A ROEHR'S AND HERMAN H SAMSON

University of Washington, Seattle, WA 98105

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ROEHR'S, T A AND H H SAMSON *Relative responding on concurrent schedules. Indexing ethanol's reinforcing efficacy.* PHARMAC BIOCHEM BEHAV 16(3) 393-396, 1982 —Five rats were trained to lever press on a concurrent schedule resulting in 3 second access to a dipper (0.1 ml) with either ethanol (5% v/v) or water. Stable concurrent fixed ratio (FR8) ethanol and water responding was established. The proportion of responses for ethanol relative to the total number responses varied among rats from 77 to 98%. While the absolute number of responses for ethanol varied greatly day to day, the proportion of ethanol responding was stable. Absolute number of responses for ethanol and proportion of ethanol responding both declined as the body weight of the rats was allowed to increase from an initial 80% of ad lib to 110%, with absolute responding showing the greater change. It was concluded that the relative measure of responding on a concurrent schedule could be useful as an index of a drug's reinforcing efficacy, but must be interpreted carefully in regards to the context of drug availability.

Ethanol's reinforcing efficacy Concurrent schedules Ethanol drinking Relative responding
Lever press Rats

MANY studies have demonstrated that drugs like other stimulus events (i.e., food, water, electrical brain stimulations) can function as reinforcers to maintain behavior [15]. Recently, research interest has focused on the differential capacity of various drugs and dosages to maintain behavior [4, 5, 24]. These studies suggest that the capacity of a drug to maintain behavior reflects the 'efficacy' of that drug as a reinforcer. One possible way to assess reinforcer efficacy is to study a complex behavioral situation where two different reinforcers are available according to a concurrent schedule. Given concurrent responding for two different reinforcers, the efficacy of either of the reinforcers might be indexed as the ratio of responses for that reinforcer relative to the total responses for both reinforcers.

Ethanol has been shown to function as a reinforcer in several laboratory animals. Monkeys and rats will press a lever for intragastric [1, 2, 19] or intravenous injections [10, 11, 16, 25, 27] of ethanol. Rats and monkeys will lever press to obtain access to a dipper filled with ethanol solutions varying in concentrations as high as 32% [12, 20]. These studies have demonstrated that responding for ethanol is greater than responding for the ethanol vehicle (water) available during baseline sessions.

A recent study showed in rats that ethanol will maintain responding when there is simultaneous access to water available on a second schedule associated with a separate lever [22, 23]. In the Roehrs and Samson [23] study on concurrent and functionally independent schedules (FR8 FR8) for ethanol or water, average ethanol to water responding

was 11 to 1 and in some instances, sufficient ethanol was ingested to produce blood ethanol levels to 50 mg/100 ml. As a result of this study, the authors proposed that ethanol's efficacy as a reinforcer might be indexed using a relative measure of responding obtained with such a concurrent procedure.

The present study investigated the characteristics of relative responding as an index of ethanol's efficacy using two equally valued schedules producing ethanol or water. The session to session stability of the measure and the measure's sensitivity to changes in level of food deprivation were evaluated. Prior studies have shown that level of food deprivation is an important factor in responding maintained by oral access to ethanol [21], oral and intravenous administration of etonitazene [6], intracranial self-stimulation [3], and mouse killing by rats [18]. Thus, in the present study, level of food deprivation was manipulated to evaluate the usefulness of relative responding as an index of ethanol's efficacy.

METHOD

Animals

Five male Long Evans rats (approximately 120 days old when obtained from the Department of Psychology, University of Washington, Vivarium Breeding facility) served in this experiment. Two were experimentally naive (R41 and R42) and the remaining three (R6, R7 and R8) had served previously in an oral ethanol self-administration experiment [23]. All rats initially were gradually reduced to 80% of their free-feeding body weight by restricting daily food supply.

TABLE 1
MEAN ABSOLUTE AND RELATIVE RESPONDING FOR ETHANOL
AND WATER OVER SEVEN CONSECUTIVE DAILY SESSIONS

Rats	Number of Ethanol Responses	Number of Water Responses	Percent Ethanol Responses*
41	690 ± 34.6†	58 ± 17.5	92 ± 2.3
42	354 ± 68.8	85 ± 19.1	77 ± 5.8
6	422 ± 79.8	9 ± 2.1	98 ± 0.6
7	300 ± 45.3	22 ± 8.3	94 ± 2.1
8	189 ± 57.8	24 ± 12.7	90 ± 2.6

*(Ethanol responses/total responses) × 100

† ± SEM

During the initial water training phase of the experiment, the rats were maintained at the 80% level by restricting both the daily food supply and allowing only 30 min access to water. During the ethanol testing phase of the experiment, the rats had continuous access to water and were given daily food rations to maintain them at the desired body weight level. The rats were housed individually in hanging, stainless steel rodent cages in a room artificially illuminated from 7:30 to 19:30 hr.

Apparatus

Daily sessions were conducted in operant conditioning chambers, 23×37×21 cm, placed in sound attenuated cubicles equipped with exhaust fans. Toward the end 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, Arlington, MA). 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, were two levers (BRS/LVE Corp., #CRL-500, Fogelsville, PA) 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 recorded with standard electromechanical equipment. Digital counts and cumulative records (Scientific Prototype Corp., Model #3-B, New York, NY) of the lever responses and dipper operations were collected.

Procedure

Sixty minute experimental sessions were conducted daily between 8:30 to 14:30 hr. The training procedure used to establish concurrent water and ethanol reinforced responding has been described in detail [23]. All animals were trained initially to lever press on a concurrent FR8 FR8 schedule with a 3 sec change-over delay (COD) for access (3 sec) to either of two dippers filled with water (0.1 ml). The independence of the two levers and alternations between levers was established further by increasing the fixed-ratio requirement for the preferred lever over successive sessions until the rat switched responding to the non-preferred lever which remained at FR8. Testing continued under these conditions until two alternations from the larger ratio lever to the smaller-ratio lever had occurred.

After being trained to lever press for water, all rats were

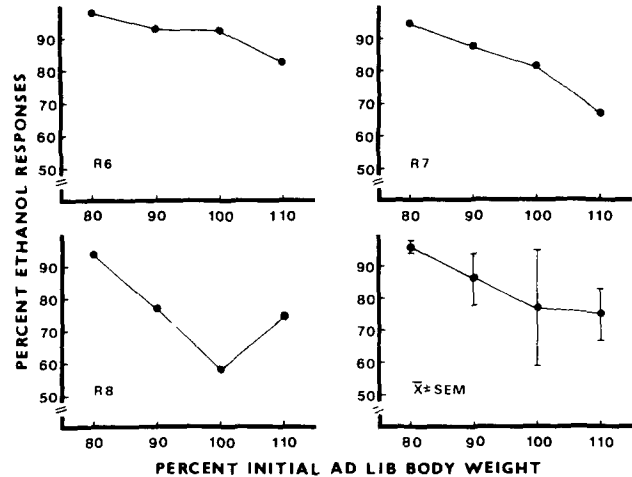


FIG 1 Percent ethanol responses as a function of percent initial ad lib body weight for rats, 6, 7 and 8 individually and as a group (lower right panel)

given free access to water in their home cage and maintained at 80% body weight by daily food rationing only. For 5 to 12 days, 5 gm of the food ration was placed in the operant chamber at the beginning of each session with water and 5% (v/v) ethanol available during the session according to a concurrent FR8 FR8 schedule. From day to day, ethanol availability alternated from the left dipper to the right dipper. The within-session feeding was discontinued after the initial 5-12 sessions and the total daily food ration was placed in the home cage following each experimental session. Sessions of concurrent FR8 FR8 water and ethanol presentation were continued and stable concurrent performance was maintained for at least 20 sessions.

Then, body weight of rats 6, 7 and 8 were allowed to increase to 110% of the initial ad lib level by gradually increasing the daily food ration. Food rations were increased so that at least four experimental sessions each at 80, 90, 100 and 110% of original ad lib body weight occurred. Rats 41 and 42 served in another experiment which precluded a manipulation of body weight.

RESULTS

All rats responded for ethanol at greater levels than for water with greater responding for ethanol maintained as its availability switched daily from side to side. Over a randomly chosen block of seven consecutive days of stable responding from the initial 20-session baseline, rats obtained an average of 48.5 ethanol dipper operations and 4.6 water dipper operations on the concurrent schedule.

In rats 6, 7 and 41, the majority of responding for ethanol occurred during the first 30 min of the 60 min session. In contrast, for rats 42 and 8, ethanol responding was distributed across the 60 min session. Water responding occurred in two distinct patterns: a single burst of responses during the first 5 min of the session sufficient to produce one or two dipper operations with no subsequent responding, or bursts of responses distributed across the whole session. These patterns of responding for water in rats which had 24 hr ad lib access to water in the home cage could be the result of the

TABLE 2

MEAN NUMBER OF RESPONSES FOR ETHANOL AND WATER AS A FUNCTION OF PERCENT INITIAL AD LIB BODY WEIGHT*

		Percent ad lib Body Weight			
		80	90	100	110
Rat 6	Ethanol	427	190	165	175
	Water	7	15	13	36
Rat 7	Ethanol	415	272	103	61
	Water	22	38	23	30
Rat 8	Ethanol	204	125	62	88
	Water	13	38	42	29

*On concurrent fixed-ratio eight, fixed-ratio eight schedule Mean number over four 60 min sessions

procedure of daily alternating ethanol and water presentation from lever to lever

Mean absolute and relative responding for water and ethanol for the seven consecutive daily sessions is presented in Table 1. Ethanol's efficacy indexed as the percent of responding for ethanol relative to the total number of responses per session ranged from 77 to 98% with four of the five rats scoring 90% or greater. Interestingly, the two rats (42 and 8) which distributed their ethanol responding across the whole session showed the lowest mean efficacy scores. As is seen in the Table, large differences in absolute responding for ethanol and water produce comparable ethanol efficacy scores (i.e., compare rats 41 and 8). At the same time, almost equal absolute response totals for ethanol result in markedly different efficacy scores (i.e., compare rats 42 and 7). Inspection of the SEMs indicates that day to day variability in responding for water and ethanol was great, while efficacy scores remained relatively stable on a day to day basis.

Figure 1 presents the efficacy scores (percent ethanol responses) as a function of percent initial ad lib body weight for rats 6, 7 and 8. For all rats, ethanol's efficacy decreased from baseline as body weight increased. At 110% initial ad lib body weight, ethanol was maintaining approximately 75% of total responding. Table 2 presents the mean number of responses for ethanol and water as a function of body weight increases. Number of ethanol responses declined as body weight increased and number of responses for water remained the same or increased slightly. At 110% initial ad lib body weight, number of ethanol responses was 31% of baseline, while the efficacy scores were 78% of baseline levels.

DISCUSSION

With increasing interest in the differential capacity of reinforcers to maintain behavior, investigators have been concerned with the appropriate way to measure the "efficacy" of a reinforcer. Absolute number or rate of responding are not satisfactory since these measures are differentiated by schedules of reinforcement and interact in a complex manner to changes in reinforcer magnitude [14]. One alternative has been the use of a relative measure (the number of responses on one reinforcement schedule as a proportion of the total responses on all schedules) obtained with multiple or concurrent schedules [24].

A relative measure can provide a means of separating reinforcing effects from other nonspecific effects on responding, and in the case where a drug is the reinforcer, from the direct effects of the drug itself on responding [15]. Relative responding has been used to compare the reinforcing efficacy of different doses of the same drug [27] or two different drugs [14]. In the present experiment, ethanol's efficacy indexed as the percentage of responding for ethanol relative to the total number of responses for ethanol and water was stable on a day to day basis, while absolute responding for ethanol varied from day to day. The stability of the relative measure compared to the absolute measure demonstrates a possible value of using a relative measure as an index of a reinforcer's efficacy.

However, to assume that reinforcing efficacy indexed with a relative measure directly reflects the pharmacological properties of a drug as reinforcer is probably inaccurate. In the present experiment, absolute responding for ethanol decreased approximately 70% as body weight increased which is similar to the results reported by Meisch and Thompson [21] with a single reinforcement schedule. Ethanol's efficacy also declined, suggesting that food deprivation factors may also be important in the reinforcing effects of ethanol. Such an effect might be expected due to the caloric value of ethanol. However, responding for oral etonitazene [6] and phencyclidine [8] and for intravenous administration of amphetamine [26] and etonitazene [7], drugs with no caloric value, also changes as a function of the nutritional status of the animal. Thus, the reinforcing efficacy of a drug reflects a combination of many factors.

One limitation of the concurrent procedure and a relative measure is that each of the two reinforcement contingencies concurrently available must maintain at least a minimal amount of responding. The concurrent schedule is of no value and the relative measure is meaningless if responding is maintained exclusively by one of the two concurrent schedules [9]. In the present experiment, both schedules maintained responding, although responding for water was minimal. Such an extreme preference for one of the two available reinforcers on the concurrent schedule may artificially limit the sensitivity of the relative measure of ethanol's efficacy to the body weight manipulation. In a situation where the baseline ratio of responding for two available reinforcers was closer to 0.5, the relative measure of ethanol's efficacy may be more sensitive to the body weight manipulation.

Another factor to consider in interpreting a relative measure as an index of a reinforcer's efficacy is the context in which that reinforcer is available. In the present experiment, ethanol's efficacy was assessed relative to responding for water and relative responding did not change as greatly as absolute responding changed over the body weight manipulation. Different results might be obtained if ethanol was compared to responding for a different reinforcer such as sucrose solution, even if the baseline ratio of ethanol to sucrose responding was the same as for ethanol to water. The quality or class of the different reinforcers being concurrently paired (i.e., two different drugs, a drug and a food source, or a drug and commodity with strong gustatory qualities) may change the effects of a third manipulation [17]. This could be the case even when the schedules are considered to be functionally independent. In the present experiment, a COD was used throughout and all rats experienced unequal schedules with the same reinforcer (water) before being placed on the FR8 FR8 ethanol-water schedule. These

procedures were used to establish the functional independence of the two schedules and reinforcers

As well, when pairing two commodities as reinforcers, there can be interactions between commodities themselves (i.e., a drug with an anorexic effect in a drug-food pair), invariances between commodities (i.e., a tendency to consume them in a constant ratio independent of the schedule), or invariance in one of the two available commodities. For example, rhesus monkeys lever pressing for food or water on a concurrent variable-interval, variable-interval schedule maintained a constant ratio of food to water responding irrespective of the rate of food or water delivery [13]. In the present experiment, responding for water did not change as body weight changed.

A relative measure obtained with a concurrent schedule may be a useful procedure for assessing the reinforcing efficacy of a drug. The measure was relatively stable on a day to

day basis and did correspond to the within session pattern of responding among the rats in the present experiment, but the relative measure as an index of efficacy must be interpreted with caution in regard to food deprivation, the magnitude of preference for either reinforcer, and the qualities of the commodity against which a particular reinforcer is being assessed.

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