ETHANOL, FRUSTRATION EFFECTS, AND CONDITIONED FRUSTRATION WITH FREE OPERANT FIXED RATIO BARPRESSING BY RATS

by

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INTRODUCTION

Scientists searching for important factors in the etiology of persistent or recurrent alcohol consumption have enquired whether alcohol provides relief from unpleasant emotional states. If such an effect of alcohol were demonstrated, one could theorize that repeated experiences with amelioration by alcohol of fear, anxiety, frustration, or other analogous "tension" states would result in a tendency to consume alcohol when those or similar states are impending or present. This basic notion comprised the rationale for efforts by early researchers (e.g., Conger, 1951; Masserman & Yum, 1946) to demonstrate an effect of alcohol on behavior controlled by aversive stimuli. In the years since those early experiments, various tension-reduction hypotheses have had a pervasive influence on theories about use and abuse of ethanol. However, as Cappell and Herman (1972) noted, tension-reduction hypotheses have not been widely supported by empirical evidence. The only area in which Cappell and Herman (1972) found suggestions of an effect of ethanol on a tension state was that of conflict, where they noted that the tension-reduction hypothesis "enjoys a remarkably good record of confirmation in the literature" (p. 59).

Conflict has traditionally been defined as the result of the elicitation of incompatible response tendencies. The tendencies aroused may be to attain mutually exclusive goals (approach-approach conflict), to

evade undesirable alternatives (avoidance-avoidance conflict), or both to evade and to attain an ambivalent goal (approach-avoidance conflict). Approach-avoidance conflict has most commonly been used in tests of the impact of ethanol on conflict behavior (e.g., Barry & Miller, 1962; Freed, 1967, 1968a, 1968b; Smart, 1965). The typical procedure has been to train animals to approach an area in which food has been received, then to shock them when they approach that area. It is of interest that this sort of approach-avoidance conflict can also be characterized as the partial thwarting of a tendency to approach and considered operationally equivalent to another emotional motivational construct, frustration, which has customarily been thought to occur when a response tendency is elicited but the response is prevented from occurring. Brown and Farber (1951), noting the similarities between conflict and frustration, assumed that the operations typically used to induce frustration functioned to arouse a reaction tendency incompatible with an ongoing response. This assumption equates frustration with the traditional definition of conflict. Brown and Farber (1951) thus contended that a distinction between conflict and frustration was not useful. In spite of the obvious parsimony of such an assumption, and despite the "remarkably good confirmation [of a tension-reduction hypothesis] in the literature on conflict" (Cappell & Herman, 1972, p. 59), the literature on frustration contains few studies of the effects of ethanol on frustration. Perhaps because of this, scant attention has been paid to frustration in recent published reviews of

ethanol and tension reduction (Cappell, 1975; Cappell & Herman, 1972; Higgins, 1976; Mello, 1968).

In view of the possible similarities between the emotional states aroused by the operations used to induce frustration and conflict, and considering the record of confirmation of ethanol's effects in conflict situations, it seems likely that studies relating ethanol and frustration would support a limited or selective tension-reduction hypothesis. That is, even though a general tension-reduction hypothesis may be untenable because of the lack of supporting evidence in areas such as avoidance and escape behavior, fear conditioning, conditioned suppression, etc., nonetheless ethanol may mitigate certain specific tensions, i.e., those aroused by the operations used to induce conflict and frustration. This working hypothesis requires the assumption of a tension state sui generis, which is induced via relations common to frustration and conflict experiments. The following review of studies of ethanol and frustration was undertaken in an attempt to discover support for a specific tension-reduction hypothesis in addition to support available in the conflict literature.

A Review of Studies of Ethanol and Frustration

While a variety of operations have been defined as antecedents to frustration (cf. Brown & Farber, 1951), the most extensively used method of inducing frustration has been the omission of expected reward. Reward omission can occur in many experimental situations, and there are several experimental effects wherein frustration may play a role.

What is perhaps the simplest example has been labeled the frustration effect by Marzocco (1951), although it is sometimes referred to as the Amsel effect or the Amsel frustration effect because Amsel is more commonly associated with research and theory relating to it (Amsel & Roussel, 1952; Amsel, 1958; 1962). This effect consists of the increased vigor of responding by an animal on trials subsequent to nonreinforcement as opposed to trials following reinforcement. In the classic demonstration of the frustration effect, Amsel and Roussel (1952) used a starting box and a set of runways and goal boxes, arranging the five pieces in a straight line: starting box, Runway A, Goal Box 1, Runway B, Goal Box 2. After extensive training during which rats traversed each runway and received food reinforcement in each goal box, the frustration effect was demonstrated during trials with intermittent reinforcement in Goal Box 1. On trials on which no reinforcement was encountered in Goal Box 1, rats ran faster through Runway B than on trials when reinforcement was received in Goal Box 1. Although the frustration effect has been demonstrated by a variety of experimenters (e.g., Bower, 1962; Longstreth, 1960; Marzocco, 1951; Penney, 1960; Wagner, 1959), apparently no studies have been conducted to examine the frustration effect as affected by ethanol.

Amsel (1958) has postulated that with repeated elicitation of frustration, stimuli immediately preceding the frustrating event will come to elicit a fractional, anticipatory, classically conditioned form of the frustration response. This anticipatory frustration is a response tendency which competes with the approach tendency previously

conditioned during acquisition training, presumably because the frustrating event is aversive and elicits avoidance responses. A relatively straightforward example is the case of extinction of an appetitively motivated instrumental response. Each time a response previously associated with reinforcement is not reinforced, frustration results. According to Amsel's (1958, 1962) frustration theory, extinction procedures suppress responding because the cues preceding the goal come to elicit anticipatory frustration. Available data indicate that responding decreases in vigor and ultimately ceases as nonrewarded extinction continues. Barry, Wagner, and Miller (1962) examined the effects of ethanol on the performance of a food-rewarded running response by rats, and found that ethanol enhanced running during extinction. They interpreted the results as indicating that ethanol decreased the intensity of anticipatory frustration. In reaching this conclusion, Barry et al. were able to discount several alternative ethanol effects, i.e., motor effects, sensory effects, and stimulus generalization decrement.

Another paradigm in which frustration may suppress responding is that of discrimination learning, where frustration may underlie the inhibition of responding to a nonrewarded cue or goal. Wagner (1966) has reported a study by Wagner, Pendleton, and Perry in which alcohol was shown to interfere with discriminative responding. He interpreted the data in terms of frustration theory, suggesting that the drug increased running speeds that had previously been inhibited by nonreinforced discrimination trials. These data are consistent

with those reported by Blough (1956), namely, that ethanol increased pecking of a nonreinforced key by three pigeons which had previously learned to discriminate that key from a reinforced key.

In the experimental paradigms already discussed, frustration has been hypothesized to suppress responding on some occasions, to enhance it on others. Response facilitation is the assumed role of frustration in producing the remaining effects to be discussed, one of which is the partial reinforcement extinction effect. The partial reinforcement extinction effect consists of greater resistance to extinction following intermittently reinforced learning than after continuously reinforced learning. Amsel (1962) has developed his frustration theory to account for the partial reinforcement extinction effect by assuming that the stimulus concomitants of anticipatory frustration (developed on nonreinforced trials as discussed above) are paired with forward locomotion during partially reinforced acquisition. He suggests that the avoidance tendency (resulting from the conditioning of frustration to preceding alley cues) never grows strong enough to counteract the approach tendency. Instead, repeated evocation of the cues of anticipatory frustration during forward locomotion results in experimental subjects learning to run in the presence of frustrative cues. Frustration arousal during extinction thus acts as less of a deterrent to running for subjects partially rewarded during acquisition than for subjects continuously rewarded.

One study is available concerning the impact of ethanol on the partial reinforcement extinction effect (Taylor, Lehr, Berger &

Terry, 1968). In that study, rats were trained to traverse a runway for food reinforcement on either 50% or 100% of trials, after either saline or ethanol injections (a four group study). All rats were then given nonrewarded extinction trials without any injections. Training under alcohol did not diminish the partial reinforcement extinction effect, although both partially reinforced and continously reinforced rats which were trained with alcohol ran more slowly during extinction than their saline injected (during training) counterparts. Because the authors assumed that alcohol does have an inhibiting effect on anticipatory frustration, they interpreted the experimental results as contradicting Amsel's (1958) frustration explanation for the partial reinforcement extinction effect. Additionally, they noted that their data were not in agreement with those of Barry et al. (1962). They neglected to mention, however, that Barry et al. (1962) found that while alcohol interfered with the elicitation of anticipatory frustration, it did not seem to affect the conditioning process whereby the alley cues came to elicit anticipatory frustration. If the effects of alcohol appear only when anticipatory frustration is elicited, then the data of Taylor et al. (1968) are not relevant to statements about the interactions of alcohol and frustration during extinction. Taylor et al. (1968) did not even administer alcohol during extinction, when the elicitation of frustration enhanced running, but only during acquisition, when the rats were presumably learning to run in the presence of frustration cues. Further, Taylor et al. (1968) failed to find another

effect of frustration which sometimes appears during acquisition training in partial reinforcement studies, the partial reinforcement acquisition effect.

The partial reinforcement acquisition effect appears when animals reinforced on some percentage (less than 100%) of training trials develop faster asymptotic running speeds than animals reinforced on 100% of training trials. It has been hypothesized (Amsel, 1958; Spence, 1960) that these elevated speeds are owing to anticipatory frustration, which increases motivation. Nelson and Wollen (1965) have demonstrated that ethanol depresses the performance of partially reinforced rats to the level of their continuously reinforced counterparts, while placebo treated rats reinforced on 50% of acquisition trials run faster than placebo treated rats continuously reinforced. This apparent ethanol effect on anticipatory frustration was in addition to a motor effect which suppressed performance for continuously reinforced-ethanol-treated rats below the level of their continuously reinforced-placebo-treated counterparts. A similar report by Nelson (1967) again indicated that ethanol eliminated the difference between 50% and 100% reinforcement in terms of asymptotic running speeds.

Six studies have been mentioned which involve ethanol and effects attributable to frustration. Data from five of those six experiments indicate that ethanol reduces frustration effects, and thus support the notion that ethanol alleviates a tension state of frustration. Considering, in addition, the above-mentioned shortcomings of the remaining study (Taylor, et al., 1968), one can conclude that for frustration, as

for conflict, a tension-reduction hypothesis enjoys "a remarkably good record of confirmation." It would seem, then, that research directed toward uncovering the relations between frustration and ethanol would be particularly productive, despite the fact that little effort has apparently been expended in this direction.

Direct Tests of Conditioned Frustration

All six of the cited studies of frustration and ethanol involve the assumption that anticipatory frustration was strongly influencing the observed behaviors. It is appropriate, then, to review briefly the evidence bearing on conditioned frustration as an explanatory construct. Use of anticipatory frustration in explanations of behavior requires a mechanism whereby cues of the experimental situation operate as conditioned stimuli (CSs), eliciting a conditioned form of the frustration response. In perhaps the first attempt to evaluate directly the assumption that the pairing of primary frustration with previously neutral cues will produce a learned form of the frustration response, Wagner (1963) demonstrated that an interrupted-noise flashing-light CS would serve, after being paired with nonreinforcement of a previously reinforced locomotor response, to elicit an escape response. Subsequent studies have nearly all involved the use of environmental cues as CSs and a hurdle jumping escape response as the dependent behavior (see Daly, 1974, for review). Available data from those studies, as well as from studies wherein discrete CSs were used (Cohen, 1973; Daly, 1969a, 1969b; Daly & McCroskery, 1973; Senkowski & Vogel, 1976) support the

status of conditioned frustration as an acquired motive, demonstrating its efficacy both as a motivator (when aroused) and as a reinforcer (when reduced). In addition, Senkowski and Vogel (1976) have demonstrated a relation between number of CS-US pairings and strength of conditioned frustration. However, in all of the studies save that of Wagner (1963), the CS has been either cues accompanying the experimental environment or a light. Further, the only response to provide dependent measures has been an escape response. Thus, knowledge remains scanty with respect to the parameters and limits of conditioned frustration. In an effort to extend our knowledge about conditioned frustration, a CS other than light and a paradigm other than one requiring escape were used in the present study.

It should also be noted that no studies have been published examining the effects of ethanol on primary frustration. That is, the frustration effect has not been examined in relation to ethanol. It is possible that ethanol would have no effect on primary frustration, even though it seems to alleviate conditioned frustration. Such a dichotomous result has been demonstrated for the depressant sodium amobarbital: Ison, Daly, and Glass (1967) and Freedman and Rosen (1969) have shown that primary frustration was unaffected by the drug; while Ison et al. (1967) and Ison and Rosen (1967) have demonstrated an attenuation of conditioned frustration by sodium amobarbital. Thus, it was deemed appropriate to examine both conditioned and primary frustration in relation to ethanol in the present study.

A paradigm was desired, then, which would allow:

1) a demonstration of primary frustration,
2) an examination of the effects of ethanol on primary frustration,
3) a demonstration of conditioned frustration with a nonvisual CS and a behavior other than escaping, and
4) an examination of the effects of ethanol on conditioned frustration.

Frustration and Barpressing

The CER (conditioned emotional response) paradigm seemed to meet all of these requirements. The rationale of the CER paradigm suggests that presentation of cues previously paired with an emotion-eliciting event will alter the rate of ongoing operant behavior (cf. Estes & Skinner, 1941). Conditioned-suppression paradigms have been used to examine the effects of various drugs on a fear response (Cicala & Hartley, 1967; Lauener, 1963), and in an analogous fashion conditioned frustration might be demonstrated and examined in relation to ethanol. While facilitation rather than suppression might be the outcome, the use of ratios of response durations allows for quantification of either effect.

The barpress task characteristic of CER paradigms has already been used to demonstrate primary frustration effects. Researchers pursuing this line of inquiry have typically used operant chambers in

attempts to demonstrate a frustration effect in paradigms analogous to the double alley. A popular paradigm has involved the use of two levers (comparable to the double-alley) and fixed ratio schedules. The term fixed ratio (FR) is used because the number of lever presses required to produce reinforcement is constant (fixed) throughout a session, and is customarily reported as a ratio of lever presses to one reinforcement. The FR in barpress studies has been compared to the relatively constant number of steps required to traverse an alley of fixed length (cf. Logan & Wagner, 1965; Platt, 1971; Spence, 1956). The frustration effect in double lever FR experiments has been demonstrated and examined by a variety of experimenters (e.g., Carlson, 1968; Davenport, Flaherty, & Dryud, 1966; Davenport & Thompson, 1965; Hughes & Dachowski, 1973; Quirt & Cohen, 1975; Zaslav & Porter, 1974). Other experimenters have used a single lever with multiple reinforcement schedules, either FR (Hamm & Zimmerman, 1967; Platt & Senkowski, 1970; Wookey & Strongman, 1971), fixed interval (Jensen & Fallon, 1973; Staddon & Innis, 1966), or mixed (Senkowski, 1973).

An Outline of the Experiment

For the present investigation, a perfect congruence with the double alley situation was not necessary. It was simply desired to demonstrate an effect attributable to primary frustration, an effect attributable to conditioned frustration, and to examine the impact of ethanol upon each. To that end, then, the experimental design involved training rats to barpress at a FR30 both after drinking ethanol solution and after

drinking sugar water. The levers were then removed from the chambers so that no barpressing was possible during sessions of frustration conditioning. Half the rats (conditioned frustration groups) underwent frustration conditioning, during which a tone CS preceded the frustration presumably aroused by nonreinforced feeder clicks. For the remaining half of the rats (unpaired frustration groups), tones were sounded during the sessions, but were not paired with the nonreinforced feeder clicks. There is evidence that the ability to perform learned responses may be conditional upon the drug conditions present during acquisition (cf. Overton, 1972). To avoid problems of data interpretation which might occur if such "state dependent" effects were to appear in the present experiment, barpress training and frustration conditioning occurred for all animals both under drug and non-drug conditions.

Next, all rats were exposed to conditions of intermittent reinforcement which were expected to result in a primary frustration effect. For all rats, primary frustration was elicited both after ethanol and after sugar water consumption.

Subsequent testing procedures were designed to maintain barpressing behavior long enough to allow examination of the relations between ethanol and elicitation of conditioned frustration, and ethanol and extinction of barpressing. The first four FR sequences in each test session were reinforced, but all subsequent FR sequences in each session terminated with "empty" feeder clicks. That is, two feeder clicks occurred as they had on reinforced sequences, but no food pellets were delivered. Thus, the only difference between reinforced and

nonreinforced sequences was the absence of pellets after the latter. It is possible that the "empty" feeder clicks functioned as secondary reinforcers and thus prolonged barpressing in the absence of primary reinforcement, but that event, if occurring, would be consonant with the desire to maintain barpressing for testing purposes. Tone CSs were sounded, allowing examination of the effects of conditioned frustration, both during reinforced and nonreinforced FR sequences. It was anticipated that barpressing after the last reinforced FR sequence would extinguish over the course of a few test sessions. As was discussed earlier, this extinction of barpressing could be attributed to the effects of primary frustration. In an effort to ascertain the influence of ethanol on extinction, and, by implication, on primary frustration, drug conditions were held constant for all subjects during days of testing of conditioned frustration, then shifted for half the rats for additional tests of rates of extinction of barpressing.

Reflecting the exploratory nature of this research, several dependent measures were monitored, with the goal of comparing and contrasting the patterns of results revealed by each. One of these measures was the time from onset of the first barpress of a FR sequence to onset of the final barpress of a sequence. Additional measures were the durations of the intervals between barpresses and the durations of discrete barpresses. For purposes of analyses, all three of these measures were converted to rates. Thus the basic measure of rate of barpressing was supplemented with rate measures (i.e., reciprocals) for interbarpress intervals and barpress durations. Also ratios of

suppression were calculated from the dependent measures relating to effects of frustration and conditioned frustration. Finally, measures of response variability which might vary with elicitation of frustration or consumption of ethanol were computed. In this regard, Boroczi and Nakamura (1964) have shown that an increase in between-trial variability of responding can be used as a reliable indicant of frustration, even in the absence of reliable changes in vigor of responding because of ceiling effects. The impact of ethanol on response variability within subjects, or even between subjects, is unknown at present so that any information generated should be of interest.

Summary

Tension reduction has been a widely touted effect of alcohol. Studies of the effects of alcohol in conflict situations have supported a notion of tension reduction by alcohol, but the results of studies with other experimental paradigms (e.g., avoidance, escape, conditioned fear, etc.) have been equivocal. Frustration is operationally similar to conflict but has not been extensively studied in relation to alcohol. What studies of frustration and alcohol are available suggest that alcohol does reduce frustration. The operational similarities between conflict and frustration and the support engendered from the two paradigms for a tension-reduction hypothesis suggest that the emotional concomitants of conflict and frustration paradigms may be identical and are affected by ethanol.

Direct testing of the impact of alcohol on frustration is proposed by training rats to barpress at a FR30 and then subjecting them to conditions of intermittent reinforcement both with and without alcohol. In addition, pairing of a tone with frustration elicited in the absence of barpressing, with subsequent testing for conditioned frustration during reinforced and nonreinforced barpressing, will allow an analysis of the effect of alcohol on conditioned frustration. The influence of alcohol on extinction of barpressing will be examined by altering the drug conditions for half the subjects before the final two extinction sessions. Several dependent measures will be monitored to allow diverse analyses of the effects of frustration and alcohol on the barpress response.

METHOD

Subjects

In April of 1977, 80 female, hooded, Long-Evans rats were obtained from Simonsen Laboratories, Gilroy, California. Upon arrival at the Health Sciences Center the rats were 61 days of age and weighed 180 - 200 grams. They were initially housed four rats per cage (wire mesh hanging cages) and placed in quarantine for 5 days during which they had ad-lib access to food and water treated with Aureomycin (50 mg/l) as a prophylactic. When released from quarantine they were moved to a room in the animal care facility, the bottles containing antibiotic solution were replaced with clean bottles containing only tap water, and the wood chip bedding beneath the cages was replaced. A day later the rats were moved to a room in the Department of Medical Psychology. The wood chip bedding was changed twice weekly thereafter, on Tuesday and Friday afternoons after completion of the days' experimentation. A 14 h day-10 h night cycle was in effect, with lights on at 0530 h and off at 1930 h.

Apparatus

The principal experimental equipment comprised four operant chambers, each housed in a ventilated and sound attenuating enclosure (36 cm x 71 cm x 34 cm, inside). A 6-W bulb illuminated each enclosure.

The enclosures shared the same room as a PDP-8/F computer which recorded all dependent measures and controlled stimulus presentations. The four operant chambers (22.5 cm x 23 cm x 19 cm, inside) were constructed with 1.5-mm aluminum end panels and 6-mm clear Plexiglas side walls and ceilings. The grid floors (2.3-mm stainless steel rods on 1.27-cm centers) were covered by perforated 3-mm thick Masonite. One of the aluminum end panels in each chamber contained cut-outs for two levers (2.5 cm from grid floor to lever center) and two lamps (12 cm from grid floor to lamp center), as well as a Plexiglas food cup centered at the bottom of the end panel. The centers of the cut-outs for lamps and levers were 6 cm in from each side of the end panel. The lamp cut-outs contained pilot lamps which were inoperative throughout the present experiment. The right-side-lever cut-outs were covered with 3-mm Plexiglas shields; the left-side cut-outs contained Gerbrands levers (Model G6312) which required a force of approximately 20 g to depress. During the off-the-baseline conditioning phase, the levers were removed and both cut-outs were covered with 3-mm Plexiglas shields.

Gerbrands feeders (Model D), located behind the end panels, delivered food pellets (45 mg, P.J. Noyes) to the Plexiglas food cups. Two Peerless 2-in (5-cm diameter), 8 Ω speakers were wired in series and mounted to the ceiling of each sound-attenuating enclosure, 1 cm above the ceilings of the operant chambers. Tones were delivered through the speakers via sine wave generators (Testan, 114/04). Tone intensity was adjusted to 90 $\pm$ 5 dB SPL with a background noise level of 64 $\pm$ 3 dB (re 20 $\mu N/m^2$). The feeder clicks were measured at 80 $\pm$ 5 dB. All SPL

measurements were done with a H. H. Scott Sound Level Meter, Type 450-B (A Scale).

Procedure

The experiment is summarized and the separate phases are delineated in Table 1. The first step of the experiment was to institute a deprivation schedule which ultimately involved 10 min of access to fluid before daily barpress sessions and 60 min of access to food and water after daily barpress sessions. Adaptation to this deprivation schedule occurred in successive stages over a 7-day period from Apr 27 through May 3. Details of the procedure followed during this week of the experiment and the subsequent barpress shaping phase are attached as Appendix A. During this week the tail of each of the 80 rats was marked with a colored marking pen to indicate the unique subject number of that rat, and each rat was assigned at random to one of 20 four-rat squads. Thereafter, rats were housed one squad per cage in gang cages. The duration of access to food and water was gradually reduced so that by the end of the week each squad had 60 min of ad-lib food and water each day in a feeding cage similar to the home cages.

Barpress Shaping

The period from May 4 through May 23 was devoted to training the rats to barpress at least 40 times during a 20-min session in an operant chamber. The details of the barpress shaping phase are included in Appendix A. In summary, each day each rat was weighed, given 10 min of

Table 1

Procedures and Phases of the Experiment

Phase: Treatment	Fluid Drunk
Deprivation Adaptation (Apr 27 - May 3): gradual reduction in time for ad lib eating and drinking to final level of 60 min each day.	Tap Water
Barpress Shaping (May 4-23): 10-min presession drinking period instituted; daily 20 min sessions with a food pellet delivered every 2 min and after every barpress until rat barpressed 40 times in a single session.	Tap Water
FR Training (May 24 - Jul 27): daily sessions to criterion of 40 reinforcements or 20 min. FRs increased for next session whenever a session ended before 20 min. At FR15 reinforcements increased to two 45-mg pellets per FR sequence. Four sessions at FR30 terminated this phase.	Ethanol and sugar water alternating
Respite (Jul 28 - Sep 14): ad-lib food and water 24 h per day in home cages, four rats per cage.	Tap Water
Deprivation Reinstatement (Sept 15-20): ad-lib access to food and water for 60 min each day in feeding cages.	Tap Water
Refresher Sessions I (Sep 21-28): daily sessions at FR30 to criterion of 40 reinforcements or 20 min; rats assigned to either conditioned frustration group or unpaired frustration group for next phase on the basis of barpress performance over the last four sessions of this phase.	Ethanol and sugar water alternating

Conditioning of Frustration (Sep 29 - Oct 2): daily 20-min sessions of off-the-baseline conditioning, levers removed from chambers. Eight of 40 pairs of feeder clicks were not followed by food pellets--for conditioned rats these nonreinforced clicks were followed by 3-sec tone (pairing tone w/frustration); tones and nonreinforced clicks were separated by at least 5 sec for unpaired rats.	Ethanol and sugar water alternating
Refresher Sessions II (Oct 3 & 4): daily sessions at FR30. All barpress sessions from Oct 3 through Oct 12 terminated with 40 FR sequences or 20 min.	Ethanol and sugar water alternating
Primary Frustration Tests (Oct 5 & 6): daily sessions wherein every fourth or fifth FR30 sequence was nonreinforced	Ethanol and sugar water alternating
Conditioned Frustration Tests (Oct 7-10): rats assigned to either ethanol or sugar water on the basis of barpress performances on the final 4 days of Refresher Sessions I. First four FR30 sequences were reinforced; no other FR sequences were. Tones occurred in every FR sequence from the fourth to session end, initiated by either 6th or 16th barpress. Data were collected in packets for each five barpresses.	Either ethanol or sugar water
Drug Shift Tests (Oct 11 & 12): half the ethanol rats of the previous phase shifted to sugar water and vice versa. First four but no other FR sequences were reinforced. No tones were presented.	Either ethanol or sugar water
Blood Ethanol Analyses (Oct 13-20): rats maintained on 22.5 h deprivation schedule until sacrificed at various times after ethanol consumption. Blood samples cooled, centrifuged, and plasma frozen for later fluorometric assay.	Ethanol and sugar water alternating

access to a premeasured amount of water in an individual cage, then placed for 20 min in an operant chamber. During the 20 min in the operant chamber, wet mash was present on the bar, any barpresses made were reinforced (i.e., followed by delivery of one 45-mg Noyes food pellet), and every 2 min a food pellet was delivered automatically. In addition, the experimenter spent about 5 min individually shaping the barpressing response of each rat. These 20-min shaping sessions occurred daily until each rat emmitted 40 barpresses during a session. After each 20-min barpress session, rats were given 60 min of access to food and water in a feeding cage, then returned to the home cage. Midway through the 20-min barpress session of Squad 1 (SQ1), the 10-min drinking period began for SQ2. Thus SQ2 could be moved into the operant chambers as soon as SQ1 was moved to a feeding cage. In this fashion, all 20 squads were handled each day until each rat had barpressed 40 times in a single session. Those rats that met the 40-barpress criterion before the end of the barpress shaping phase were no longer placed in the operant chambers. Instead, they were returned to the home cage after the 10-min drinking period, then placed in the feeding cage with their squadmates after the 20-min barpress session ended.

All rats were exposed to all four operant chambers over the course of barpress shaping sessions. This rotation through the operant chambers continued through the experiment until the conditioning phase. For the conditioning phase and the duration of the experiment each rat was assigned to one of the four operant chambers. It should be noted that

although rats were together in squads of four most of the time, when measures were being taken (e.g., amount consumed during drinking period, weight, barpress durations) the rats were alone in the particular apparatus (e.g., drinking chamber, scale, operant chamber).

Drinking Solutions

Throughout the barpress shaping phase, the fluid available to the rats was limited to tap water. Beginning with the FR training phase and continuing through the rest of the experiment (cf. Table 1), the fluid available during the 10-min drinking periods consisted of tap water supplemented with either sugar (S) or ethanol (E) and sugar. The ethanol solutions used during the 10-min drinking periods were a nominal 2% ethanol and a nominal 5% ethanol. Variable amounts of sugar were used in these solutions to insure that they were of equivalent caloric value. The 2% solution was mixed by combining 20 ml of 95% ethyl alcohol, 73.7 g granulated cane sugar, and room temperature tap water to a volume of 1000 ml (a 1.9% v/v solution). A sugar water solution consisted of a mix of 100 g granulated cane sugar and tap water to a volume of 1000 ml, making it equicaloric with the ethanol solutions (.4 calories/ml).

A rat drank ethanol solution on some days and sugar water on the other days. Half the rats of each squad were assigned to an ESSE schedule, the other half to the counterbalanced SEES schedule. In addition, half the rats on each of the two counterbalanced schedules drank 2% ethanol; the other half drank 5% ethanol. These assignments

were made on the basis of weight on the final shaping day, so that the subgroups were matched with each other for body weight. As a result of the assignment procedure (details in Appendix A), on any given day two rats from each squad drank sugar water, one drank 2% ethanol, and one drank 5% ethanol.

FR Training

The FR ratios were gradually increased over a training phase beginning the first day after the barpress shaping phase. On that day and each subsequent day SQ1 began the daily drinking period at 0730 h. SQ2 began the drinking period 25 min later, at 0755 h, and subsequent squads began the drinking periods at 25 min intervals thereafter. After 10 min in the drinking cages rats were moved to the operant chambers. They were moved to the feeding cages after the barpress sessions. After an hour of ad-lib food and water the rats were returned to their home cages. This schedule continued throughout the FR training phase.

The durations of the barpress sessions during this phase were determined by each rat's own behavior: the daily barpress sessions were terminated after 40 reinforcements or 20 min, whichever occurred first. Whenever a rat earned 40 reinforcements in less than 20 min the FR was incremented by at least one for the next session. If a session was only 10 to 15 min long, the FR was incremented by two for the next session. If a session was shorter than 10 min the FR was incremented by three for the next session. If 40 reinforcements were not delivered and a session terminated after 20 min, the same FR was used during the next

day's session. In this manner the FR ratio was gradually increased to FR30. To insure brisk responding, at FR15 the number of pellets delivered at the end of the barpress sequence was increased from one to two. From that time to the end of the experiment reinforcement consisted of two 45-mg food pellets which were delivered with two successive clicks of the feeders (separated by 100 msec). FRs were incremented only to FR30. After a session of less than 10 min at FR27, 15 min at FR28, or 20 min at FR29, a FR30 was assigned for the next session. Four daily barpress sessions ensued at FR30. Thereafter, rats which had already completed the four FR30 sessions were moved directly from the drinking cages to the feeding cages each day. As the other members of each squad finished the FR sessions, they were moved from the operant chambers to the feeding cage. When all squad members had completed 1 h of ad-lib eating and drinking they were returned to the home cage. If an entire squad had completed four FR30 sessions, that squad was moved from the drinking cages directly to a feeding cage for 1 h of ad-lib food and water.

After 16 days of FR training the data revealed that the consumption of the 5% ethanol solution varied greatly among animals. The range of doses resulting from consumption of the 2% solution was subsumed by the range of doses from the 5% solution on most days. In an attempt to reduce the variability of dosing while maintaining the possibility of two dose levels, the 5% solution was reduced to a nominal 3.5% (35 ml of 95% ethyl alcohol, 54 g granulated sugar, and room temperature tap water to a volume of 1000 ml--a 3.3% v/v solution). This 3.5% solution was

first introduced on the 17th day of FR training and was used throughout the remaining days of the experiment. The FR training phase lasted 64 days, which allowed a complete progression through the ESSE schedule listed below.

ESSE SEES SEES ESSE SEES ESSE ESSE SEES

SEES ESSE ESSE SEES ESSE SEES SEES ESSE

Of course the half of the rats which were on the counterbalanced schedule received the alternate fluid on each day throughout FR training.

When the FR training phase terminated 69 rats had reached FR30 and completed four sessions at that FR. The remaining rats were discarded. On the next day all rats were returned to a schedule of ad-lib food and water in their home cages. During the course of FR training several rats developed a fungal disease which caused a loss of hair about the head and jaw. These rats were treated daily with Tinactin, an antifungal cream, after completion of the feeding sessions. Other rats were apparently not gnawing enough to keep their lower incisors short. The teeth of these rats were trimmed at the beginning of this period of ad-lib food and water.

Refresher Sessions

Beginning on Sep 15, rats were again placed on a 22.5 h deprivation schedule. After 5 days of adaptation to the deprivation schedule a counterbalanced ESSE schedule for ethanol and sugar water began for daily 10-min drinking sessions. Rats were assigned the same fluid schedule as during FR training; they began again and continued for 16

days the sequence that had started on May 24. After each of these drinking sessions rats underwent "refresher" barpress sessions consisting of a maximum of 20 min or 40 reinforcements at a FR30. Duration of barpress sessions was averaged for each rat for the final four of these sessions, and rats within each of the four groups (2%ESSE, 2%SEES, 3.3%ESSE, 3.3%SEES) were rank ordered according to average session duration and average number of reinforcements delivered. Five of the rats did not perform well during refresher sessions, averaging fewer than 22 FR sequences per session; these five rats were discarded. Within each of the four groups two conditioning subgroups were then formed, matched for average session duration and number of reinforcements. In this manner half the rats were assigned to the "conditioned frustration" (CF) contingency and half to the "unpaired frustration" (UF) contingency. Details of this assignment procedure are included in Appendix A.

Conditioning of Frustration

Subjects next began 4 days of frustration conditioning sessions, during which pairs of feeder clicks were sometimes followed by two food pellets (reinforced) and sometimes not (nonreinforced). Ethanol and sugar water continued to alternate for the drinking periods so that two of these conditioning sessions occurred after ethanol consumption and two after sugar water consumption. The levers were removed from the operant chambers so that no barpressing was possible. Sessions lasted for 20 min; the interval between pairs of clicks was either 15 sec, 30 sec, or 45 sec (mean = 30 sec). Those intervals occurred in a random order.

Each day eight sets of two feeder clicks were nonreinforced; the remaining 32 sets of two feeder clicks were reinforced. Reinforced (R) and nonreinforced (N) pairs of feeder clicks occurred in the following order: RRRRNRRRNRRRRNRRRRNRRRNRRRRNRRRRNRRRNRRR.

Eight tone presentations (4 kHz at 90 dB for 3 sec) occurred during each of the four conditioning sessions. For half the rats (CF rats) these tones occurred immediately after the second feeder click of the nonreinforced pairs and thus presumably preceded the frustration aroused by nonreinforcement. For the other half (UF rats) the tones were distributed throughout the sessions in approximation to the distribution of tones for CF rats, but did not sound within 5 sec of any feeder click; thus tone presentations for the UF rats could be considered as explicitly unpaired with feeder clicks. No tone sounded during the first 2 min or final 2 min of unpaired sessions. The remaining 16 min of the sessions were divided into 32 intervals of 30 sec each. The tones were distributed so that each 30-sec interval contained one tone sometime during the 4 days of conditioning. On the first day of conditioning a tone occurred during the sixth 30-sec interval (between 2.5 and 3 min into the session) and every fourth interval thereafter. On the second day of conditioning a tone occurred during the eighth 30-sec interval and during every fourth interval thereafter. Similarly on the third and fourth days of conditioning, the tones occurred first during the fifth and seventh 30-sec intervals, respectively, and during every fourth 30-sec interval thereafter until eight tone presentations had occurred. Within any 30 sec interval tone onset was scheduled randomly during one of the ten possible 3-sec segments.

Refresher Sessions

On each of the next two days the levers were again extended into the chambers and a FR30 was in effect. Sessions lasted for 20 min or 40 reinforcements, whichever occurred first. The continuing ESSE schedule for ethanol and sugar water resulted in each rat's undergoing a barpress refresher session once after ethanol and once after sugar water consumption.

Primary Frustration

On each of the following 2 days nonreinforced FR30 barpress sequences were distributed throughout each of the sessions. The effects of nonreinforcement on barpressing and of ethanol on barpressing after nonreinforcement were measured at this time. Of the 40 possible FR sequences each day, 8 were nonreinforced and 32 were reinforced. The distribution of these reinforced and nonreinforced sequences was the same as the distribution of reinforced and nonreinforced feeder clicks during the conditioning sessions. The counterbalanced ESSE sequence for ethanol and sugar water continued through these 2 days of primary frustration sessions, so that each rat barpressed in conjunction with primary frustration 1 day with and 1 day without ethanol. Sessions terminated after 20 min or 40 FR sequences, whichever occurred first.

Testing for Conditioned Frustration

Extinction of barpressing and testing for conditioned frustration took place over the next 4 days. On these days half the rats in each

conditioning group drank ethanol before every session and the other half drank sugar water before every session. This assignment was made on the basis of session duration and number of reinforcements received during the last four refresher sessions before frustration conditioning, with ethanol and sugar water rats matched with respect to these two measures. Details of this assignment procedure are included in Appendix A. The first four FR30 barpress sequences of each of these sessions were reinforced in the usual manner; thereafter no reinforcements were delivered during the sessions, although the feeder clicked twice at the end of each FR30 sequence. The CS was sounded during the fourth FR30 sequence of each session and once during every FR30 sequence thereafter. The tone was initiated by the 6th or 16th barpress of the FR30 sequences according to a counterbalanced schedule taken from Fellows (1967). Appropriate details about scheduling of tones are included in Appendix A. Extinction sessions were terminated after 20 min or 40 FR sequences, whichever occurred first.

Drug Shift Test

Next, 2 days of extinction ensued during which drug conditions were switched for half the rats. Rats within each of the extinction conditions for testing conditioned frustration were rank ordered according to total number of FR30 barpress sequences completed during the last two extinction test sessions. Each subgroup was then further divided, by a procedure detailed in Appendix A, into two subgroups which were matched for performance on the preceding 2 days. One subgroup was maintained on

the fluid that had been available during extinction test days; the other subgroup was switched to the alternate fluid. During these final 2 days of testing, the tone no longer was sounded. The first four FR30 sequences on each day were reinforced as previously, and no further barpressing was reinforced on either day.

Blood Ethanol Analysis

After the final day of extinction, the rats were maintained on the 22.5 h deprivation schedule until they could be sacrificed for blood ethanol analyses. For several days the rats were offered fluid for 10 min in the drinking cages, then moved directly to the feeding cages for 1 h of ad-lib food and water. Ethanol and sugar water alternated as the fluid available during the 10-min drinking periods. Details of the blood ethanol assay procedures are attached as Appendix B. Beginning on the fifth day after the final test session, about a dozen rats were sacrificed each day after the drinking periods. The remaining rats were given an hour of ad-lib food and water and then returned to the home cages. Decapitations occurred at intervals after the start of the drinking period: 10, 15, 20, 25, 30, 40, 55, and 70 min. These intervals were selected to provide information about the dose-time relations within the parameters of the experiment. Rats were assigned to the intervals so that each of the extinction test conditions was represented at each of the intervals; there were eight rats sacrificed at each interval.

RESULTS

Because of the great number of analyses anticipated for examination of the data generated during the course of the experiment, an alpha level of .01 was deemed appropriate. A programming error in the data collection system was not discovered until after the rats had been sacrificed. Because of this error, the analysis of average standard deviations of interbarpress intervals had to be abandoned. Measures of response variability thus depended solely upon average standard deviations for durations of discrete barpresses.

Important results from analyses of the data from the various phases of the experiment are presented in this section. The processes by which these results were determined were sometimes tedious, and the descriptions of them are somewhat unwieldy. Those processes are detailed in Appendix C, and the section which ensues may be considered a digest of Appendix C.

Fixed Ratio Training Data

During the course of FR training, rats progressed to larger fixed ratios at a rate determined by individual performances. Because of the details of this procedure not all rats performed on every fixed ratio between 1 and 30. In addition, individual rats did not necessarily perform after drinking ethanol solution on the same ratios as after

drinking sugar water. For each rat a mean barpress rate was calculated for each FR and drug condition with which that rat had experience. This average rate weighted equally each FR sequence which a rat had completed at any given FR and drug condition. Then the ratios from 5 through 29 were segregated into five groups, and the mean barpress rates for each rat under ethanol were averaged for all FRs within each group, as were the rates for sugar water for FRs within each group. Thus, means of mean rates were calculated for each rat under ethanol and sugar water for FRs 5-9, 10-14, 15-19, 20-24, and 25-29. Finally, mean rates for ethanol and sugar water were computed for the 4 days of barpressing at FR30, the last days of the FR training phase. These mean rates were subjected to a four way analysis of variance with two between subjects factors (ethanol concentration: 2% or 3%, and future conditioning contingency: CF or UF) and two within subjects factors (fluid consumed: ethanol or sugar water, and FR blocks: six levels).

A similar process was followed for measures of barpress durations and interbarpress intervals. Average values were calculated for each rat after consumption of each fluid for every FR at which that rat performed. These mean values were averaged across FRs within the six FR blocks from FR5 through FR30. Reciprocals were computed for these means of means, and these reciprocals of barpress durations and interbarpress intervals were subjected to four way analyses of variance with the same factors as for the rates of barpressing.

The same averaging and collapsing techniques were used to derive mean numbers of FR sequences completed per session for each rat in each

FR range after both sugar water and ethanol consumption. These data were then subjected to a four way analysis of variance with the same factors as for the rate measures.

In each of the four analyses of data from the FR training phase the factors of fluid consumed [all $\underline{F}s(1,60) > 16.0$, $\underline{p} < .001$] and FR blocks [all $\underline{F}s(5,300) > 25.0$, $\underline{p} < .001$] were significant. In addition the interaction of fluid consumed by FR blocks was significant for the analyses of interbarpress interval reciprocals and numbers of FR sequences completed per session [$\underline{F}s(5,300) = 4.08$ & 3.09, $\underline{p}s < .005$ & .01, respectively), and the interaction of fluid consumed by ethanol concentration was significant [$\underline{F}(1,60) = 7.09$, $\underline{p} < .01$) for analysis of number of FR sequences completed per session. The relation between FR blocks and each of the four dependent measures is shown in Figure 1. Each of the measures increased across FR blocks.

The interbarpress interval reciprocals increased more across FR blocks when rats drank ethanol than when they drank sugar water, indicating that the tendency for interbarpress intervals to grow briefer with increasing FRs was more pronounced when ethanol was influencing barpressing.

More FR sequences were completed per session at the higher FRs, and more were completed per session with ethanol than with sugar water. But with this measure the change across FRs was more dramatic with sugar water than with ethanol.

The impact of ethanol on the various measures during FR training is illustrated in Figure 2, where the performances at FR30 are shown

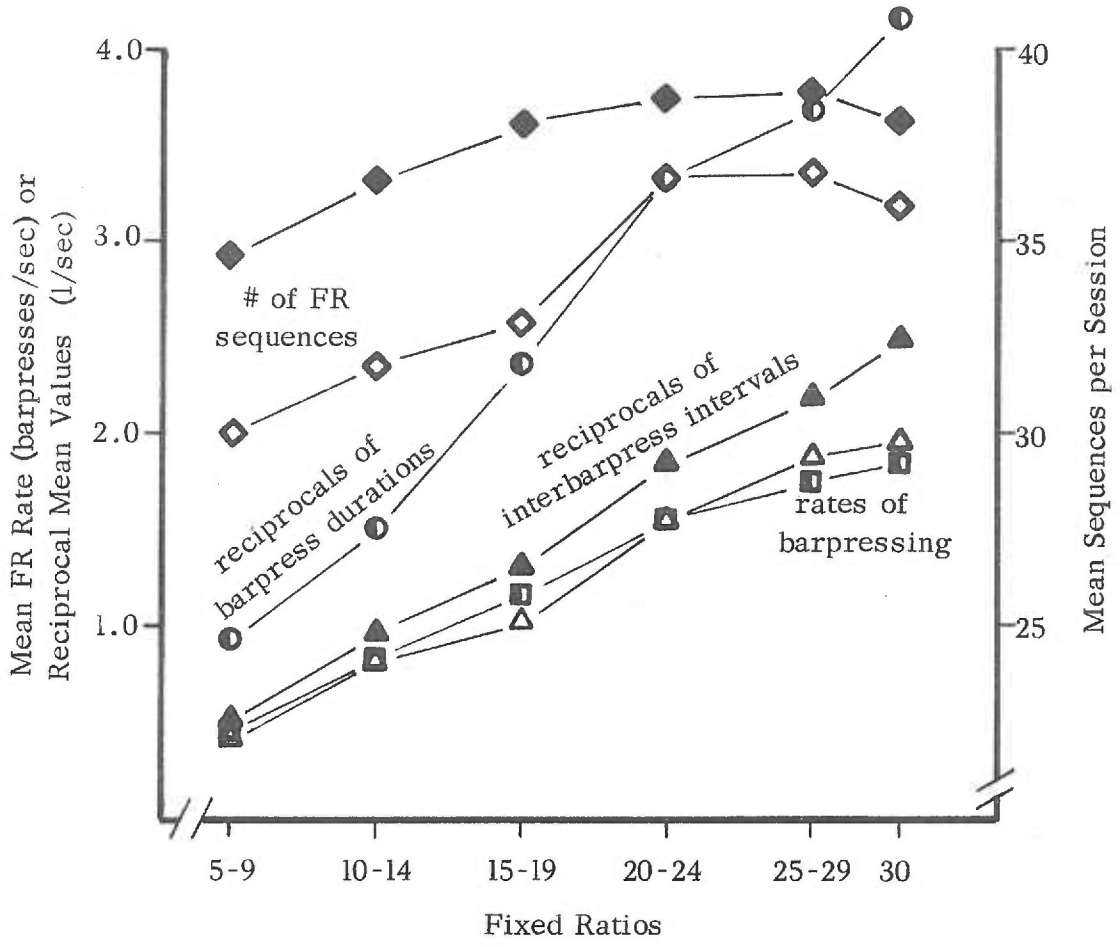

Figure 1. The relation between fixed ratios and each of the four dependent measures. Open symbols indicate performances after consumption of sugar water; filled symbols after ethanol. Half-filled symbols indicate means of both ethanol and sugar water days. Rates of barpressing (□), reciprocals of interbarpress intervals (△), reciprocals of barpress durations (○), and sequences completed per session (◇) all increased with increasing FRs.

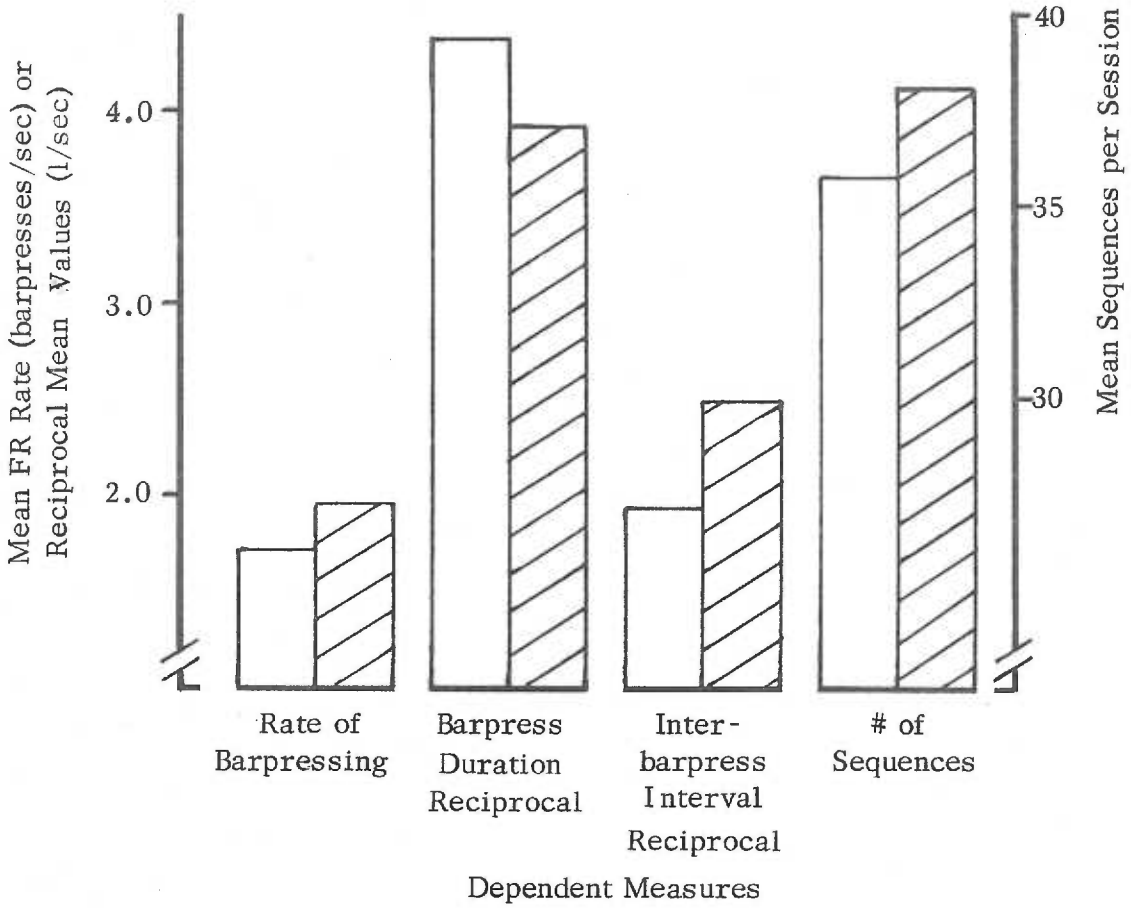

Figure 2. The influence of ethanol on performance of a FR30 barpress task at the end of the FR training phase. Four dependent measures are represented. Open areas represent performances after consumption of sugar water; shaded areas after ethanol. Only the performances of 3% rats are represented for the "sequences per session" measure.

for each measure after ethanol and sugar water. For the number of sequences completed per session, only the 3% rats are represented because only their performance differences were significant (recall the concentration by fluid consumed interaction for this measure). As is readily seen in Figure 2, one measure, reciprocals of barpress durations, was decreased by ethanol. The other measures all increased significantly with ethanol. The influence of ethanol on FR30 barpressing was to shorten interbarpress intervals, lengthen barpress durations, increase rate of barpressing, and increase the number of sequences completed per session.

Refresher Sessions

A FR30 was in effect throughout the refresher sessions on Sep 21-28 and Oct 3-4. Data from these sessions were averaged for each day for each rat, and subjected to four way analyses of variance with two between subjects factors (ethanol concentration: 2% or 3%, and future conditioning contingency: CF or UF) and two within subjects factors (fluid consumed: ethanol or sugar water, and sessions: five levels). The notable results which differed from the data presented in Figures 1 and 2 were a lack of an effect of ethanol on reciprocals of barpress durations, an effect of ethanol on interbarpress interval reciprocals only for 3% rats, and an effect of ethanol on sequences per session for both 2% and 3% rats.

Primary Frustration

Intermittent FR sequences were not reinforced during sessions of Oct 5-6. Of the possible 40 FR sequences each session, 8 were nonreinforced. All other sequences terminated with the usual two food pellets. Data for each rat after consumption of each fluid were averaged for all nonreinforced sequences completed by that rat. Similarly, data for each rat after consumption of each fluid were averaged for all FR sequences immediately after nonreinforcement. Thus four of each of the dependent measures were available for each rat. The FR durations were converted to rates, and barpress durations and interbarpress intervals were converted to reciprocals. These rates, reciprocals, and the mean standard deviations of barpress durations were subjected to four way analyses of variance with two between subjects factors (ethanol concentration: 2% or 3%, and conditioning contingency: CF or UF) and two within subjects factors (fluid consumed: sugar water or ethanol, and temporal relation to nonreinforcement: before or after). An effect of primary frustration was demonstrated with every dependent measure. The rate measures and reciprocals increased after nonreinforcement, but the standard deviations of barpress durations decreased after nonreinforcement. In addition, interbarpress interval reciprocals were greater after ethanol consumption than after sugar water consumption.

However, in no case was the interaction of fluid consumed with temporal relation to nonreinforcement significant. That is, there was no evidence of an effect of ethanol on primary frustration. To pursue this issue, and to demonstrate unequivocally that the effects were owing

to nonreinforcement, frustration ratios were computed for each measure for each rat after sugar water and ethanol consumption. These ratios were computed for each occasion on which a rat encountered nonreinforcement and completed the FR sequence after nonreinforcement. Event durations were used in calculating these ratios; the computational formula was: ratio = POST/(PRE + POST). Ratios of less than .5 indicated that event durations were shorter during later (POST) FR sequences than during earlier (PRE) FR sequences, or, when the "events" were standard deviations, that response variability was less during later FR sequences than during earlier FR sequences.

Three FR sequences near each occurrence of nonreinforcement provided data for two ratios. The first ratio, computed with data from the two FR sequences before the occurrence of nonreinforcement, provided an indicant of performance changes owing to factors other than nonreinforcement. It was assumed that no frustration was present to influence barpressing in these two sequences. This ratio involved the penultimate FR sequence (PRE) before nonreinforcement and the nonreinforced FR sequence (POST). A second ratio involved the nonreinforced FR sequence (PRE) and the FR sequence immediately after nonreinforcement (POST). This ratio, computed with data from FR sequences immediately prior and subsequent to nonreinforcement, provided an indicant of performance changes owing to nonreinforcement and to other nonspecific factors. Thus it was assumed that frustration was present to influence barpressing during the FR sequence immediately after nonreinforcement.

Mean ratios were computed for each rat after sugar water and ethanol consumption for FR sequences before nonreinforcement and for FR sequences immediately prior and subsequent to nonreinforcement. These mean ratios were subjected to four way analyses of variance with two between subjects factors (ethanol concentration: 2% or 3%, and conditioning contingency: CF or UF) and two within subjects factors (frustration: present or absent, and fluid consumed: sugar water or ethanol). For all four measures the factor of frustration produced a significant F ratio [all $\underline{F}s(1,52) > 50.0$, $\underline{p} < .001$].

Reference to Figure 3 reveals that both the operation of nonreinforcement and the presence of ethanol reliably increased the reciprocal interbarpress intervals. However, only the increase produced by nonreinforcement is representative. That is, no other measure was reliably altered by the presence of ethanol, but rates of barpressing, barpress duration reciprocals, and average deviations of barpress durations all reliably reflected the operation of nonreinforcement.

For all measures the frustration ratios differed significantly from ratios based on sequences without frustration. The ratios for interbarpress intervals shown in Figure 3 differed most dramatically. But in spite of main effects of both nonreinforcement and ethanol on reciprocals, suppression ratios based on intervals produced only a main effect of nonreinforcement. One must conclude that while ethanol decreased interbarpress intervals, it did not do so differentially with regard to the presence or absence of frustration. In the cases of the other measures, ethanol did not reliably affect them, either with or without the presence of frustration.

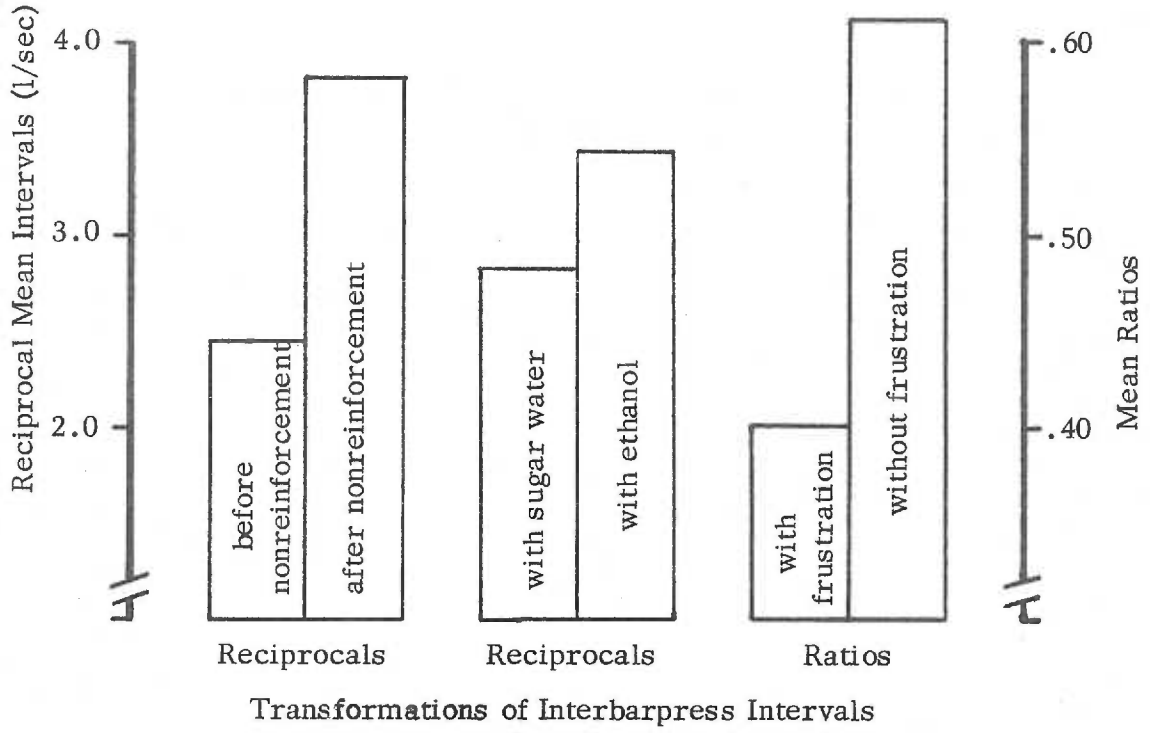

Figure 3. Average reciprocals of interbarpress intervals before and after nonreinforcement and after sugar water and ethanol consumption, and ratios based on FR sequences with and without frustration. These means were calculated from data taken on Oct 5 and 6. Ratios less than .5 indicate that intervals of later sequences were shorter than those of earlier sequences.

Testing for Conditioned Frustration

Data were collected somewhat differently from the beginning of tests for conditioned frustration to the end of the experiment than had been the case earlier. Each FR30 sequence was divided into six groups of five barpresses each, and all of the information that had been punched at the end of each FR sequence was punched on paper tape after every five barpresses. Thus there were six data packets punched for every FR30 sequence.

Tones were superimposed on barpressing during sessions occurring from Oct 7-10. Either the 6th or 16th barpress of a FR sequence instigated a tone presentation. These tones first occurred during the fourth FR30 sequence of a session, and occurred during every FR sequence thereafter. Also, delivery of food pellets occurred only after the first four FR30 sequences of a session; all other FR sequences were nonreinforced. There were thus three types of FR sequences during these sessions of testing for conditioned frustration. The first three FR sequences of each session were simply reinforced FR30 barpressing. The fourth and fifth sequences involved tone presentations paired with reinforced FR30 barpressing. In the remaining sequences tone presentations were paired with nonreinforced barpressing wherein 30-barpress sequences terminated with two "empty" feeder clicks.

During this phase of the experiment there were three between subjects factors (ethanol concentration: 2% or 3%, fluid consumed: ethanol or sugar water, and conditioning contingency: CF or UF) and four within

subjects factors (days: four levels, data packets: six levels, FR sequence type: three levels, and tone locations: two levels) which warranted consideration. Because overall seven way analyses of variance were not feasible, the data from the three types of FR sequences were considered separately. A general strategy was adopted of conducting initial four way analyses with separate replications for the remaining factors. Subsequent analyses were then computed which included the factors previously treated as replications, and ignored one or more of the factors of the initial analyses. Interpretations of the results of these subsequent analyses were, of course, subject to constraints provided by the results of the initial analyses.

Data from nine rats were eliminated from consideration for analyses of conditioned frustration testing data. For some of these rats the temporal relationship between nonreinforcement and tones during conditioning sessions was unknown because the feeder systems were not aligned correctly at the beginning of one or more sessions. For others of these rats the feeders had jammed during conditioning sessions. The distribution of these rats between experimental subgroups was relatively even, ranging from zero to two rats per subgroup. Within each of the subgroups from which one rat had been eliminated, the last rat to reach FR30 during the FR training phase was also eliminated. Within those subgroups from which no rats had yet been eliminated, the last two rats to reach FR30 during the FR training phase were eliminated. By this means the group sizes were equalized (6 subjects/group) for purposes of analyses of variance.

FR Sequences Without Tones

Barpress behavior changed as rats progressed from the first to the final barpress of a FR sequence. These changes in barpress behavior were reflected in all of the dependent measures. As can be seen in Figure 4, each of the three rate measures increased from the first through the fifth data packets. Thereafter, rates slowed significantly for both rates of barpressing and reciprocals of barpress durations, but did not slow for the interbarpress interval reciprocals. The average standard deviations of barpress durations were greater in the first and final data packets than in the other packets.

The first three FR sequences of sessions of testing for conditioned frustration provided "baseline" data which could be used to assess the impact of the tone CS on the reinforced and nonreinforced barpressing which occurred subsequently.

FR Sequences With Tones

The factors of fluid consumed and conditioning contingency were not significant in any of the factorial analyses of data from FR sequences with tone presentations. Prior to this phase "fluid consumed" had been a within subjects factor, and analyses had often revealed it to be significant or to interact with other experimental variables. The failure of ethanol consumption to affect performance between subjects can most easily be accounted for on the basis of variability between subjects.

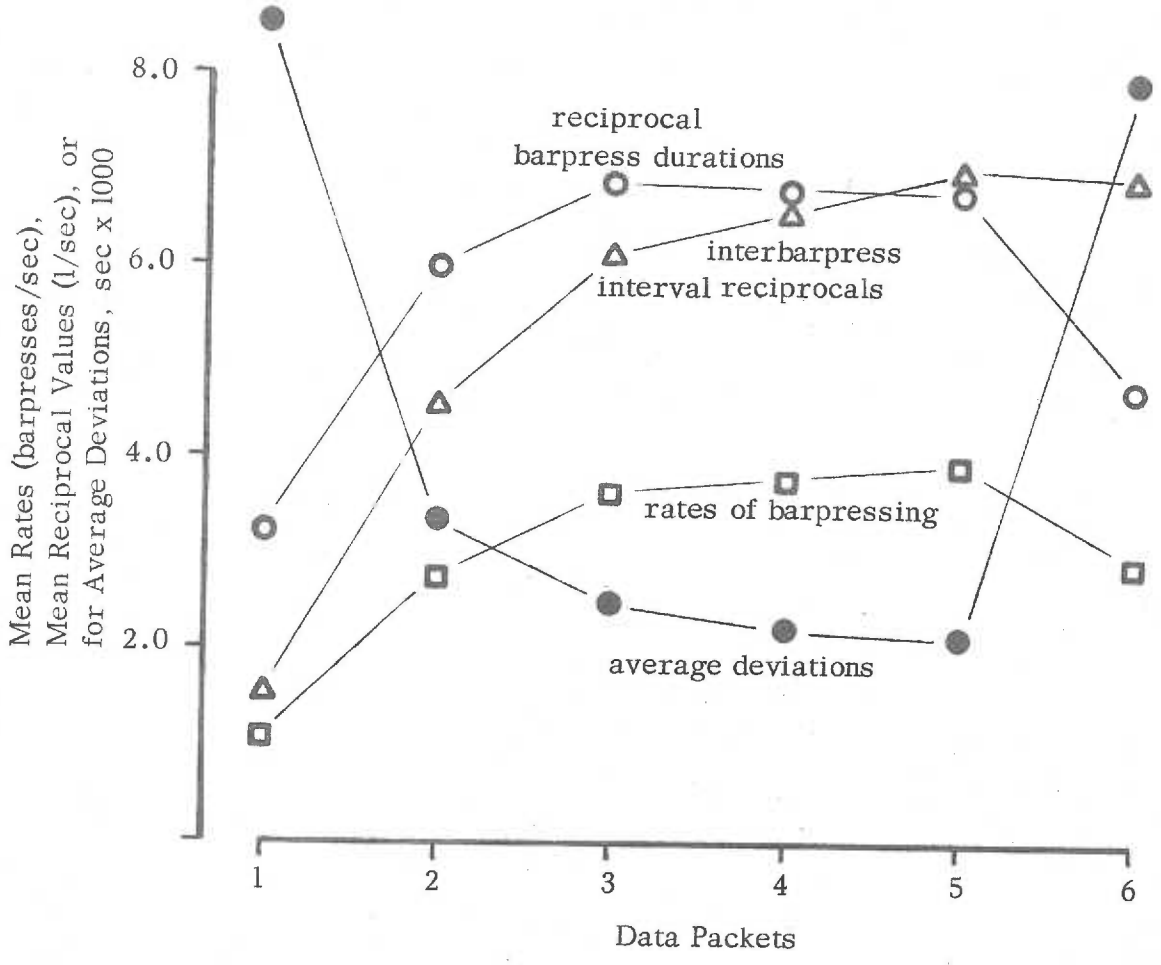

Figure 4. Changes in barpress behavior within the first three FRs during testing for conditioned frustration. Rates of barpressing (□), barpress duration reciprocals (○), interbarpress interval reciprocals (△), and average standard deviations of barpress durations (●) are all shown.

Indeed, a check of mean square error terms for one series of analyses (12 four way analyses mentioned in the first paragraph of "FR Sequences with Tone Presentations" in Appendix C) revealed that the between subject error terms averaged nearly ten times larger than within subject error terms. This between subject variability could also account for the failure to find an effect of conditioning contingency. In spite of the lack of a conditioning effect, CS presentations in both locations did have a reliable impact upon barpressing, as revealed by all four measures. The effect of the CS was to impede barpressing both by lengthening the intervals between barpresses and by lengthening the durations of discrete barpresses, and to increase the standard deviations of durations of discrete barpresses. Further, these effects of the CS were limited to a range of ten barpresses after onset of the 3-sec tones.

In an effort to counter the problems of between subject variability, ratios of suppression were computed for each data packet of the sequences in which tones were presented. These ratios were based on mean latencies for each of the dependent measures. Mean latencies during the first three sequences of each session provided the standard against which latencies in the second and third parts were "measured" for suppression or facilitation. The same formula was used as had been used for similar ratios computed from data collected during primary frustration sessions: ratio = POST/(PRE + POST). Now, however, the PRE component was a mean duration from the first three FR sequences of a session, and the POST component was a mean duration from the sequences with tone presentations. For example, ratios were computed for each rat for each packet of

nonreinforced sequences by dividing the mean duration in that packet in nonreinforced sequences by the sum of the mean duration in that packet in the first three sequences (PRE) plus the mean duration in that packet in nonreinforced sequences (POST). Ratios greater than .5 indicated that durations were longer in tone-containing sequences than in the first three sequences, and thus that rates were slower, or, for average standard deviations, that variability was greater. Ratios less than .5 indicated that durations were shorter and rates faster, or, for standard deviations, that variability was less in tone-containing FR sequences than in the first three sequences of these sessions of testing for conditioned frustration.

The only evidence that the tones were effective in eliciting a conditioned form of the frustration response came from the standard deviations of barpress durations. In an analysis of the suppression ratios for standard deviations of 3% rats during FR Sequences 4 and 5, a significant [$F(1,20) = 12.25$, $p < .005$] three way interaction between the factors of conditioning contingency, fluid consumed, and tone location occurred. The mean ratios which reflect that interaction are shown in Figure 5. When the tone occurred in the second data packet, the ratios for conditioned animals that drank sugar water were higher than those of their unconditioned counterparts, were, in fact, higher than ratios of unconditioned rats with or without ethanol, with the tone in either location.

While the use of suppression ratios did not expose a reliable relation between conditioning contingency or fluid consumed and

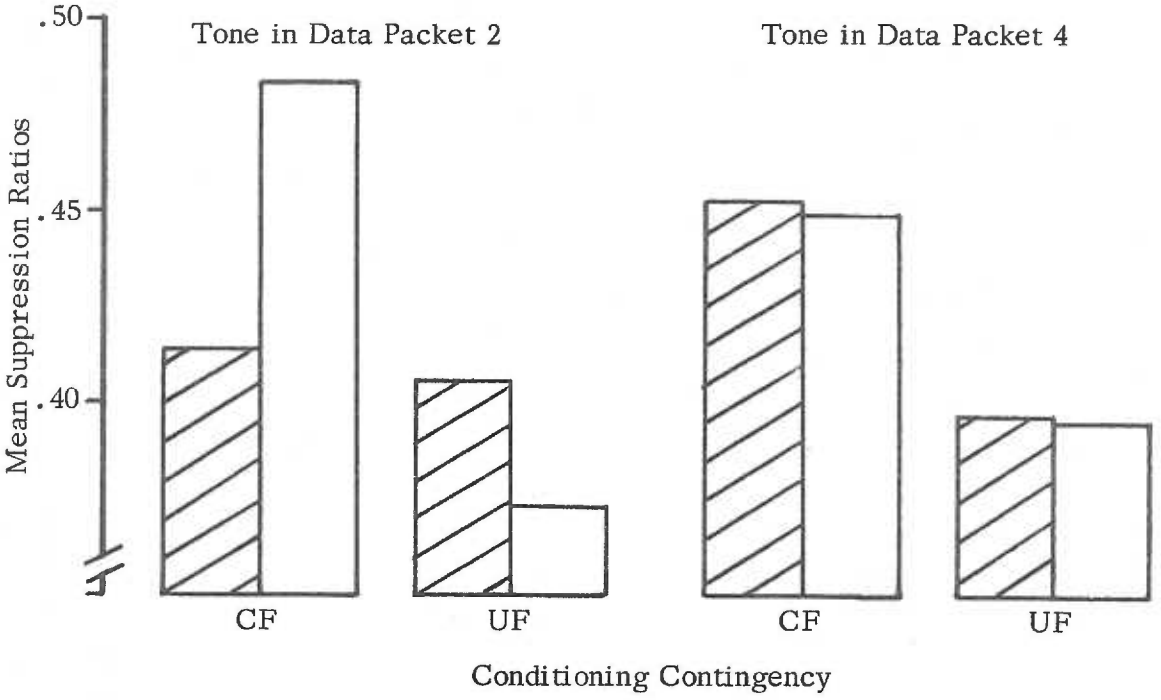

Figure 5. Suppression ratios for average standard deviations of barpress durations of 3% rats during FR Sequences 4 and 5 of sessions of testing for conditioned frustration. Shaded areas indicate ratios of rats that drank ethanol prior to these sessions; open areas ratios of those that drank sugar water.

any of the dependent measures, it did accentuate the impact of tone presentations on barpress behavior. An example is provided in Figure 6, where ratios based on FR durations are shown. The durations of nonreinforced sequences were greater than those of the fourth and fifth sequences, which were about equivalent to those of the first three sequences of these sessions. Tone presentations tended to increase the ratios, which means that rats slowed their rates of barpressing in the presence of tone.

Drug Shift Results

Ethanol was not shown to influence rate of extinction by the data from days of drug shift. Neither a main effect of ethanol nor any interaction with the other factors was significant in any of the analyses of these data. Nonreinforcement did influence all measures during this phase, with barpress rates slowing in nonreinforced sequences with concurrent increases in both barpress durations and interbarpress intervals, average standard deviations of barpress durations increasing somewhat, and the number of FR sequences completed per session decreasing over days.

Ancillary Information

Body Weights

Careful measurements were made daily of individual body weights. Medians for each rat were extracted every 5 days and subjected to analysis. The various experimental subgroups did not differ

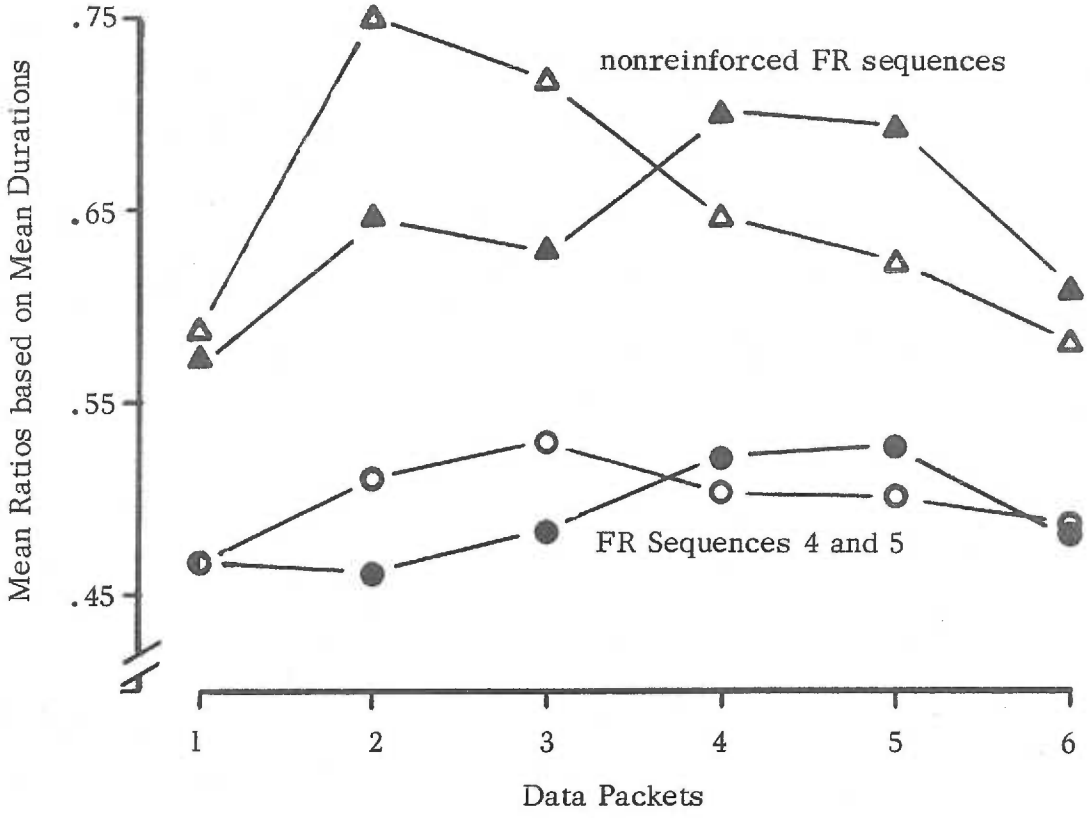

Figure 6. Ratios of suppression based on FR durations during tests for conditioned frustration. Open symbols indicate FR sequences with the tone in the second data packet; filled symbols indicate sequences with the tone in the fourth data packet. FR Sequences 4 and 5 are indicated by a ○; nonreinforced sequences are indicated by a △.

significantly during any phase of the experiment. The rats gained weight from the beginning of the experiment to the end of the FR training phase. They lost some weight (less than 3%) over the course of the conditioning and testing days.

Ethanol Dosing

The self-administered amounts of ethanol solutions were carefully monitored. On each day that a rat drank ethanol solution, a dose was calculated based on the body weight of that rat and the amount and strength of the solution consumed. The various experimental subgroups did not differ significantly with respect to dosing during any phase of the experiment, except that rats drinking the 3% solution consistently self-administered higher doses (about 1.6g/kg) than those drinking the 2% solution (about 1.1g/kg).

Blood Alcohol Analysis

Rats were sacrificed and plasma samples extracted at intervals after the start of the drinking periods on Oct 17-20. A variety of doses had been self-administered by the rats so that at each time interval there were several doses, and, presumably, correspondingly different blood levels. Regression lines based on doses and blood alcohol levels at each time interval were used to generate Figure 7, where hypothetical blood alcohol curves resulting from the mean doses of each of the ethanol solutions are shown.

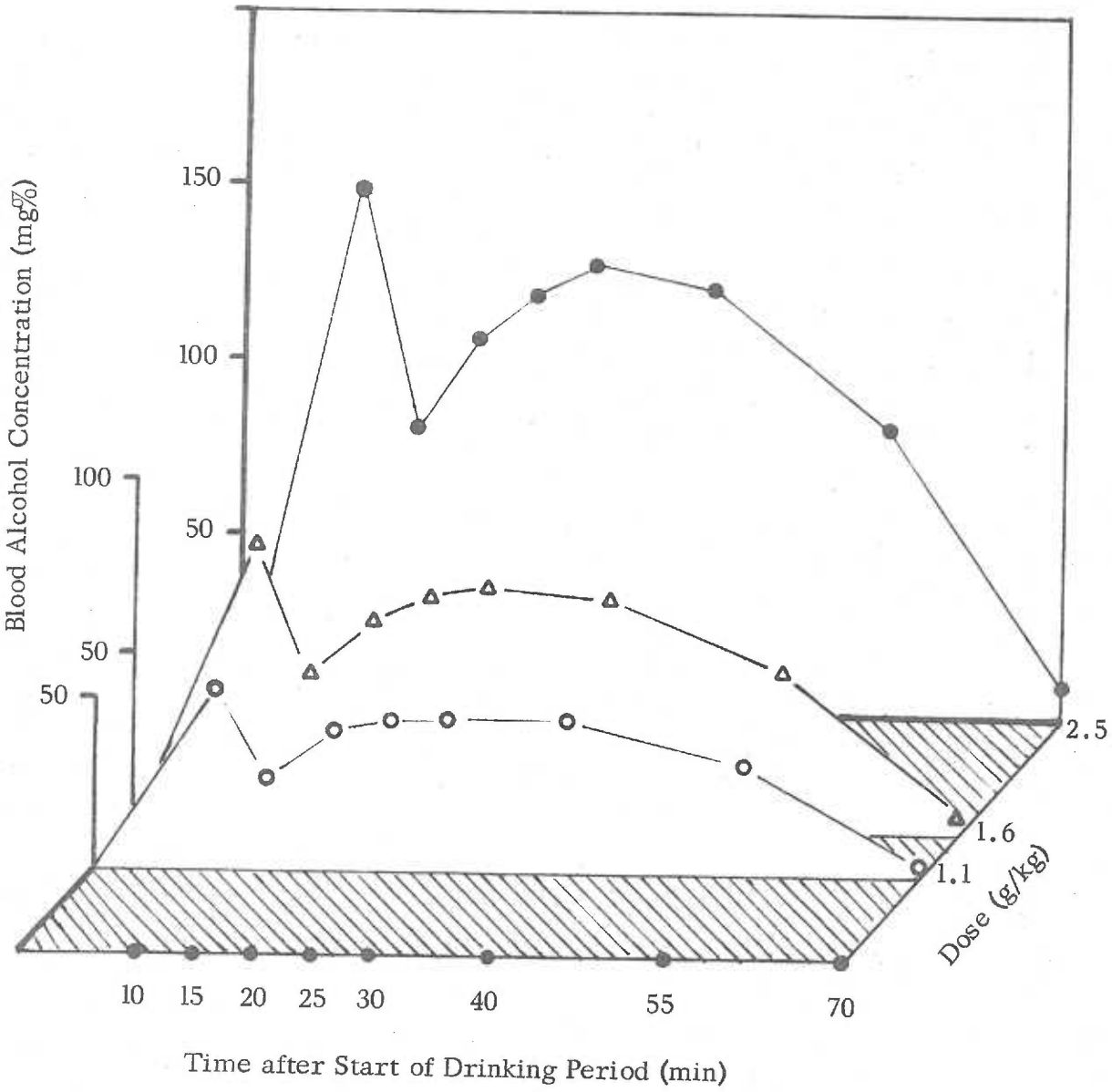

Figure 7. Blood alcohol concentrations as a function of self-administered doses (means) and time after the beginning of the drinking session. Filled circles describe the curve for a dose of 2.5 g/kg; triangles for a dose of 1.6 g/kg; open circles for a dose of 1.1 g/kg.

DISCUSSION

Fixed Ratio Training

Each of the rate measures increased with increasing fixed ratios through the FR training phase. The most interesting observation during this period was an effect of ethanol on barpress durations which was opposite ethanol's effect on the other two rate measures. That is, barpress durations were longer with ethanol than with sugar water, whereas FR durations and interbarpress intervals were shorter with ethanol than with sugar water (cf. Figure 2). Thus the relative contributions of interbarpress intervals and barpress durations were such that in spite of increased barpress durations, rates of barpressing were significantly faster with ethanol than with sugar water. When under the influence of ethanol, then, rats held the bar down longer each time they pressed it, but waited a shorter period of time between barpresses.

The effect of ethanol on barpress durations was limited to sessions early in the rats' history of exposure to alcohol, since ethanol was not shown to affect barpress durations during the refresher or test sessions later in the experiment. The effect could be attributed to motor impairment by alcohol which interfered with the coordination required for efficient barpressing. Indeed, the change in barpress durations over the course of FR training was more dramatic than any other change as

the rats became proficient barpressers (see Figure 1). It can reasonably be argued that slight motor impairment effects of alcohol are more likely to appear with a measure which is more susceptible to practice effects.

Alternatively, it has been suggested that in the early phase of runway training performance may be inhibited by fear of the unfamiliar situation (Logan, 1960, pp. 30-33). If a similar process were operative here, ethanol might reasonably be expected to elevate rates of barpressing by reducing such fear (cf. Barry et al. 1962). However, in order to explain the interaction of ethanol with fixed ratios for the interbarpress intervals, one would need to postulate more fear being alleviated by ethanol at the higher fixed ratios. Either more fear would be present, or alcohol would be more effective: Neither possibility seems likely. Further, it is by no means clear how ethanol would increase barpress durations by reducing fear.

A third alternative, especially attractive to a tension-reduction theorist, is that ethanol acted to reduce the frustration which is assumed to have been present during FR training. The fixed ratios can be regarded as partial reinforcement schedules, and one can assume that frustration plays the same role as in the partial reinforcement acquisition effect. Thus the increased durations of barpresses when ethanol was present can be attributed to alleviation of the frustration which would otherwise energize the responding and keep barpresses brief.

The shortening of interbarpress intervals by alcohol, however, is not so easily handled by this sort of frustration-reduction notion. Thus without extensive post hoc interpretations, no single approach seems to handle the results of the FR training phase.

Primary Frustration

The predominant outcome of the experiment was a frustration effect evidenced with each of four dependent measures. Frustration (i.e., nonreinforcement) increased rates of barpressing by shortening both barpress durations and interbarpress intervals. As barpress durations grew shorter with frustration, their variability within subjects also decreased.

With only one measure was ethanol shown to affect barpressing. Interbarpress intervals were shorter when ethanol was present than without it. This effect was in the same direction as that resulting from nonreinforcement. But in spite of main effects of both ethanol and nonreinforcement, the interaction between these two factors did not prove significant. The evidence available here thus fails to support the notion that ethanol mitigates primary frustration.

As mentioned earlier, variability within subjects, as measured by average standard deviations of barpress durations, was shown to decrease after nonreinforcement. Presumably, then, in the present experiment frustration acted to reduce variability of responding. This result is

opposite to that found by Boroczi and Nakamura (1964), where an increase in between-trials variability of responding was attributed to frustration. However, there are a number of differences between the two studies. Perhaps the most crucial is the fact that Boroczi and Nakamura (1964) were unable to show an effect of frustration on vigor of responding, which indicated that performance levels were near ceiling during their testing. In the present study, however, all measures were shown to be affected by the manipulation of nonreinforcement. Thus it would seem that variability of responding can be used to measure frustration effects, but further experimentation is needed to establish the limits of its utility.

Testing for Conditioned Frustration

Examination of the topography of responding within FR sequences was first possible during days of tesing for conditioned frustration. It is of interest that barpress durations increased in length during the terminal barpresses of FR sequences, whereas interbarpress intervals continued at asymptotic levels (cf. Figure 4). These results might be construed as contradicting an interpretation of anticipatory goal responses being the primary factor responsible for the decline in rates of barpressing at the end of FR sequences. This view is probably not tenable, however, because the physical characteristics of the operant chambers did not preclude approaches to the food cups while the bars were depressed.

Only meager evidence is available to suggest either an effect of conditioned frustration or some impact of ethanol thereon. Further research is obviously needed. Tone presentations did, however, markedly affect barpressing during these tests for conditioned frustration. The failure to obtain reliable differences between tone effects for rats that underwent conditioning sessions and those for which tones were unpaired with frustration can be attributed to two alternatives. The tone effects may reflect unconditioned responses to tone presentations. In that case, the conditioning procedures were unsuccessful. Alternatively, the tone effects may reflect conditioned responses for both paired and "unpaired" rats. In that case, the procedures for producing an unconditioned control group were unsuccessful. In either event, further refinement is required with respect to appropriate procedures for conditioning frustration. If the tone CS became an elicitor of conditioned frustration for both paired and unpaired groups, then ethanol failed to have an effect on conditioned frustration.

Dependent Measures

Throughout the course of the experiment several dependent measures were monitored. While the results presented from analyses of each of the measures were similar to those of the other measures, one measure seemed more sensitive to the experimental manipulations than the others. That measure, interbarpress intervals, was the only one to reveal an effect of ethanol during tests of primary frustration. Also, the tone effects

of the sessions of testing for conditioned frustration were more dramatically revealed with interbarpress intervals than with the other measures. Further, the impact of ethanol on interbarpress intervals was shown to increase across FR training and to remain in evidence during refresher sessions and primary frustration sessions, whereas ethanol no longer reliably affected either barpress durations or FR durations in the primary frustration phase. Thus the data from this experiment suggest that interbarpress intervals will serve as adequately as any of the other measures used here and may be more sensitive than the others for some of these manipulations.

Blood Alcohol Analysis

The hypothetical blood alcohol curves shown in Figure 7 show an initial peak at 10 min after the start of drinking sessions, and a later peak about 30 min after the start of drinking sessions. These curves may reflect the patterns of consumption during the 10-min drinking periods. When rats were first placed in the drinking chambers they tended to engage in a prolonged bout of drinking which lasted from 3 to 6 min. This initial drinking bout was followed by a period of time during which the rats retreated to the rear of the drinking cages and engaged in grooming and exploration. Then, shortly before the end of the drinking periods, the rats tended to return to the fluid tubes, engaging in a second bout of drinking. This second drinking bout usually terminated with the rat being removed from the drinking cage.

Presumably, then, the first rather sharp rise in blood alcohol levels reflects the rapid absorption and distribution of the initial dose of alcohol by a rat both food and fluid deprived for 22.5 hours. The second more gradual rise in blood alcohol levels may reflect the slower absorption of the second dose by a rat with high blood alcohol levels already. The consumption of food by the rats during the period of absorption of the second dose may also have affected the uptake of alcohol.

It is likely that absorption was not complete for rats sacrificed immediately upon termination of the drinking sessions. That is, for rats sacrificed at the 10 min interval, ethanol solutions may have been present in the stomach in significantly greater amounts than for rats sacrificed later. Thus it is possible that the peaks in the blood alcohol curves at this interval reflect simply the evacuation of liquid stomach contents into the blood samples which were collected.

SUMMARY AND CONCLUSIONS

Ethanol was shown to affect barpressing during fixed ratio training both by shortening interbarpress intervals and by lengthening barpress durations. Interbarpress intervals were shortened more by ethanol at high fixed ratios than at low fixed ratios. These effects of ethanol on interbarpress intervals and barpress durations combined such that alcohol increased rates of barpressing slightly. In addition, both interbarpress intervals and barpress durations decreased with increasing fixed ratios, so that rates of barpressing were greater at the larger fixed ratios than at smaller fixed ratios.

The effects of nonreinforcement were revealed with all dependent measures. Thus an effect of primary frustration was demonstrated with each measure. The most sensitive dependent measure proved to be interbarpress intervals: Ethanol was shown to shorten interbarpress intervals. However, the interaction of factors of ethanol and nonreinforcement was not significant, so alleviation of primary frustration by alcohol was not supported in this experiment.

Conditioned frustration was not successfully demonstrated. In spite of the lack of a difference between conditioned and nonconditioned rats, however, the tone CS did reliably alter behavior. Ethanol was not shown to affect barpressing during tests for conditioned frustration or to change the alterations in behavior produced via the tone CS.

REFERENCES

Amsel, A. The role of frustrative nonreward in noncontinuous reward situations. Psychological Bulletin, 1958, 55, 102-119.

Amsel, A. Frustrative nonreward in partial reinforcement and discrimination learning: Some recent history and a theoretical extension. Psychological Review, 1962, 69, 306-328.

Amsel, A., & Roussel, J. Motivational properties of frustration: I. Effect on a running response of the addition of frustration to the motivational complex. Journal of Experimental Psychology, 1952, 43, 363-368.

Barry, H., & Miller, N. E. Effects of drugs on approach-avoidance conflict tested repeatedly by means of a "telescope alley." Journal of Comparative and Physiological Psychology, 1962, 55, 201-210.

Barry, H., Wagner, A. R., & Miller, N. Effects of alcohol and amobarbital on performance inhibited by experimental extinction. Journal of Comparative and Physiological Psychology, 1962, 55, 464-468.

Blough, D. S. Technique for studying the effects of drugs on discrimination in the pigeon. Annals of the N.Y. Academy of Sciences, 1956, 65, 334-344.

Boroczi, G., & Nakamura, C. Y. Variability of responding as a measure of the effect of frustration. Journal of Abnormal and Social Psychology, 1964, 68, 342-345.

Bower, G. H. The influence of graded reductions in reward and prior frustrating events upon the magnitude of the frustration effect. Journal of Comparative and Physiological Psychology, 1962, 55, 582-587.

Brown, J. S., & Farber, I. E. Emotions conceptualized as intervening variables--With suggestions toward a theory of frustration. Psychological Bulletin, 1951, 48, 465-495.

Cappell, H. An evaluation of tension models of alcohol consumption. In R. J. Gibbins, Y. Israel, H. Kalant, R. E. Popham, W. Schmidt, & R. G. Smart (Eds.), Research advances in alcohol and drug problems (Vol. 2). New York: John Wiley & Sons, 1975.

Cappell, H., & Herman, C. P. Alcohol and tension reduction: A review. Quarterly Journal of Studies on Alcohol, 1972, 33, 33-64.

Carlson, J. G. Frustrative nonreinforcement of operant responding: Magnitude of reinforcement and response force effects. Psychonomic Science, 1968, 11, 307-308.

Cicala, G. A., & Hartley, D. L. Drugs and the learning and performance of fear. Journal of Comparative and Physiological Psychology, 1967, 64, 175-178.

Cohen, J. M. Drive level effects on the conditioning of frustration. Journal of Experimental Psychology, 1973, 98, 297-301.

Conger, J. J. The effects of alcohol on conflict behavior in the albino rat. Quarterly Journal of Studies on Alcohol, 1951, 12, 1-29.

Daly, H. B. Learning of a hurdle-jump response to escape cues paired with reduced reward or frustrative nonreward. Journal of Experimental Psychology, 1969, 79, 146-157. (a)

Daly, H. B. Is responding necessary for nonreward following reward to be frustrating? Journal of Experimental Psychology, 1969, 80, 186-197. (b)

Daly, H. B. Reinforcing properties of escape from frustration aroused in various learning situations. In G. H. Bower (Ed.), The psychology of learning and motivation: Advances in research and theory (Vol. 8). New York: Academic Press, 1974.

Daly, H. B., & McCroskery, J. H. Acquisition of a bar-press response to escape frustrative nonreward and reduced reward. Journal of Experimental Psychology, 1973, 98, 109-112.

Davenport, J. W., Flaherty, C. F., & Dryud, J. P. Temporal persistence of frustration effects in monkeys and rats. Psychomomic Science, 1966, 6, 411-412.

Davenport, J. W., & Thompson, C. I. The Amsel frustration effect in monkeys. Psychonomic Science, 1965, 3, 481-482.

Estes, W. K., & Skinner, B. F. Some quantitative properties of anxiety. Journal of Experimental Psychology, 1941, 29, 390-400.

Fellows, B. J. Chance stimulus sequences for discrimination tasks. Psychological Bulletin, 1967, 67, 87-92.

Freed, E. X. The effect of alcohol upon approach-avoidance conflict in the white rat. Quarterly Journal of Studies on Alcohol, 1967, 28, 236-254.

Freed, E. X. Effect of alcohol on conflict behaviors. Psychological Reports, 1968, 23, 151-159. (a)

Freed, E. X. Effect of self-intoxication upon approach-avoidance conflict in the rat. Quarterly Journal of Studies on Alcohol, 1968, 29, 323-329.

Freedman, P. E., & Rosen, A. J. The effects of psychotropic drugs on the double alley frustration effect. Psychopharmacologia, 1969, 15, 39-47.

Gellerman, L. W. Chance orders of alternating stimuli in visual discrimination experiments. Journal of Genetic Psychology, 1933, 42, 207-208.

Hamm, H., & Zimmerman, J. The "frustration effect" in operant studies: A necessary control procedure. Psychonomic Science, 1967, 9, 253-254.

Higgins, R. L. Experimental investigations of tension reduction models of alcoholism. In G. Goldstein & C. Neuringer (Eds.), Empirical studies of alcoholism. Cambridge, Mass.: Ballinger Publishing Company, 1976.

Hughes, L. R., & Dachowski, L. The role of reinforcement and nonreinforcement in an operant frustration effect. Animal Learning & Behavior, 1973, 1, 68-72.

Ison, J. R., Daly, H. B., & Glass, D. H. Amobarbital sodium and the effects of reward and nonreward in the Amsel double runway. Psychological Reports, 1967, 20, 491-496.

Ison, J. R., & Rosen, A. J. The effects of amobarbital sodium on differential instrumental conditioning and subsequent extinction. Psychopharmacologia, 1967, 10, 417-425.

Jensen, C., & Fallon, D. Behavioral aftereffects of reinforcement and its ommission as a function of reinforcement magnitude. Journal of Experimental Analysis of Behavior, 1973, 19, 459-468.

Lauener, H. Conditioned suppression in rats and the effect of pharmacological agents thereon. Psychopharmacologia, 1963, 4, 311-325.

Linton, M., & Gallo, P. S., Jr. The practical statistician. Belmont, California: Wadsworth Publishing Company, 1975.

Logan, F. A. Incentive: How the conditions of reinforcement affect the performance of rats. New Haven: Yale University Press, 1960.

Logan, F. A., & Wagner, A. R. Reward and punishment. Boston: Allyn and Bacon, 1965.

Longstreth, L. E. The relationship between expectations and frustrations in children. Child Development, 1960, 31, 667-671.

Marzocco, F. N. Frustration effect as a function of drive level, habit strength and distribution of trials during extinction. Unpublished doctoral dissertation, State University of Iowa, 1951.

Masserman, J. H., & Yum, K. S. An analysis of the influence of alcohol on experimental neuroses in cats. Psychosmatic Medicine, 1946, 8, 36-52.

Mello, N. K. Some aspects of the behavioral pharmacology of alcohol. In D. H. Efron, et al. (Eds.), Psychopharmacology: A review of Progress. Proceedings of the 6th Annual Meeting of the American College of Neuropsychopharmacology, U.S. Printing Office, Washington, D. C., 1968.

Miller, W. A. The fluorometric determination of ethyl alcohol in blood, serum, or other fluids. Palo Alto: Turner Associates, 1967. (Reprint No. 8978)

Nelson, P. B. The effects of alcohol upon frustrative nonreward produced aggression (Doctoral dissertation, Washington State University, 1967). Dissertation Abstracts, 1968, 28, 3476B. (University Microfilms No. 68-711)

Nelson, P. B., & Wollen, K. A. Effects of ethanol and partial reinforcement upon runway acquisition. Psychonomic Science, 1965, 3, 135-136.

Overton, D. A. State-dependent learning produced by alcohol and its relevance to alcoholism. In B. Kissen & H. Begleiter (Eds.), The biology of alcoholism: Vol II: Physiology and behavior. New York: Plenum, 1972.

Penney, R. K. The effects of non-reinforcement on response strength as a function of number of previous reinforcements. Canadian Journal of Psychology, 1960, 14, 204-215.

Platt, J. R. Discrete trials and their relation to free-behavior situations. In H. H. Kendler & J. T. Spence (Eds), Essays in neo-behaviorism. New York: Appleton-Century-Crofts, 1971.

Platt, J. R., & Senkowski, P. C. Effects of discrete-trials reinforcement frequency and changes in reinforcement frequency on preceding and subsequent fixed-ratio performance. Journal of Experimental Psychology, 1970, 85, 95-104.

Quirt, B. M., & Cohen, J. S. Frustration effect in a free operant situation for albino rats. Psychological Reports, 1975, 36, 999-1006.

Senkowski, P. C. Temporal aftereffects of reward and nonreward in an operant analogue of the double-runway. Journal of Experimental Psychology, 1973, 101, 348-359.

Senkowski, P. C., & Vogel, V. A. Effects of number of CS-US pairings on the strength of conditioned frustration in rats. Animal Learning & Behavior, 1976, 4, 421-426.

Smart, R. G. Effects of alcohol on conflict and avoidance behavior. Quarterly Journal of Studies on Alcohol, 1965, 26, 187-205.

Spence, K. W. Behavior theory and conditioning. New Haven: Yale University Press, 1956.

Spence, K. W. Behavior theory and learning. Englewood Cliffs, N.J.: Prentice-Hall, 1960.

Staddon, J. E., & Innes, N. K. An effect analogous to "frustration" on interval reinforcement schedules. Psychonomic Science, 1966, 4, 287-288.

Taylor, A., Lehr, R., Berger, D. F., & Terry, C. A. Effects of alcohol on the partial reinforcement effect. Psychonomic Science, 1968, 11, 371-372.

Wagner, A. R. The role of reinforcement and nonreinforcement in an "apparent frustration effect." Journal of Experimental Psychology, 1959, 57, 130-136.

Wagner, A. R. Conditioned frustration as a learned drive. Journal of Experimental Psychology, 1963, 66, 142-148.

Wagner, A. R. Frustration and Punishment. In R. N. Haber (Ed.), Current research in motivation. New York: Holt, Rinehart and Winston, 1966.

Wookey, P. E., & Strongman, K. T. Emotional and instrumental effects of reward shift. Psychological Record, 1971, 21, 181-189.

Zaslov, M. R., & Porter, J. J. The effects of reinforcement frequency on performance in a multiple fixed-ratio schedule. Animal Learning & Behavior, 1974, 2, 54-58.

APPENDIX A

Additional Details Pertaining to Experimental Procedures

Adaptation to Deprivation

The first step of the experiment was to institute a deprivation schedule which ultimately involved 10 min of access to fluid before daily barpress sessions and 60 min of access to food and water after daily barpress sessions. Adaptation to this deprivation schedule occurred in successive stages over a 7-day period from Apr 27 through May 3. First, beginning at 1645 h on Apr 27, rats were food deprived for 17 h while water was available ad libitum. Food and water were then available ad libitum for about 9 h on Apr 28. During the final 2 h of ad-lib food and water, rats were assigned subject numbers, tails were marked with colored Sharpie marking pens according to a modified binary color code, and each rat was weighed. After being deprived of both food and water for 16 h beginning at 1830 h on Apr 28, rats were allowed 4 h access to food and water from 1030 to 1430 h on Apr 29. During the final 2 h of this period the rats were randomly assigned to 4-rat squads numbered 1 through 20 and housed one squad per cage in gang cages.

The next deprivation of food and water lasted at least 17 h and terminated with 2 h access to food and water on Apr 30. After being weighed, 12 rats (three squads) were fed during each of seven overlapping 2 h eating sessions which began at 0800 h and hourly thereafter. These eating sessions took place in the home cages, but the food was placed inside the cages rather than in feeders mounted against the wire mesh cage fronts as had previously been the case. The following day, May 1, feeding sessions lasted 60 min, beginning at 0700 h and every 30 min

thereafter, with one squad eating during each 60-min feeding session. Just prior to these 60-min feeding sessions each rat was weighed and each squad was placed in a "feeding cage" similar to its home cage. The food, however, was again placed on the floor of the cage, rather than held against the wire mesh of the cage front. Two water bottles were mounted against the cage front, with the sipper tubes extending through the mesh into the cage. When the 60-min feeding sessions ended, rats were replaced in their home cages (one squad per cage). Thus between 0700 and 1700 h each squad had 60 min of access to food and water in a feeding cage similar to the home cages. This procedure was followed for 3 days.

Barpress Shaping

The next day, May 4, included 10 min of fluid access and 20 min in an operant chamber for each rat, as well as 60-min feeding sessions. At 0600 h the rats of Squad 1 (SQ1) were given 10 min of access to water in a cage similar to the home cage. The water was available from two bottles mounted so that the sipper tubes extended through the cage front. This drinking period was followed by a 20-min exposure to the four operant chambers, one rat being placed in each chamber. During the 20 min in the operant chambers wet mash was present on the bar, any barpresses made were reinforced, and every 2 min a food pellet was delivered automatically. Immediately after this exposure to the operant chambers, SQ1 was given 60 min of access to food and water in a feeding cage, then returned to its home cage. After SQ1 was placed in a feeding cage, SQ2

was weighed and began its 10-min drinking period. Then SQ2 was placed in the operant chambers for 20 min, followed by 60 min in a feeding cage. This routine continued throughout the day, so that by 1900 h all rats had had 10 min of access to water, 20 min in an operant chamber, and 60 min of ad-lib food and water.

On May 5 a similar schedule was followed, except that the drinking sessions took place in individual cages, one rat per cage. Measured amounts of water were placed in Nalgene test tubes with one-hole rubber stoppers and straight stainless steel sipper tubes. The test tubes were placed so that the sipper tubes extended through the cage fronts at an angle of about 45° from horizontal. During the barpress sessions the experimenter spent about 5 min individually shaping the barpress response of each rat. These 20-min shaping sessions occurred daily until each rat emitted 40 barpresses during a session.

All rats were exposed to all four operant chambers over the course of barpress shaping sessions. On May 4 the rats were placed in the four operant chambers in accordance with their ordinal position within the squad. That is, the rat with the lowest subject number was placed in the first operant chamber, the rat with the next highest subject number in the second operant chamber, etc. On May 5 each rat was rotated to the next chamber, so that the rat with the lowest subject number went into the second chamber, and so forth. In this manner a rat was placed each day in the next operant chamber, shifting from the fourth chamber to the first to begin the sequence again. This rotation through the operant chambers continued throughout the experiment.

As rats met the 40-barpress criterion for the barpress shaping phase, they were no longer placed in the operant chambers during shaping sessions. Instead, those rats which had met criterion were returned to their home cages after the drinking periods, remaining there while the rest of the squad underwent shaping. All squad members began feeding sessions simultaneously in a single feeding cage upon completion of the 20-min barpress shaping sessions for rats which had not yet met criterion. In cases where an entire squad had met criterion, that squad was moved directly from the drinking cages to the feeding cage upon completion of the drinking period.

By May 13 only 15 rats had not met the barpress shaping criterion. Of those 15, four showed evidence of fear while in the operant chambers. They crouched in one corner of the chamber, defecated frequently during the 20-min shaping sessions, emitted startle responses when the feeder clicked, and did not approach the feeder cup or bar. In an effort to reduce the apparent fear of the four rats, the shaping session on May 13 involved placing another rat in the operant chamber with the fearful rat. The first rat to have met the barpress shaping criterion from the squad of the fearful rat was selected as the "companion" rat. The "companion" rat was placed in the operant chamber with the fearful rat at the beginning of the session and remained there throughout the session. In all four cases the "companion" rat engaged in much barpressing and both rats ate the pellets which resulted from the FR1 schedule. On the next day, May 14, and during the rest of the experiment, rats were placed alone in the operant chambers. This single session for each of four rats on

May 13 was the only occasion when more than one rat was in a single operant chamber at a given time. During barpress sessions subsequent to the May 13 "therapy" session, the behavior of the four previously fearful rats was amenable to shaping, which involved one 20-min session per day on May 14 and 15.

On May 16 the seven rats which had not yet met criterion were subjected to three 20-min shaping sessions. The first two sessions occurred consecutively, beginning at the end of the drinking period; squadmates which had met the criterion were returned to the home cage for 20 min, then placed in a feeding cage. After 40 min of shaping (two consecutive 20-min sessions), each of the seven rats joined its squadmates in the feeding cage for 10 min, then the third shaping session ensued. After the third 20-min shaping session the rat was again placed in the feeding cage with its squadmates. All four rats were moved to the home cage when the hour of ad-lib eating and drinking had expired for the three rats which previously had met criterion and thus no longer underwent barpress shaping. As on previous days, those squads in which no rat underwent shaping were moved from the drinking cages directly to a feeding cage.

On days subsequent to May 16 only two barpress shaping sessions occurred each day for each rat. The consecutive 20-min sessions were followed by ad-lib access to food and water with the squad in a feeding cage for about 40 min. As previously, the other three squad members began the feeding session after 20 min in the home cage (which followed the drinking period). For all of the days on which more than one

barpress shaping session occurred for these rats, more than ten barpresses by a rat during a session terminated shaping for that day, and the other sessions scheduled for that day did not occur. Rats which produced more than ten barpresses in a single session usually pressed more than 40 times during the next day's session, thus meeting criterion. If a rat pressed more than 40 times during the first session on these days of two barpress shaping sessions, it was considered to have met criterion and was placed in the feeding cage with its squadmates.

Assignments to Experimental Subgroups

Drinking solutions. Each rat was assigned to an ethanol concentration and a drinking schedule on the basis of its body weight on the final day of barpress shaping, May 23. The rats of each squad were rank-ordered according to weights on that day. Rats ranked first and third from even-numbered squads (SQ2, SQ4, SQ6, etc.) were assigned to the ESSE schedule while rats ranked second and fourth were assigned to the SEES schedule. With odd-numbered squads (SQ1, SQ3, SQ5, etc.), rats ranked first and third were assigned SEES while rats ranked second and fourth were assigned ESSE. In cases of identical weights a coin toss determined the schedule assignment. In addition, half the rats on each of the two counterbalanced schedules drank 2% ethanol; the other half drank 5% ethanol. In the even-numbered squads the two heaviest rats were assigned 5% ethanol, in the odd-numbered squads the two lightest rats were assigned 5% ethanol, and the remaining rats were assigned 2% ethanol.

Conditioning contingency, tone presentation schedule, and fluid consumed before conditioned frustration testing. The four groups determined by assignment of drinking solution and schedule were further subdivided on the basis of overall barpress performances on the final 4 days of refresher sessions (Sep 25-28). The average number of FR30 sequences completed on those 4 days was computed for each rat, and a rank assigned within each of the four groups (2% SEES, 2% ESSE, 5% SEES, 5% ESSE). In cases of equal averages, average session duration over the 4 days was used to assign ranks. These ranks were then used to assign rats to the appropriate subgroups: conditioned or unconditioned frustration, tone schedule A or B, and EtOH or SW prior to conditioned frustration test sessions. Reference to Table A1 may be helpful for understanding this assignment procedure. In Table A1 the rat identification numbers are followed by the rank of each rat for barpressing on the final 4 days of refresher sessions. Evenly ranked rats (second, fourth, sixth, etc.) from SEES groups and oddly ranked rats (first, third, fifth, etc.) from ESSE groups were assigned to the unpaired contingency for conditioning sessions; oddly ranked rats from SEES groups and evenly ranked rats from ESSE groups were assigned to the conditioned frustration subgroup. An ABBA schedule (counterbalanced) was used for assigning rats to EtOH or SW. Thus, SEES rats ranked 1, 4, 6, 7, 10, 11, 13, and 16 were given EtOH before conditioned frustration test sessions along with ESSE rats ranked 2, 3, 5, 8, 9, 12, 14, and 15. The remaining rats were given sugar water before test sessions. During testing for conditioned

Table A1

Assignments of Rats to Experimental Conditions

Conditioning contingency	Fluid drunk	Tone schedule	SEES		ESSE	
			2% Animals			
paired	EtOH	A	#33:1	#66:13	#47:2	#69:12
		B	# 1:7	#36:11	# 9:8	#58:14
	SW	A	#28:3	#11: 9	#51.6	#32:16
		B	#79:5	#30:15	#78:4	#57:10
unpaired	EtOH	A	#29:4	#45:10	#65:5	# 6:15
		B	#68:6	#73:16	#77:3	#56: 9
	SW	A	#41:8	#55:14	#21:7	# 3:11
		B	#20:2	#61:12	#67:1	#31:13
			3% Animals			
paired	EtOH	A	#35:1	#43:13	#34:2	#15:12
		B	#39:7	#24:11	# 8:8	#26:14
	SW	A	#74:3	#10: 9	# 7:6	#59:16
		B	#22:5	#23:15	#49:4	#60:10
unpaired	EtOH	A	# 2:4	#71:10	#18:5	#63:15
		B	#76:6	#25:16	# 4:3	# 5: 9
	SW	A	#70:8	#14:14	#52:7	#50:11
		B	#13:2	#37:12	#62:1	#19:13

Note. Identification numbers are followed by ranks (#ID:rank).

frustration the tone was initiated by the 6th or 16th barpress of the FR30 sequences according to the following schedule:

6, 16, 16, 6, 6, 6, 16, 16, 16, 6, 6, 16.

This schedule is taken from Fellows (1967), and its use in the present study equates the two tone positions for single and double alteration effects. A Gellerman (1933) sequence was used to assign half the rats to Schedule A: rats ranked 1, 3, 4, 8, 9, 10, 13, and 14 from SEES groups and those ranked 2, 5, 6, 7, 11, 12, 15, and 16 from ESSE groups. In Schedule A tone presentations were ordered by following the Fellows (1967) schedule first from left to right, then from right to left, then from left to right, etc. For the remaining rats, tone presentations occurred according to Schedule B (first from right to left, then from left to right, etc.).

Drug shift tests. Drug conditions were shifted for half the rats for two final days of extinction testing. Rats within each of the conditioned frustration test conditions were rank-ordered according to total number of FR30 barpress sequences completed during the last 2 days of testing for conditioned frustration. In the 2%-UF and 3%-UF conditions, rats ranked 1, 4, 6, and 7 were switched to sugar water for the additional 2 days of testing. In the 2%-CF and 3%-CF conditions rats ranked 2, 3, 5, and 8 were switched to sugar water. Similarly, SW-UF rats ranked 1, 4, 6, and 7 and SW-CF rats ranked 2, 3, 5, and 8 were switched to the ethanol concentration they had previously consumed.

Blood Ethanol Analyses

After the final day of extinction the rats were maintained on the 22.5 h deprivation schedule until they could be sacrificed for blood ethanol analyses. For several days the rats were offered fluid for 10 min in the drinking cages, then moved directly to the feeding cages for 1 h of ad-lib food and water. The counterbalanced SEES schedule previously used had been disrupted by assignments to particular fluids for testing sessions. During the few days between the end of testing and sacrificing the rats, the fluids available during the 10-min drinking periods were alternated so that no rat drank the same fluid on more than 3 consecutive days. On Oct 13 the rats were offered tap water for 10 min prior to the 1 h of ad-lib food and water. On Oct 14 they were offered the alternate solution to the one they had drunk on Oct 11 and 12. On Oct 15 the rats were offered the same solution as they had drunk on Oct 11 and 12. On Oct 16 all of the rats were offered sugar water for the 10-min drinking periods. On Oct 17 the first 13 squads were offered sugar water. The remaining 12 rats (Squads 14, 15, & 16) were offered the appropriate ethanol solutions, then decapitated at preset intervals following the start of the drinking periods. All rats were offered the appropriate ethanol solutions on Oct 18. On Oct 19, SQ1-SQ8 were offered sugar water. The remaining rats, SQ9-SQ13, were offered the appropriate ethanol solutions, decapitated at preset intervals after the start of the drinking period, and drained of blood. On Oct 20 the remaining rats drank ethanol and were sacrificed in like fashion.

Blood samples were taken by draining the bodies into disposable polystyrene centrifuge tubes with the aid of disposable polystyrene funnels. The samples were immediately placed on ice, and centrifuged as quickly as possible (within 5-10 min) at 3000 rpm. During and after centrifuging, the samples were refrigerated. Within 4 h the plasma samples were pipetted from the centrifuge tubes to glass curvettes with cork stoppers. The plasma samples were then frozen.

Dependent Measures

Three events were timed during the experiment, and those durations were punched automatically by the computer on paper tape. The duration of each FR sequence, from onset of the first barpress to onset of the final barpress, was recorded for each rat in units of 1/10 sec. Also, the durations of the individual barpresses were measured, squared, and summed. Upon completion of each FR sequence both the sum of the barpress durations (in units of 1/50 sec) and the sum of the squared durations for that sequence was punched on paper tape. Finally, a similar procedure occurred for the intervals between barpresses. Beginning with offset of the final barpress of the preceding sequence, the interval between offset of one barpress and onset of the next barpress was measured, squared, and summed. Upon completion of each FR sequence (offset of the final barpress) both the sum of the interval duration (in units of 1/50 sec) and the sum of the squared interval durations were punched on paper tape. A single data packet thus consisted of the rat ID number, the FR time (FRT), the sum of the barpress durations (BPT), the sum of the squared barpress

durations, the sum of the interbarpress intervals (IBI), and the sum of the squared interbarpress intervals. The rats averaged approximately 35 FR sequences each day, so that for each rat about 175 observations were punched each day.

Beginning with the extinction phase, on Oct 7, the dependent measures were recorded for every five barpresses. All rats were barpressing at FR30, so that for each FR sequence six data packets were punched instead of one as had previously been the case. Each data packet now consisted of the duration from onset of the first barpress of a five-unit segment of a FR30 sequence to onset of the first barpress of the next segment, a BPT for five barpresses, the sum of five squared barpress durations, the sum of the intervals between the barpresses, and the sum of the squared interval durations. In the last of these six data packets, the information was punched by the computer upon offset of the final barpress of the FR30 sequence. In this case only four IBIs were summed, and the FRT was from onset of the 26th barpress to offset of the 30th barpress. Dividing a FR30 sequence in this manner allowed computation of a FR rate for the sequence by summing the FR durations for individual packets. In addition, the measures during testing sessions were not confounded by the activities, or lack thereof, of the rats during the pauses between FR sequences.

APPENDIX B

Blood Ethanol Assay Procedure

A fluorometric procedure was used for an enzymatic determination of the concentration of ethyl alcohol in the plasma samples. This procedure was taken from Miller (1976), with slight modifications. The assay depends upon the completion of the following reaction:

$$\text{EtOH} + \text{B-DPN} \xrightarrow[\text{semicarbazide}]{\text{ADH}} \text{acetaldehyde} + \text{B-DPNH}.$$

The enzyme alcohol dehydrogenase (ADH) catalyses the reduction of B-DPNH with the formation of acetaldehyde from ethyl alcohol. The semicarbazide in the pyrophosphate buffer reacts with the acetaldehyde as it is formed, preventing the reverse reaction. The reduction of B-DPN to B-DPNH is coupled to the formation of acetaldehyde from ethyl alcohol, so that the amount of B-DPNH present in a sample after completion of the reactions is an accurate measure of the ethyl alcohol that was present in the plasma. The amount of B-DPNH present can be determined by using the natural flourescence of B-DPNH when activated at 340 micron.

About three months after the plasma samples were frozen the blood ethanol analyses began. On each of the days during which these analyses were conducted, some of the plasma samples (usually 16) were allowed to thaw while disposable polystyrene reaction beakers were prepared with 100 µl of buffered DPN-ADH. Enough reaction cups were prepared to allow three separate fluorometric determinations for each plasma sample, each alcohol standard, and the blank. On each day of these analyses a blank was prepared along with four alcohol standards: 40, 80, 120, and 160 mg%. One 25 µl portion of each plasma sample was added to a 1.0 ml aliquot of 2% perchloric acid. Similarly, one 25 µl portion of each alcohol standard

and of deionized water (the blank) was diluted in 1.0 ml of 2% perchloric acid. These test solutions were mixed in glass tubes, and from them three 10 µl samples were pipetted into the reaction beakers with 100 µl of buffered DPN-ADH. The reaction beakers were then left to stand for an hour, which allowed sufficient time for the reactions to run to completion. After the blanks, standards, and samples had reacted for an hour, 100 µl was withdrawn from each reaction beaker and added to 4.0 ml of deionized water in a disposable polystyrene test tube, mixed, and poured into a fluorometer cuvette. Fluorometer readings were determined 15-20 min after the cuvettes were filled.

APPENDIX C

Data Analyses and the Results Thereof

Fixed Ratio Training Data

During the course of FR training, rats progressed to larger fixed ratios at a rate determined by individual performances. Because of the details of this procedure not all rats performed on every fixed ratio between 1 and 30. In addition, individual rats did not necessarily perform after drinking ethanol solution on the same ratios as after drinking sugar water. For each rat a mean barpress rate was calculated for each FR and drug condition with which that rat had experience. This average rate weighted equally each FR sequence which a rat had completed at any given FR and drug condition. Then the ratios from 5 through 29 were segregated into five groups, and the mean barpress rates for each rat under ethanol were averaged for all FRs within each group, as were the rates for sugar water for FRs within each group. Thus, means of mean rates were calculated for each rat under ethanol and sugar water for FRs 5-9, 10-14, 15-19, 20-24, and 25-29. Finally, mean rates for ethanol and sugar water were computed for the 4 days of barpressing at FR30, the last days of the FR training phase. Ideally, after these averaging and collapsing procedures, 768 mean FR rates (FRRs) would have been available for analysis (for each of 64 rats, six mean rates after SW & six after EtOH). However, for a few subjects one or two data points were still missing. Estimates were derived for these data points from adjacent data points. For example, no mean rate was available for Rat #6 in the FR range 10-14 w/SW. The rates for Rat #6 w/SW for FRs 5-9 and 15-19 were averaged; that average rate was used in subsequent analyses for

FRs 10-14 after SW consumption. In cases where the missing mean rate was in the range of FRs 5-9, the mean rate from FRs 10-14 (appropriate drug condition) was used. A total of 18 mean FR rates were estimated in this fashion.

The 768 mean rates were subjected to a four way analysis of variance with two between subjects factors (EtOH strength: 2% or 3%, and future conditioning contingency: CF or UF) and two within subjects factors (fluid consumed: EtOH or SW, and FR blocks: 6 levels). The significant results from that analysis are shown in Table C1 and illustrated in Figure C1. The main effect of fluid consumed is reflected in consistently faster barpressing after rats drank EtOH than after they drank SW. The main effect of FR blocks is owing to a nearly linear, non-horizontal, relationship between FR rate and FR (r^2 = .98). The coefficient of determination was computed using overall mean barpress rates at the mid-points of each FR range.

Similar analyses were computed for the reciprocals calculated from barpress durations and interbarpress intervals. Average durations were calculated for each rat after consumption of each fluid for every FR at which that rat performed. These mean durations were averaged across FRs within the six FR blocks from FR5 through FR30. Where means of means were not available, estimates were calculated in the same manner as for FR rates. Reciprocals were computed for these means of means, and these barpress reciprocals (BPRs) and interbarpress interval reciprocals (IBRs) were subjected to four way analyses of variance. Significant results are set forth in Table C1, and shown in Figures C2 and C3. Ethanol decreased

Table C1

Significant Results of FR Training Phase
Four Way Analyses of Variance[a]

Measure	Source	F	df	p <
FRR[b]	Fluid consumed	34.54	1,60	.001
	FR blocks	351.07	5,300	.001
BPR[c]	Fluid consumed	16.53	1,60	.001
	FR blocks	212.03	5,300	.001
IBR[d]	Fluid consumed	69.66	1,60	.001
	FR blocks	269.46	5,300	.001
	Fluid x FR blocks	4.08	5,300	.005
Number	Fluid consumed	50.07	1,60	.001
of	FR blocks	25.51	5,300	.001
Sequences	Fluid x strength	7.09	1,60	.01
	Fluid x FR blocks	3.09	5,300	.01

[a]Between factors: EtOH strength (2% or 3%), Conditioning contingency (CF or UF); within factors: fluid consumed (SW or EtOH), FR blocks (5-9. 10-14, 15-19, 20-24, 25-29, and 30).

[b]FRR: Fixed ratio rate (rate of barpressing)

[c]BPR: Barpress duration reciprocal

[d]IBR: Interbarpress interval reciprocal

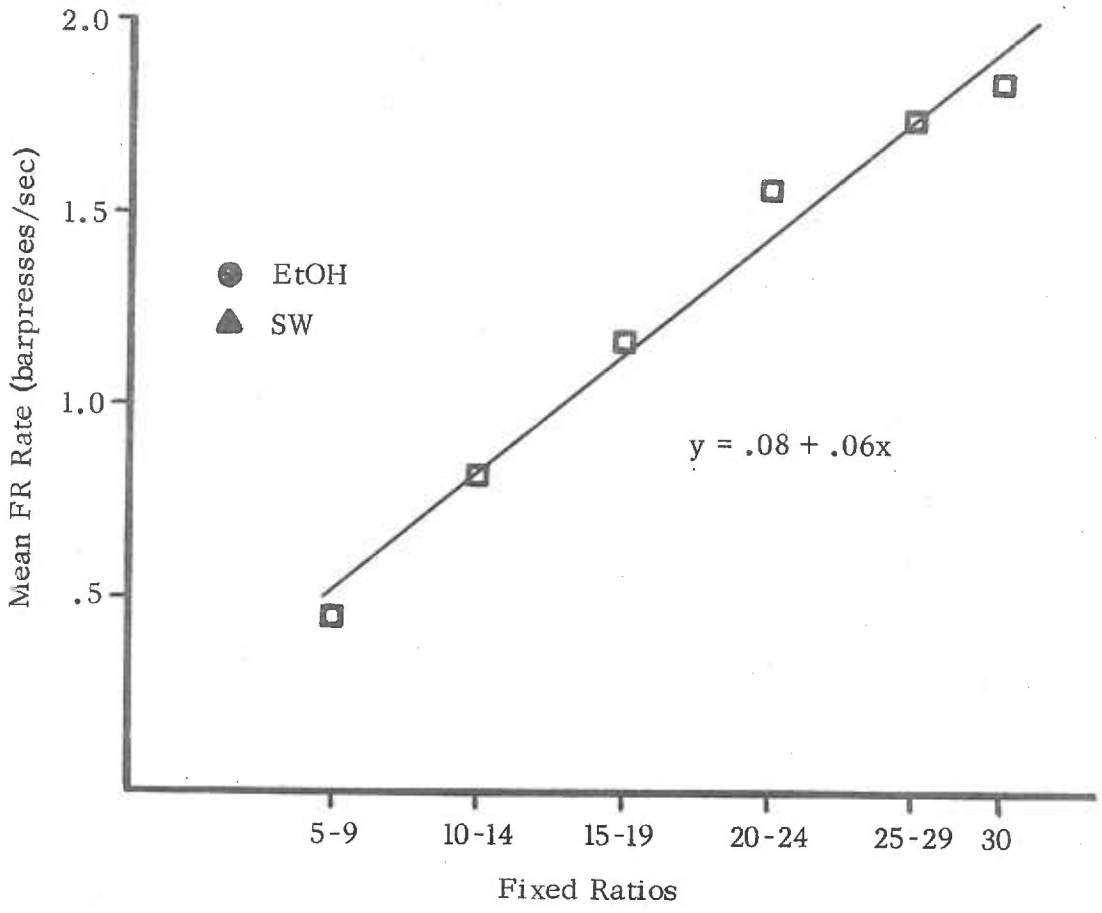

Figure C1. The relationship between rate of barpressing and FR length during FR training. Isolated points at the left indicate average rates after ethanol and sugar water consumption.

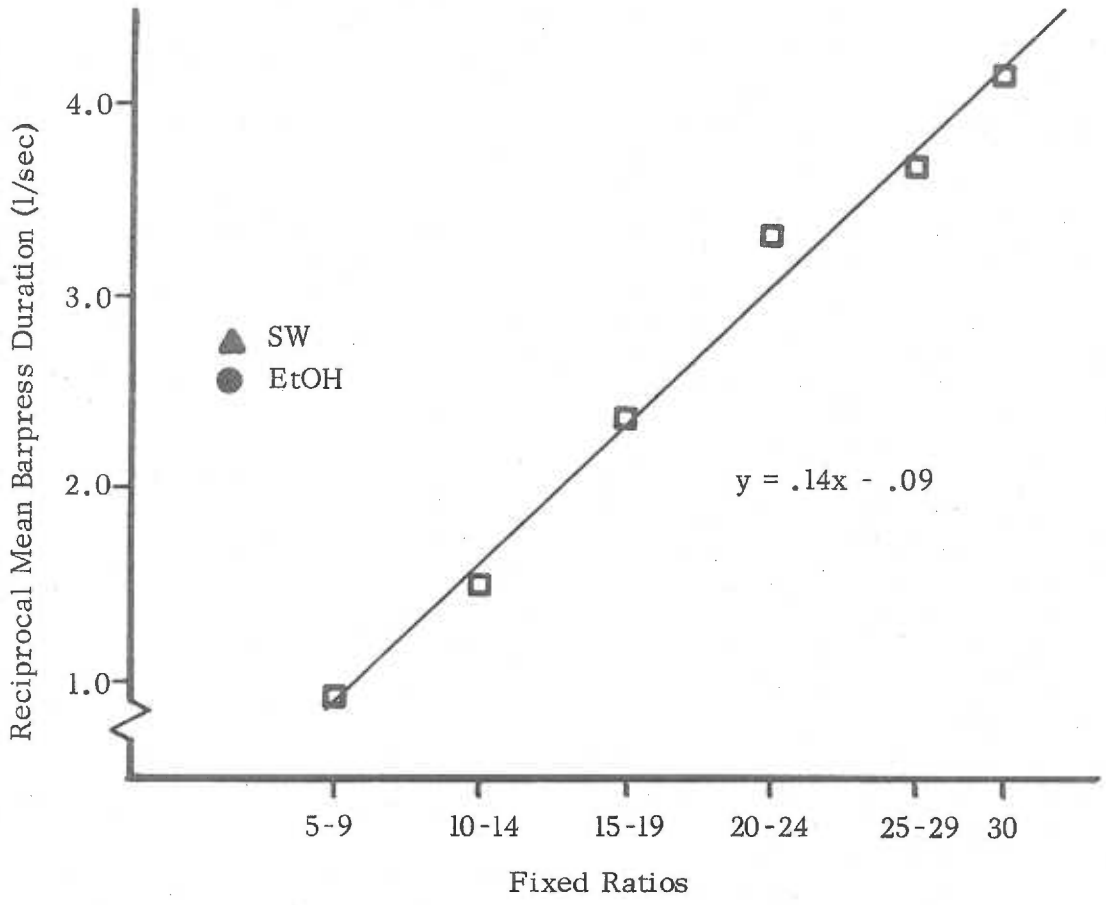

Figure C2. FR length related to reciprocals of mean barpress durations during FR training. Isolated points at left indicate average barpress speeds after ethanol and sugar water consumption.

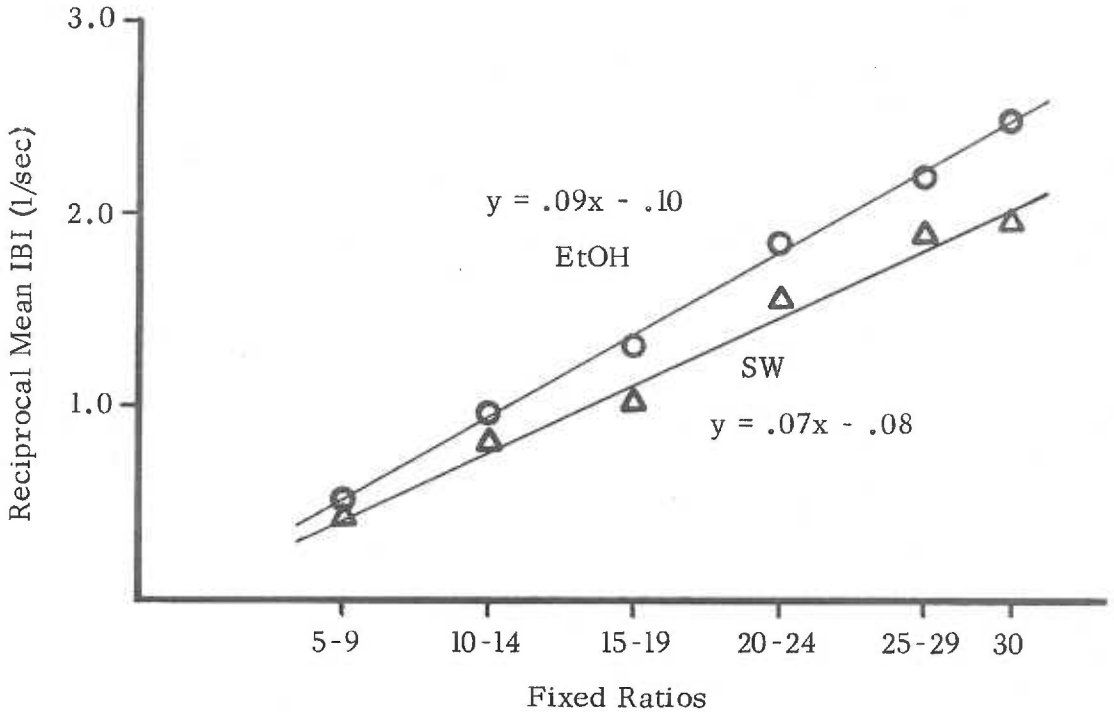

Figure C3. Ethanol shortens interbarpress intervals more with increasing FR length.

barpress reciprocals, while barpress reciprocals increased with increasing FR length (r^2 = .99, again calculated with overall mean rates at the midpoints of each FR range). The analysis of IBRs revealed that the intervals shortened both after EtOH consumption and with increasing FR length. In addition, intervals shortened more with increasing FR length after rats drank EtOH (r^2 = 1.0) than after rats drank SW (r^2 = .99).

The same averaging and collapsing techniques were used to derive mean number of FR sequences completed per session for each rat in each FR range after both SW and EtOH consumption. These data were then subjected to a four way analysis of variance with the same factors as for the rate measures. The significant results are included in Table C1 and displayed in Figure C4. After drinking EtOH, rats completed more FR sequences per session than after SW. The number of sequences per session increased with FR length (and with days, since FR lengths were increased across days), and increased more with EtOH than with SW. As can be seen from the isolated points at the left of Figure C4, rats assigned to 3% EtOH differed more after EtOH and SW than did rats assigned to 2% EtOH.

Refresher Sessions

A FR30 was in effect throughout the refresher sessions on Sep 21-28 and Oct 3-4. Data from these sessions were averaged for each day for each rat, and subjected to four way analyses of variance with two between subjects factors (EtOH strength: 2% or 3%, and future conditioning contingency: CF or UF) and two within subjects factors (fluid consumed: EtOH or SW, and sessions: 5 levels).

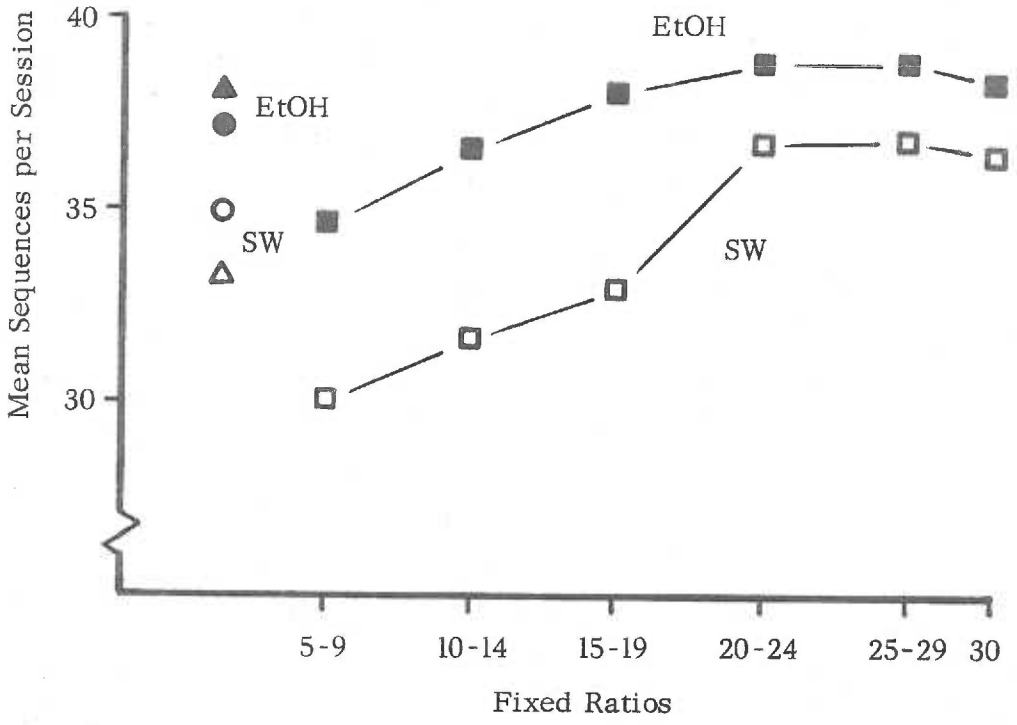

Figure C4. Mean number of FR sequences completed per session during FR training. Filled symbols indicate performances with ethanol and open symbols indicate performances without ethanol. The isolated points at the left indicate performances of rats assigned to 2% (O) and 3% (Δ) ethanol solutions.

An average rate of barpressing for each rat each day was calculated by dividing 30 (# of barpresses/sequence) by the average FR duration for that rat and day. The significant results of the four way analysis are listed in Table C2 and shown in Figure C5. Rates of barpressing increased during this phase, returning by the end of refresher sessions to about the rate observed at FR30 during FR training (about 1.75 barpresses/sec). Rats continued to barpress faster after drinking EtOH than after SW.

Average barpress durations were computed for each rat each day, and reciprocals of those means were used in the four way analysis. Table C2 contains pertinent information about the significant result, which is portrayed in Figure C6. Duration of barpresses decreased over the course of refresher sessions. A similar finding was significant for IBRs (Table C2, Figure C7). In addition, IBRs differed more under EtOH and SW for rats drinking 3% EtOH than for rats drinking 2% EtOH.

The numbers of FR sequences completed each day by each rat were used as data for a four way analysis. This measure increased during the first half of refresher sessions to about 35 sequences completed in the 20-min sessions. Across all refresher sessions, an average of 4.5 more FR sequences were completed during sessions after EtOH consumption than after SW (Figure C8).

Primary Frustration

Intermittent FR sequences were not reinforced during sessions of Oct 5-6. Of the possible 40 FR sequences each session, 8 were nonreinforced. All other sequences terminated with the usual two food pellets.

Table C2

Significant Results of Refresher Sessions' Four Way Analyses of Variance[a]

Measure	Source	F	df	p<
FRR	Fluid consumed	29.98	1,60	.001
	Sessions	78.47	4,240	.001
BPR	Sessions	33.92	4,240	.001
IBR	Fluid consumed	83.61	1,60	.001
	Sessions	67.43	4,240	.001
	Fluid x strength	17.53	1,60	.001
# of	Fluid consumed	47.66	1,60	.001
Sequences	Sessions	79.65	4,240	.001

[a]Between factors: EtOH strength (2% or 3%) and conditioning contingency (CF or UF). Within factors: fluid consumed (SW or EtOH) and sessions (five levels).

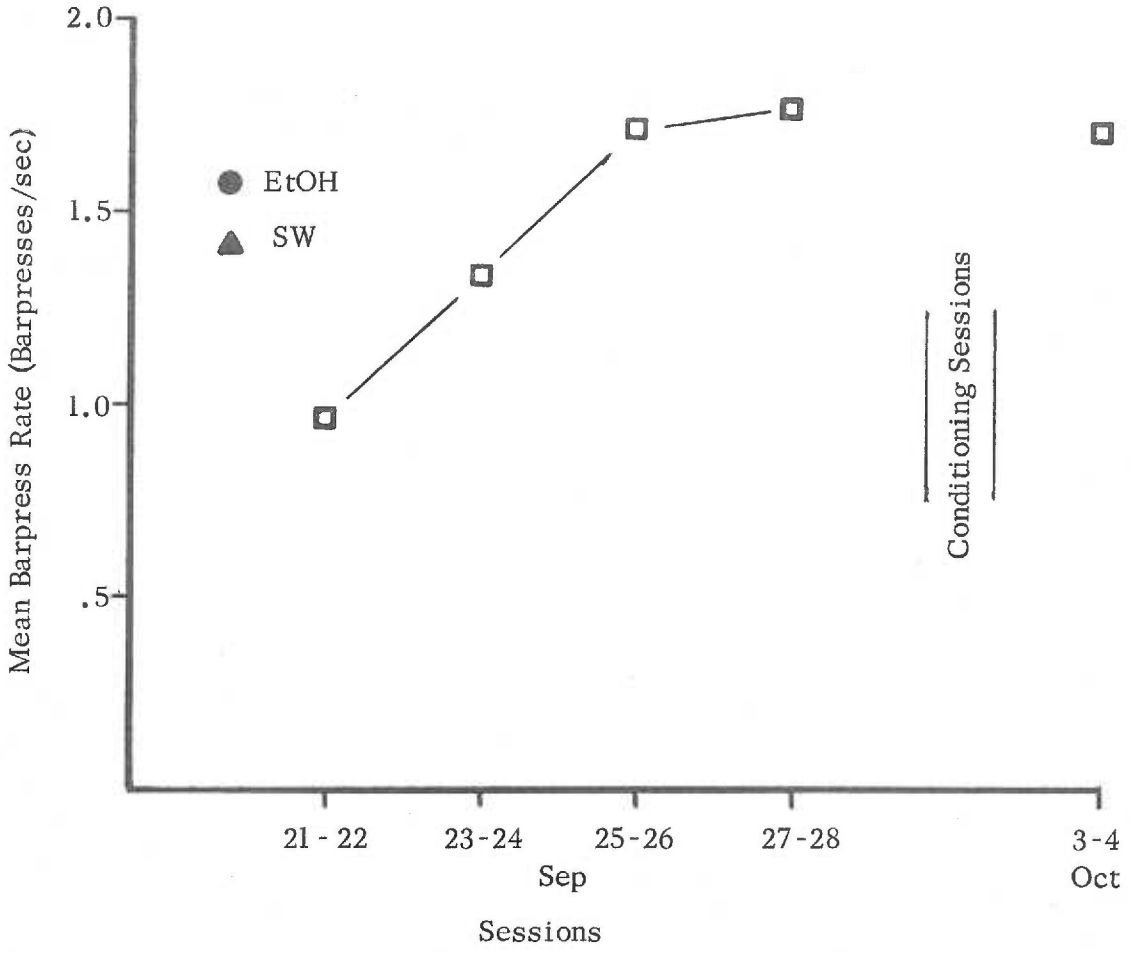

Figure C5. Rates of barpressing at FR30 during refresher sessions. Isolated points at the left indicate overall averages after EtOH and SW consumption.

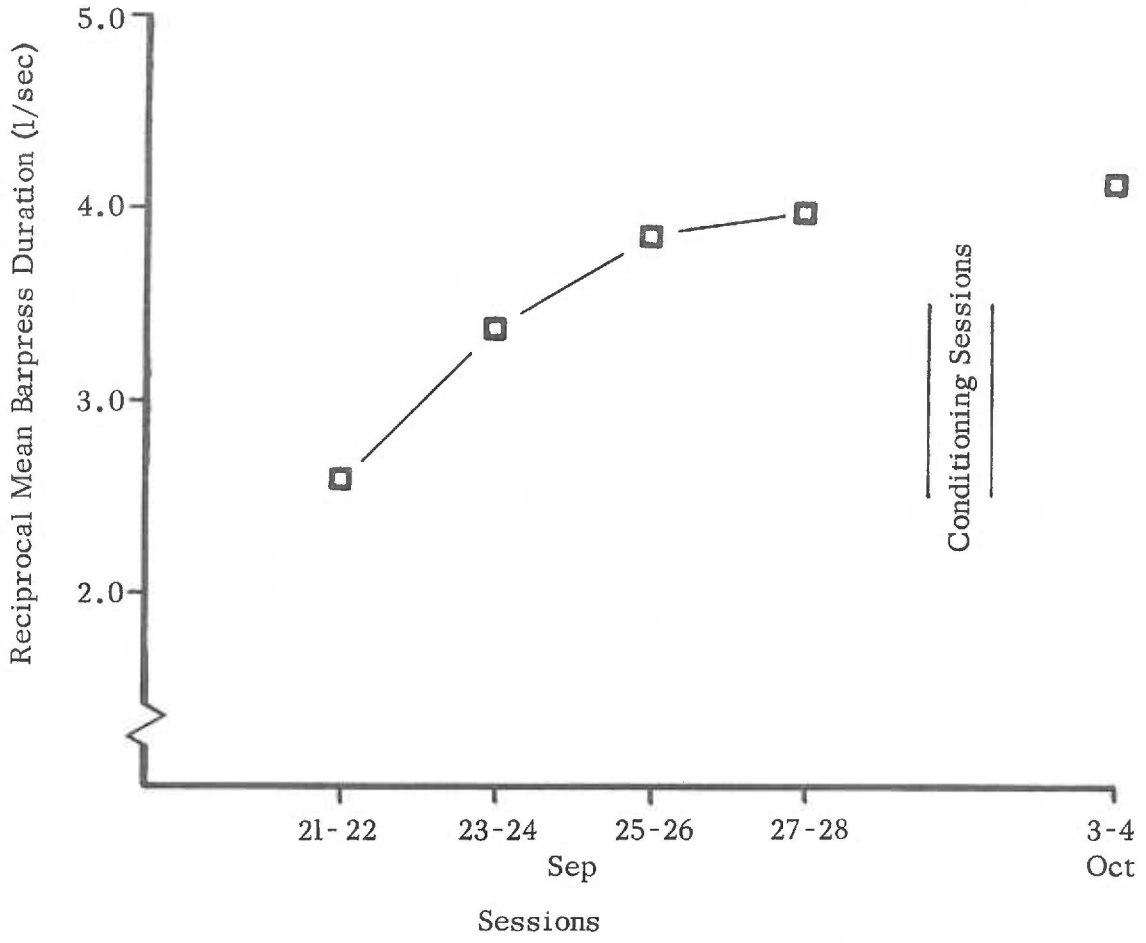

Figure C6. Reciprocals of mean barpress durations during refresher sessions.

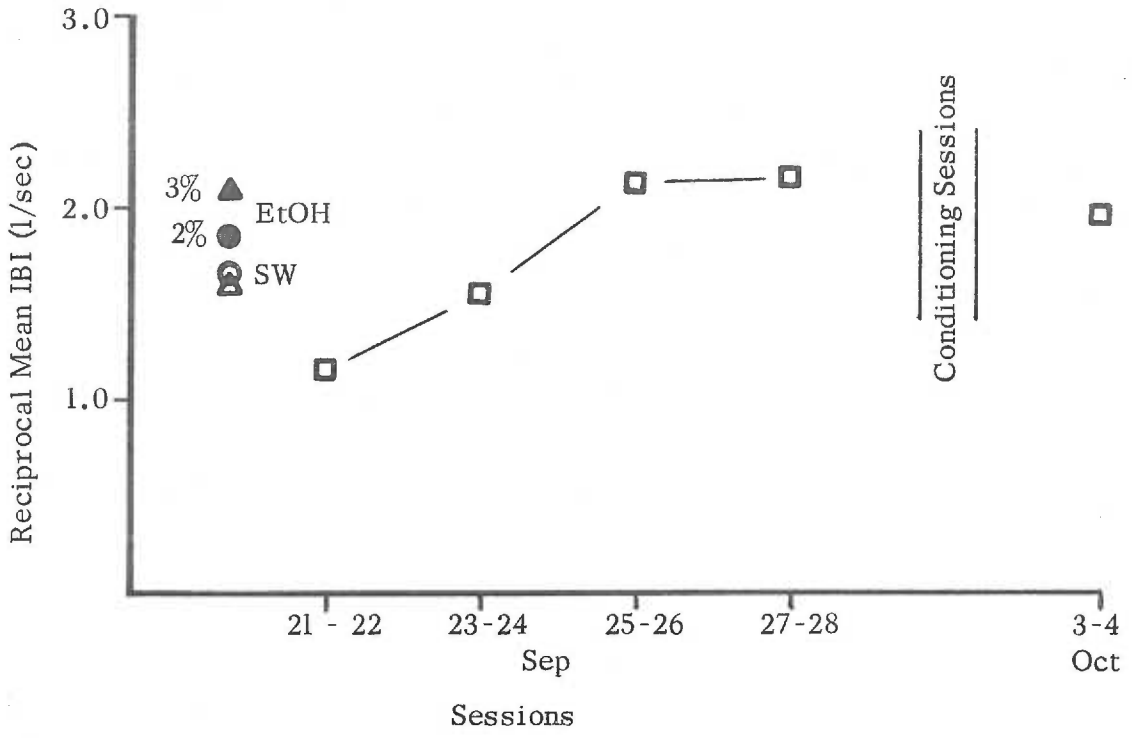

Figure C7. Reciprocals of mean interbarpress intervals during refresher sessions.

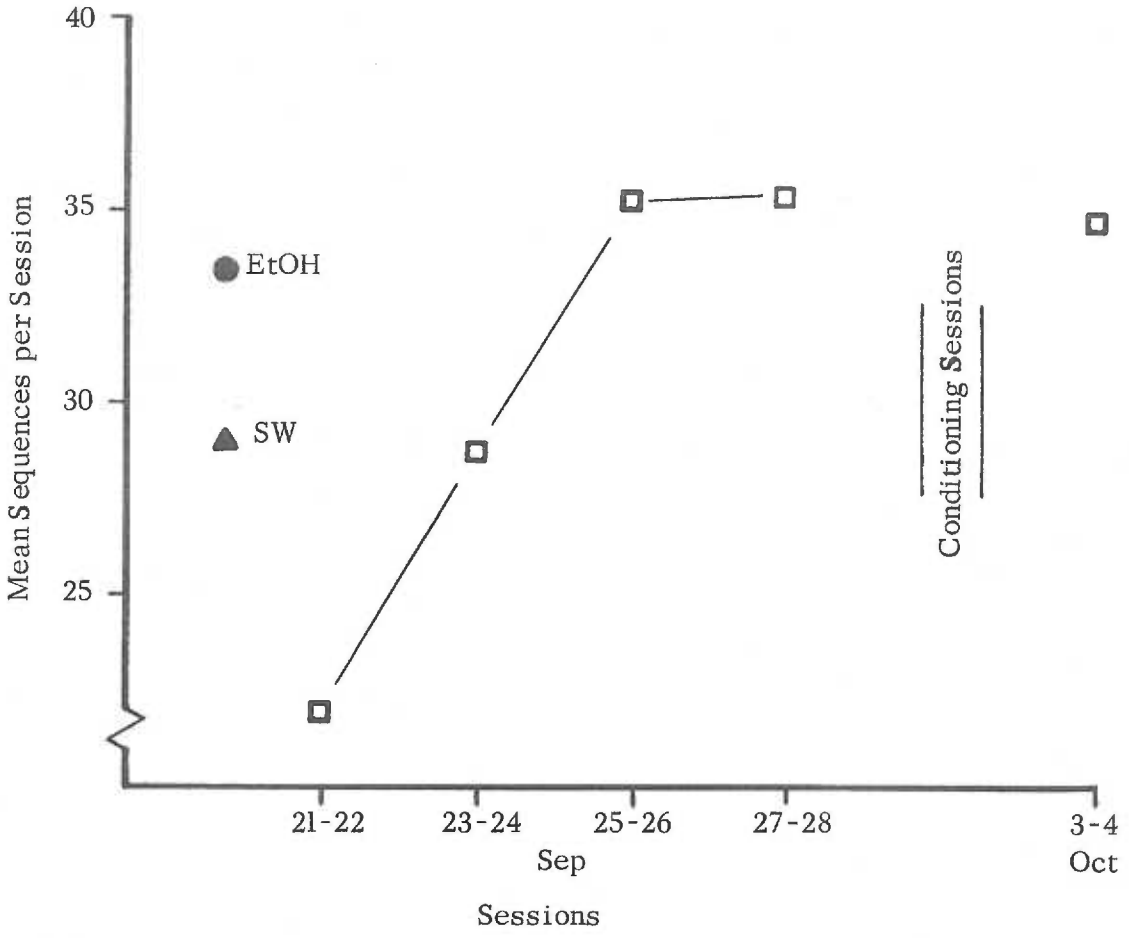

Figure C8. Mean number of FR sequences completed per session during refresher sessions. Isolated points at the left indicate overall averages after EtOH and SW consumption.

Data for each rat after consumption of each fluid were averaged for all nonreinforced sequences completed by that rat. Similarly, data for each rat after consumption of each fluid were averaged for all FR sequences immediately after nonreinforcement. Thus four of each of the dependent measures were available for each rat. For FR durations, barpress durations, and interbarpress intervals the mean durations were converted to response rates and subjected to four way analyses of variance with two between subjects factors (EtOH strength: 2% or 3%, and conditioning contingency: CF or UF) and two within subjects factors (fluid consumed: SW or EtOH, and temporal relation to nonreinforcement: PRE or POST). The significant results of those analyses are detailed in Table C3 and displayed in Figure C9. For each measure, performance rates were faster after nonreinforcement than before nonreinforcement. In addition, IBIs were shorter (IBRs were greater) after EtOH consumption than after SW consumption.

Standard deviations were computed for the barpress durations within each FR sequence before and after nonreinforcement. Mean standard deviations (BPADs) for each rat were used in a four way analysis of variance. Significant results are also shown in Table C3 and Figure C9; mean standard deviations were smaller after nonreinforcement than before.

In the preceding analyses, the relation of FR sequences to nonreinforcement was confounded with the relation of FR sequences to each other. That is, nonreinforced sequences always occurred before the FR sequences immediately after nonreinforcement. It seemed possible that

Table C3

Significant Results of
Primary Frustration Phase Analyses of Variance

Measure	Source	F	df	p<
	Four Way Analyses of Variance of Rate Data[a]			
FRR	Relation to nonreinforcement	35.40	1,52	.001
BPR	Relation to nonreinforcement	36.45	1,52	.001
IBR	Fluid consumed	11.28	1,52	.005
	Relation to nonreinforcement	57.35	1,52	.001
BPAD[c]	Relation to nonreinforcement	10.81	1,52	.005
	Four Way Analyses of Variance of Ratio Data[b]			
FR Duration	Frustration	120.22	1,52	.001
BP Duration	Frustration	50.79	1,52	.001
BPAD	Frustration	51.32	1,52	.001
IBI	Frustration	192.04	1,52	.001

[a]Between factors: EtOH strength (2% or 3%), conditioning contingency (CF or UF); within factors: fluid consumed (SW or EtOH), temporal relation to nonreinforcement (before and after).

[b]Between factors: EtOH strength (2% or 3%), conditioning contingency (CF or UF); within factors: frustration (present or absent), fluid consumed (DW or EtOH).

[c]BPAD: Barpress average deviation (mean standard deviation).

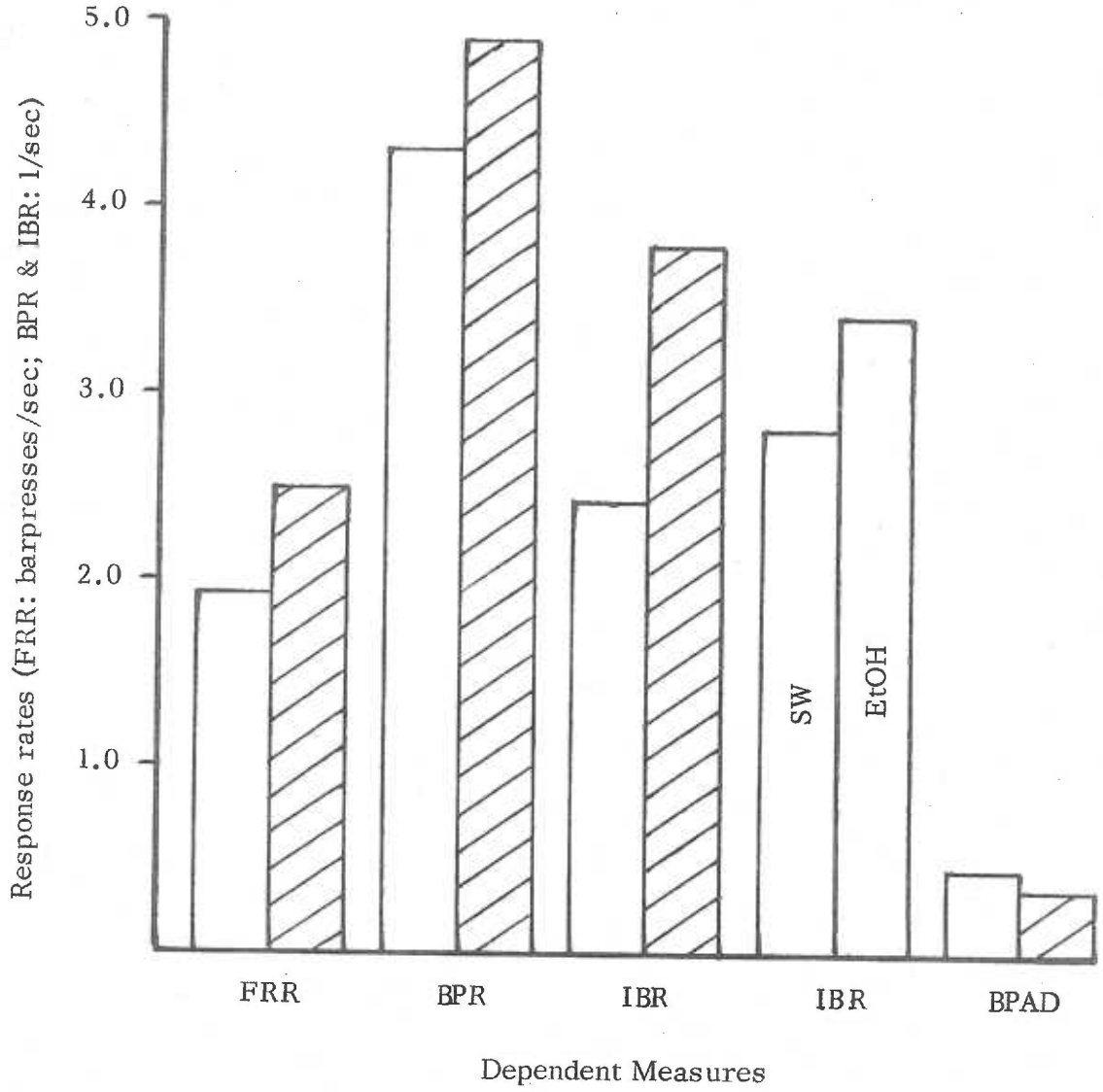

Figure C9. Rates before and after nonreinforcement for four dependent measures, and after SW and EtOH consumption for IBRs. These means were calculated from data taken on Oct 5 and 6. Shaded areas represent performances after nonreinforcement, open areas before nonreinforcement.

the increased rates which reliably appeared in the latter sequences might reflect changes in performances that could not unequivocally be attributed to the occurrence of nonreinforcement, but which might simply reflect, say, increasingly efficient barpressing within sessions. In order to refute alternative explanations of the sort which do not rely on the occurrence of nonreinforcement, additional FR sequences were considered in subsequent analyses of ratios of suppression and/or facilitation.

Frustration ratios were computed for each measure for each rat after SW and EtOH consumption. Durations were used in calculating these ratios; the computational formula was: ratio = POST/(PRE + POST). Two ratios were computed for each occasion on which a rat encountered nonreinforcement and completed the FR sequence after nonreinforcement. One ratio involved the nonreinforced FR sequences (PRE) and the FR sequences immediately after nonreinforcement (POST). The second ratio involved the penultimate FR sequences (PRE) before nonreinforcement and the nonreinforced FR sequences (POST). Thus, three FR sequences were used for data in these ratios. Ratios computed with data from the two FR sequences before the occurrence of nonreinforcement provided a quantitative indicant of performance changes owing to factors other than nonreinforcement. Ratios computed with data from the FR sequences immediately prior and subsequent to nonreinforcement provided a quantitative indicant of performance changes owing to nonreinforcement and to other nonspecific factors. Ratios of less than .5 indicated,

for example, that event durations were shorter after nonreinforcement than before nonreinforcement; ratios greater than .5 indicated that event durations were longer after nonreinforcement than before nonreinforcement. When the "events" were standard deviations, ratios of less than .5 indicated that response variability was less, for example, after nonreinforcement than before nonreinforcement; the converse was true for ratios greater than .5.

Mean ratios were computed for each rat after SW and EtOH consumption for FR sequences before nonreinforcement and for FR sequences immediately prior and subsequent to nonreinforcement. These mean ratios were subjected to four way analyses of variance with two between subjects factors (EtOH strength: 2% or 3%, and conditioning contingency: CF or UF) and two within subjects factors (frustration: present or absent, and fluid consumed: SW or EtOH). Significant results are itemized in the lower half of Table C3 and illustrated in Figure C10. In every case the ratios based on FR sequences immediately prior and subsequent to nonreinforcement were significantly smaller than ratios based on FR sequences before nonreinforcement.

Testing for Conditioned Frustration

Data were collected somewhat differently from the beginning of tests for conditioned frustration to the end of the experiment than had been the case earlier. Each FR30 sequence was divided into six data packets, and all of the information that had been punched at the end of

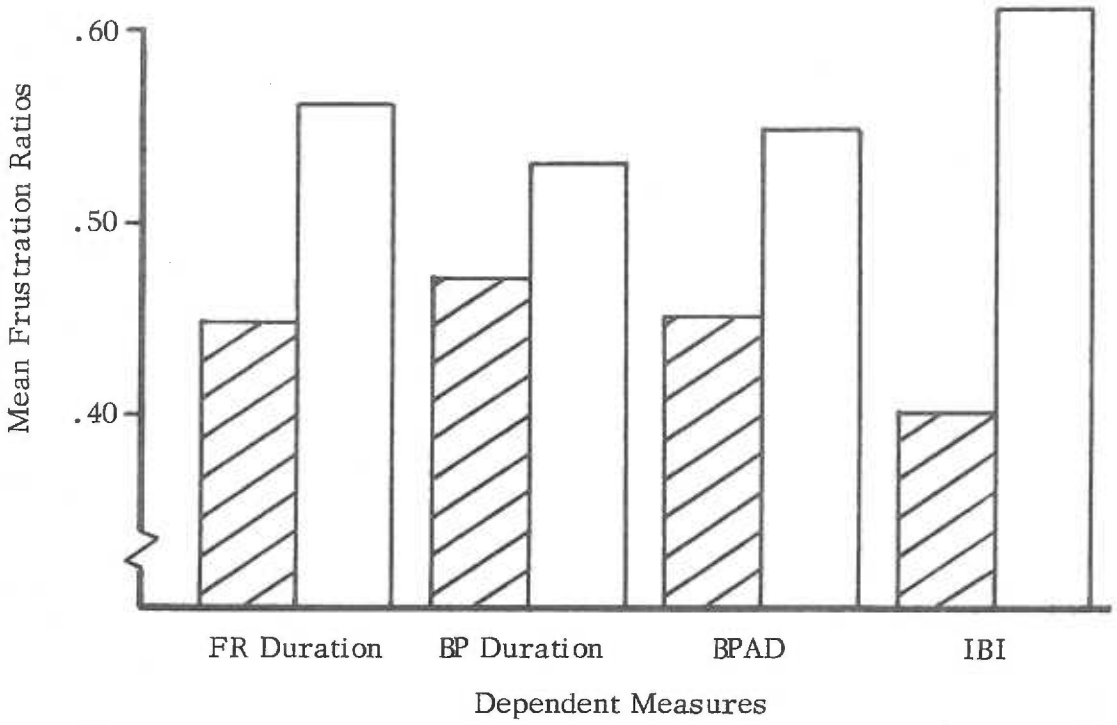

Figure C10. Average frustration ratios during primary frustration sessions for four dependent measures. Shaded areas indicate performances during FR sequences immediately prior and subsequent to nonreinforcement; open areas indicate performances during FR sequences before nonreinforcement. Ratios of less than .5 indicate that event durations were longer in the earlier sequence than in the later sequence.

each FR sequence was punched on paper tape for each data packet. Accordingly, data analyses included a within subjects factor of "packets" when appropriate. Tones were superimposed on barpressing during sessions occurring from Oct 7-10. Either the 6th or 16th barpress of a FR sequence instigated a tone presentation. These tones first occurred during the fourth FR30 sequence of a session, and occurred during every FR sequence thereafter. Also, delivery of food pellets occurred only after the first four FR30 sequences of a session; all other FR sequences were nonreinforced. Thus data from Oct 7-10 were analyzed in three parts: The first three FR30 sequences of each session were considered separately as the first part. These sequences occurred without presentation of any tone, and all were followed by food pellets. The next two sequences of each session (FR Sequences 4 and 5) comprised the second part. During each of these sequences a tone occurred, once during the second data packet (initiated by the 6th barpress) and once during the fourth data packet (initiated by the 16th barpress). Not until after the final barpress of the fifth FR30 sequence did nonreinforcement occur. All FR sequences subsequent to that first nonreinforcement of a session were considered as the third part: nonreinforced sequences.

Errors on the part of the experimenter and machine malfunctions during the days of conditioning sessions (Sep 29-Oct 2) combined to invalidate the data from nine animals insofar as conditioned frustration testing was concerned. For some of these rats the temporal relations between nonreinforcements and tone presentations were unknown because

the feeder systems were not aligned correctly. For others the feeders jammed during sessions of conditioning frustration. In order to allow factorial analyses with equal group sizes, an additional seven rats were selected on the basis of days to criterion during FR Training and eliminated from consideration for analyses of conditioned frustration testing data. These additional rats were the last to reach FR30 during the training phase. They were distributed two each from two groups, and one each from three groups. Elimination of data for a total of 16 rats during the conditioned frustration test phase reduced the total number of subjects from 64 to 48. Half of these rats had been assigned to 2% EtOH, half to 3% EtOH. For purposes of data analysis during these later stages of experimentation when the number of experimental factors became cumbersome, the study was treated as two separate experiments: a replication with 2% EtOH and a replication with 3% EtOH. Thus the analyses of variance for the remaining days of the experiment were doubled in number, but no longer included a factor of EtOH concentration. Also, during earlier days of experimentation subjects had consumed EtOH and SW on alternating days. Prior to the beginning of conditioned frustration testing, each subject was assigned to either EtOH or SW and consumed that fluid prior to each session of this phase. Thus the factor of "fluid consumed" ceased to be within subjects, becoming instead a between subjects factor. Between subjects factors for analyses of conditioned frustration test data thus consisted of conditioning contingency (CF or UF) and fluid consumed (EtOH or SW).

Average durations were computed for each rat for each of the three measures for each data packet of the three parts of each session, along with average standard deviations for barpress durations. The average durations were converted to rate measures (barpresses/sec for FRR, 1/ average barpress duration for BPR, and 1/average interval for IBR), and rates and average deviations were subjected to four way analyses of variance with two between factors (conditioning contingency: CF or UF, and fluid consumed: EtOH and SW) and two within factors (days: four levels, and data packets: six levels). A total of 40 of these four way analyses were computed. In the first part (first three FR sequences of each session) there were two replications, one with 2% EtOH and one with 3% EtOH, and four measures (FRR, BPR, IBR, & BPAD), so that eight analyses were required. Data from the second and third parts (FR sequence 4 & 5 and nonreinforced sequences, respectively) of the sessions, where tones were presented, were further subdivided into two replications. In one replication the tones always occurred in the second data packet; in the other replication the tones always occurred in the fourth data packet. Thus 16 analyses were required for data from the second part, and 16 for data from the third part. In every analyses the factor of data packets was significant [all $\underline{F}s(5,100) > 4.0$, $\underline{p} < .005$]. The directions of these effects are indicated below, in the sections "FR Sequences Without Tones" and "FR Sequences With Tone Presentations." In addition, for 3% rats in Part 3 with the tone in the second data packet the four way interaction was significant for the BPADs [$\underline{F}(15,300) = 2.94$, $\underline{p} < ,005$]. A followup (Tukey (a), Linton & Gallo, 1975) of this

interaction revealed it to be owing to exceptionally high variability of responding in the first data packet for UF-EtOH rats on the 3d day of testing and for UF-SW rats on the 4th day of testing.

Average durations were computed for each rat for all 4 days and converted to rate measures, and average standard deviations were computed for each rat for all 4 days of testing. Thus the within factor of days was no longer appropriate for analysing these means. Instead, a within factor of "parts" was included in order to ascertain whether the changes within FR sequences (which were significant in individual analyses for every part) differed between parts of the sessions. Data were again analyzed as separate replications at 2% and 3% EtOH and with tone presentations in the second and fourth data packets. The same data served to represent performances in the first part for both tone location replications, as no tones sounded during the first three FR sequences each session. Thus 16 four way analyses (four replications with four measures each) sufficed to analyze these means across days of testing with between factors of conditioning contingency (CF or UF) and fluid consumed (EtOH or SW) and within factors of parts (three levels) and data packets (six levels). In every analysis save one the factor of parts was significant [all $\underline{F}$s(2,40) > 5.0. $\underline{p}$ < .01]. The single exception was with 2% rats, tone in Packet 4 [$\underline{F}(2,40) = 2.92$, $\underline{p} < .05$]. The factor of data packets was significant [all $\underline{F}$s(10,200) > 2.8, $\underline{p}$ < .01] in every analysis save two (3% rats, BPAD; tone in Packet 2: $\underline{F} = 2.01$, tone in Packet 4: $\underline{F} = 2.22$, $\underline{p}$s < .05]. These effects and interactions are examined and illustrated below.

In addition, in the BPR analysis for 2% rats with the tone in the fourth data packet, the interaction of conditioning contingency by fluid consumed by parts was significant [$F(2,40) = 5.55$, $p < .01$]. This interaction is illustrated in Figure C11, where it can be seen that rates for UF rats were faster with SW than with EtOH in Parts 1 and 2, though not in Part 3. Also, rates slowed from Parts 1 and 2 to Part 3 for UF rats with SW, but not with EtOH. For CF rats the only significant differences were between rates in Part 1 with EtOH and Part 2 with SW as compared to Part 3 with EtOH. These followup comparisons were accomplished with Tukey (a) tests. In summary, when the CS sounded in Data Packet 4 for rats assigned to 2% EtOH, the average duration of discrete barpresses within those FR sequences was longer after consumption of EtOH than after SW in Parts 1 and 2 for rats that had undergone unpaired conditioning sessions. Also, average barpress durations were longer in Part 3 than in Part 1 for CF rats after EtOH and for UF rats after SW, for which durations were also longer in Part 3 than in Part 2.

The factor of "fluid consumed" was replaced with "EtOH concentration" for supplemental analyses of the same data. These additional analyses with between factors of EtOH concentration (2% or 3%) and conditioning contingency (CF or UF) and within factors of parts (three levels) and data packets (six levels) indicated that the main effects of parts and packets and their interactions did not differ for 2% and 3% rats with the tone occurring in either location. These interactions of parts by data packets were handled by treating "parts" as separate

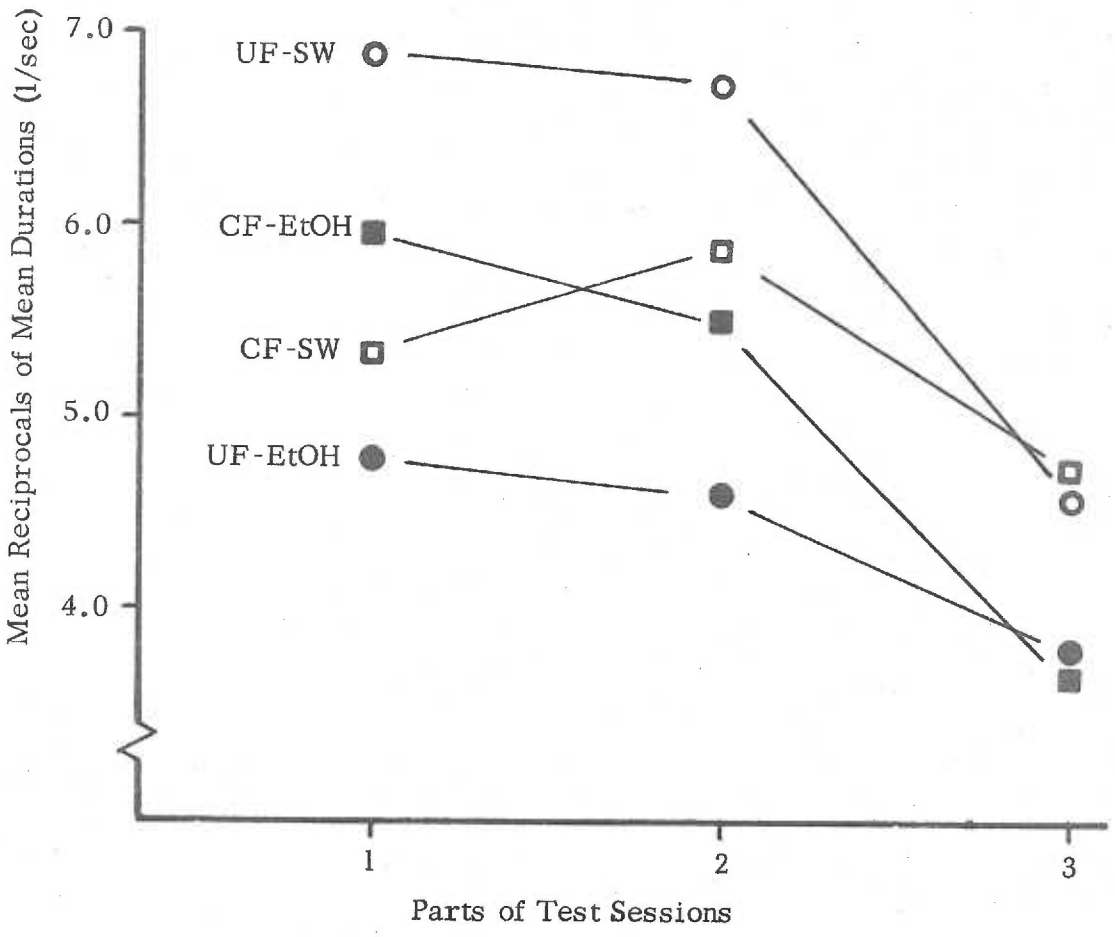

Figure C11. Reciprocals of mean barpress durations for 2% rats during FR sequences with the tone located in Data Packet 4. Open symbols indicate performances after consumption of SW; filled symbols indicate performances after EtOH. Both CF (□) and UF (○) subgroups are shown.

replications for ensuing analyses of data from sessions of testing for conditioned frustration, with the understanding that the rate changes within FR sequences differed between the three parts of test sessions.

FR Sequences Without Tones

Where the differences occurred in data from the first part was ascertained by using Tukey (a) followup tests on the data from the final overall analyses (see previous paragraph) in which the between subjects factors were EtOH concentration and conditioning contingency and the within subjects factors were parts and data packets. These followup tests indicated that for the first part the changes over data packets differed for the four different measures. These differences are evident in Figure C12. For the FRR measure, rates in the second and sixth data packets were equivalent, faster than rates in the first data packet, and slower than rates in Packets 3-5, which were equivalent. For the BPR measure, reciprocals in Packets 3-5, were equivalent and greater than those of the second packet, which were greater than those in the sixth packet, which were greater than reciprocals in the first packet. Reciprocals increased throughout packets for the IBR measure, with reciprocals in the fifth and sixth packets equivalent and greater than those in the first three packets. Rates in the third and fourth packets were equivalent and greater than those of the first two packets, which also differed significantly. For the BPAD measure, average standard deviations were equivalent in the first and sixth data packets, and greater than those of Packets 2-5, which were equivalent.

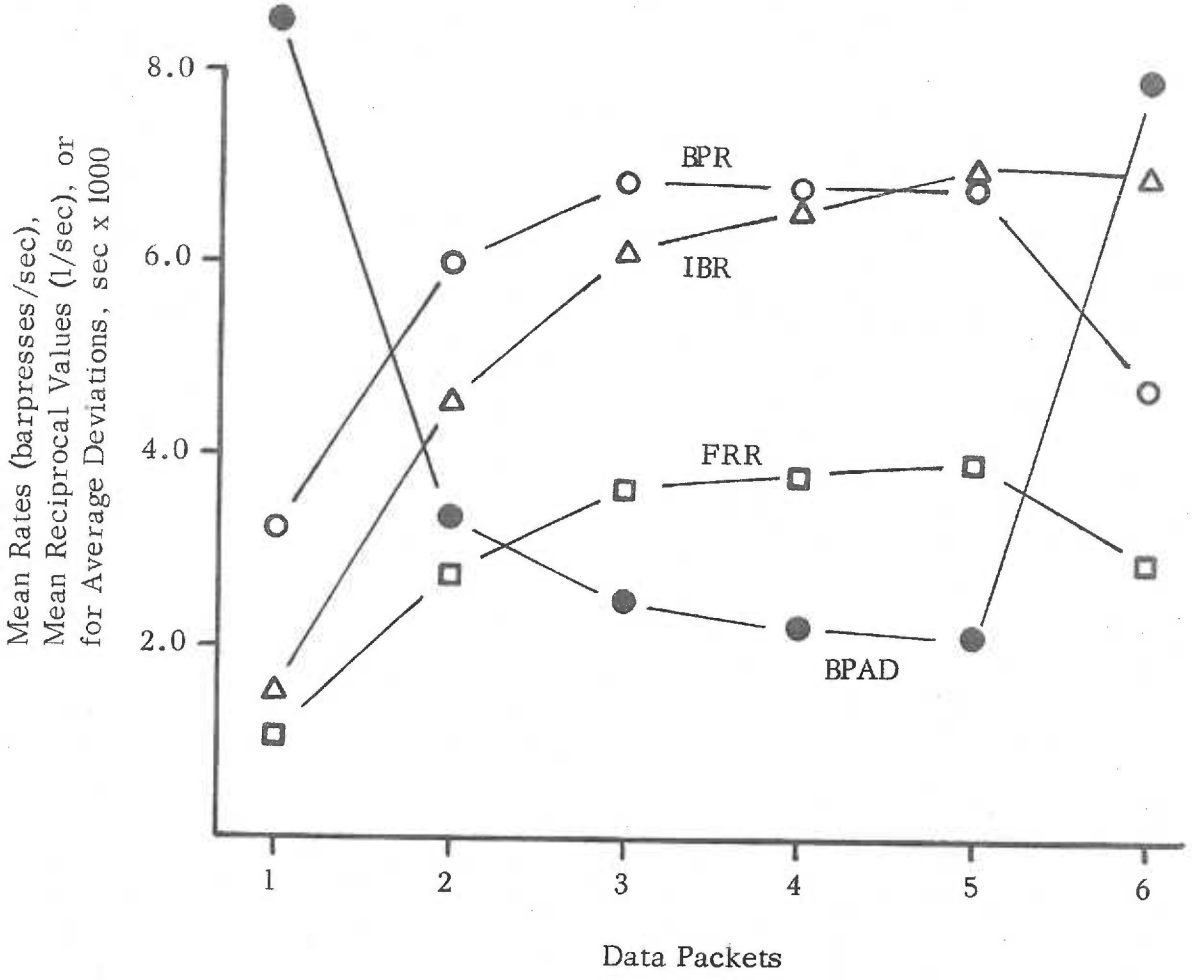

Figure C12. Changes in four measures within the first three FR sequences during testing for conditioned frustration. The filled circles indicate average standard deviations multiplied by 1000 for the BPAD measure.

In summary, the three rate measures increased from the first through the fifth data packets. Thereafter, rates slowed significantly for both the FRR and BPR measures, but did not slow for the IBR measure. The average standard deviation of barpress durations was greater in the first and final packets than in the other packets.

FR Sequences with Tone Presentations

In order to discover whether the CS affected barpressing differentially in the two positions within FR sequences, data from the second and third parts were analyzed with between factors of conditioning contingency (CF or UF) and fluid consumed (EtOH or SW) and within factors of tone location (second or fourth data packet) and data packets (six levels). Data were again analyzed in separate replications for 2% and 3% EtOH and separate replications for the second and third parts. Thus 16 four way analyses were completed (four replications for each of four measures). In every analysis the factor of data packets was again significant [all Fs(5,100) > 10.0, p < .001], and in some analyses the interaction of tone location by data packets was significant. For 2% rats the analyses of the BPAD measure revealed significant four way interactions [F(5,100) = 3.56 in Part 2 and 3.62 in Part 3, ps < .01], owing, in each case, to aberrantly high variability by a subgroup of rats on the barpresses of the first data packet. No other main effect or interaction was significant in any of these analyses.

To ascertain whether the significant effects and interactions differed reliably between EtOH concentrations, additional analyses were

completed with between subjects factors of EtOH strength (2% or 3%) and conditioning contingency (CF or UF) and within subjects factors of tone location (two levels) and data packets (six levels), with two replications (Parts 2 & 3) for each of the three measures. Because the factor of fluid consumed was not included in these analyses, the number of subjects per group increased from 6 to 12. The significant results from these analyses are denoted in Table C4 and displayed in Figures C13-C16. The effects and interactions illustrated in Figures C13-16 were followed up with Tukey (a) tests. In each of these figures it can be seen that the respective rates in Parts 2 and 3 diverge across data packets. With the BPR measure (Figure C14) and the BPAD measure (Figure C16) the rates converge again in Data Packet 6. While direct comparisons were not made between rates in Parts 2 and 3, these results are in harmony with the interactions between parts and data packets which were consistently significant in the first analyses which included "parts" as a within subject factor.

FR Sequences 4 and 5. In Part 2 the interaction of tone location by data packets for the FRR measure (see Figure C13) was apparently owing to the fact that when the tone occurred in the second packet, rates in the fourth and fifth packets were significantly higher than rates in the first two packets; but when the tone occurred in the fourth packet, rates in the third packet were higher than rates in the first and sixth packets. The other differences were the same for both tone locations--rates in the first packet were lower than rates in any other packet.

Table C4

Significant Results of Four Way Analyses of Data from Tests for Conditioned Frustration [a]

Measure	Source	F	df	p <
	Part 2 (FR Sequences 4 & 5)			
FRR	Data packets	80.87	5,220	.001
	Tone location by packets	4.30	5,220	.005
BPR	Data packets	54.12	5,220	.001
IBR	Data packets	74.18	5,220	.001
	Tone location by packets	5.27	5,220	.001
BPAD	Data packets	30.59	5,220	.001
	Part 3 (nonreinforced sequences)			
FRR	Data packets	24.70	5,220	.001
	Tone location by packets	13.27	5,220	.001
BPR	Data packets	28.45	5,220	.001
	Tone location by packets	14.18	5,220	.001
IBR	Data packets	22.76	5,220	.001
	Tone location by packets	9.96	5,220	.001
BPAD	Data packets	23.99	5,220	.001
	Tone location by packets	7.10	5,220	.001

[a]Between factors: EtOH strength (2% or 3%) and conditioning contingency (CF or UF). Within factors: tone location (second or fourth data packet) and data packets (six levels).

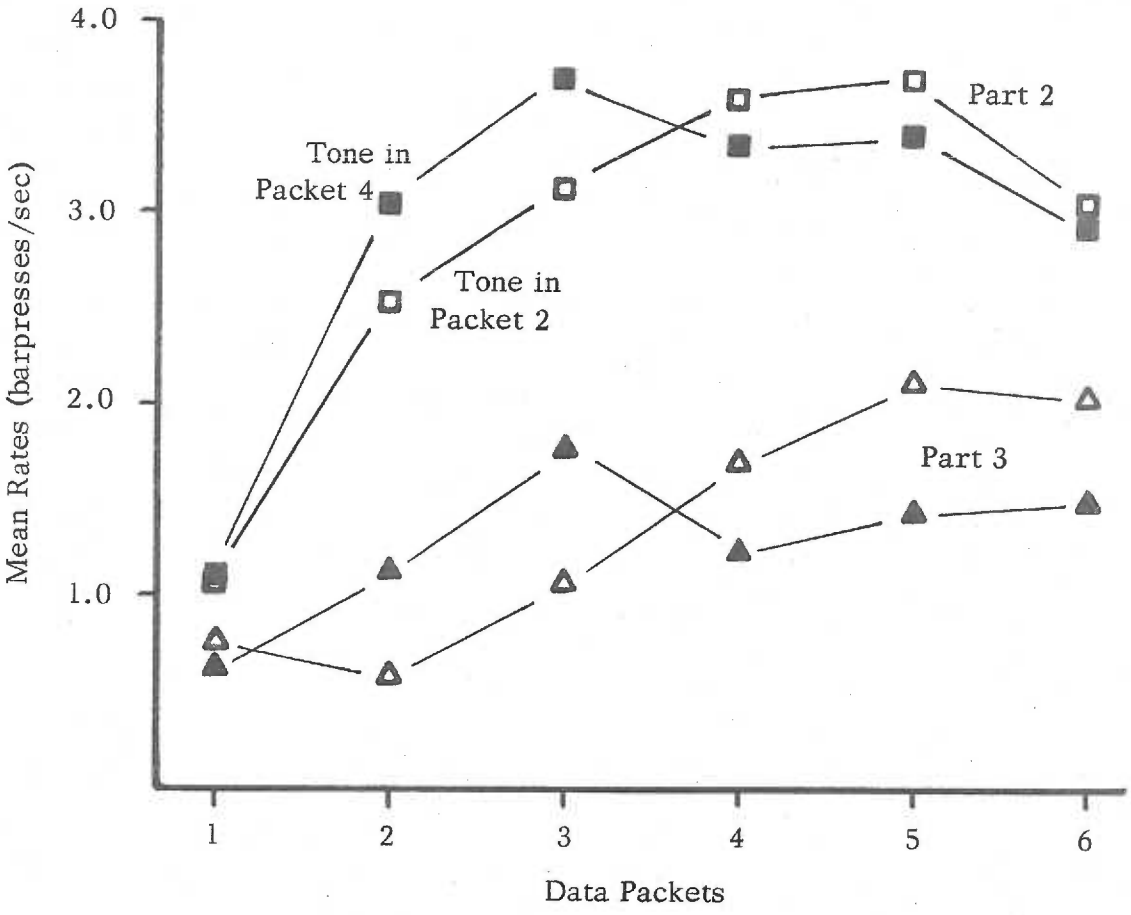

Figure C13. Mean rates of barpressing during the fourth and fifth FR 30 sequences (□) of testing for conditioned frustration, and during nonreinforced sequences (△). Open symbols indicate performance rates during sequences when the tone occurred in the second data packet; filled symbols are for sequences when the tone occurred in the fourth data packet.

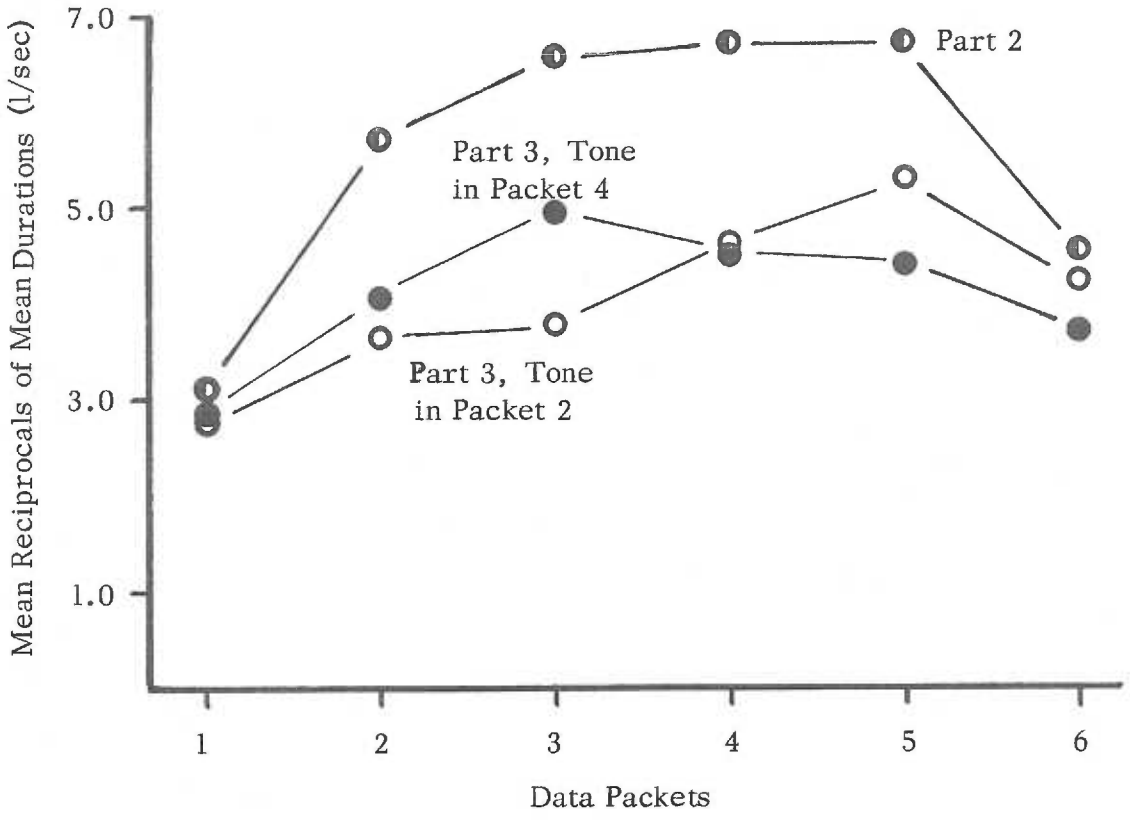

Figure C14. Reciprocals of barpress durations during testing for conditioned frustration, with data from both Part 2 (FR Sequences 4 & 5) and Part 3 (nonreinforced sequences). Open symbols indicate that the tone was initiated by the first barpress of the second data packet; filled symbols indicate that the tone was initiated by the first barpress of the fourth data packet.

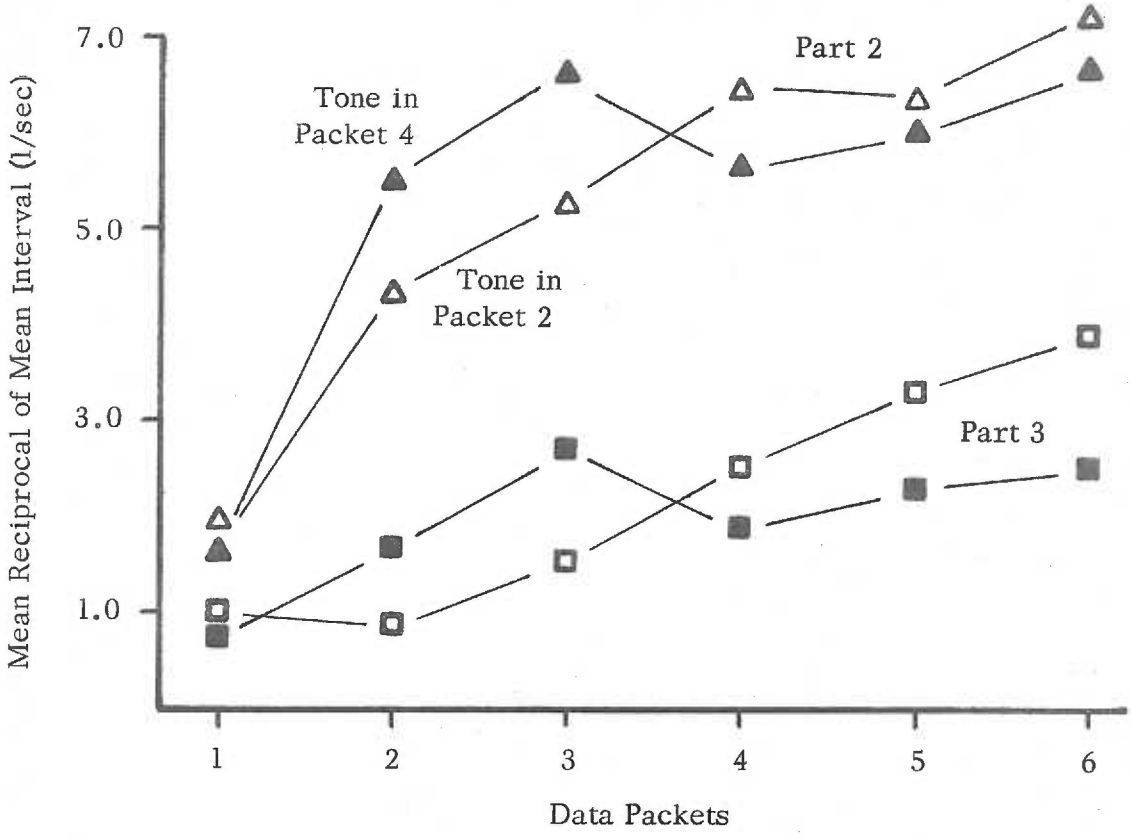

Figure C15. Performances during FR Sequences 4 and 5 (△) of testing for conditioned frustration, and during nonreinforced sequences (□), as revealed by reciprocals of IBIs. Open symbols indicate rates during sequences when the tone occurred in the second data packet; filled symbols are for sequences when the tone occurred in the fourth data packet.

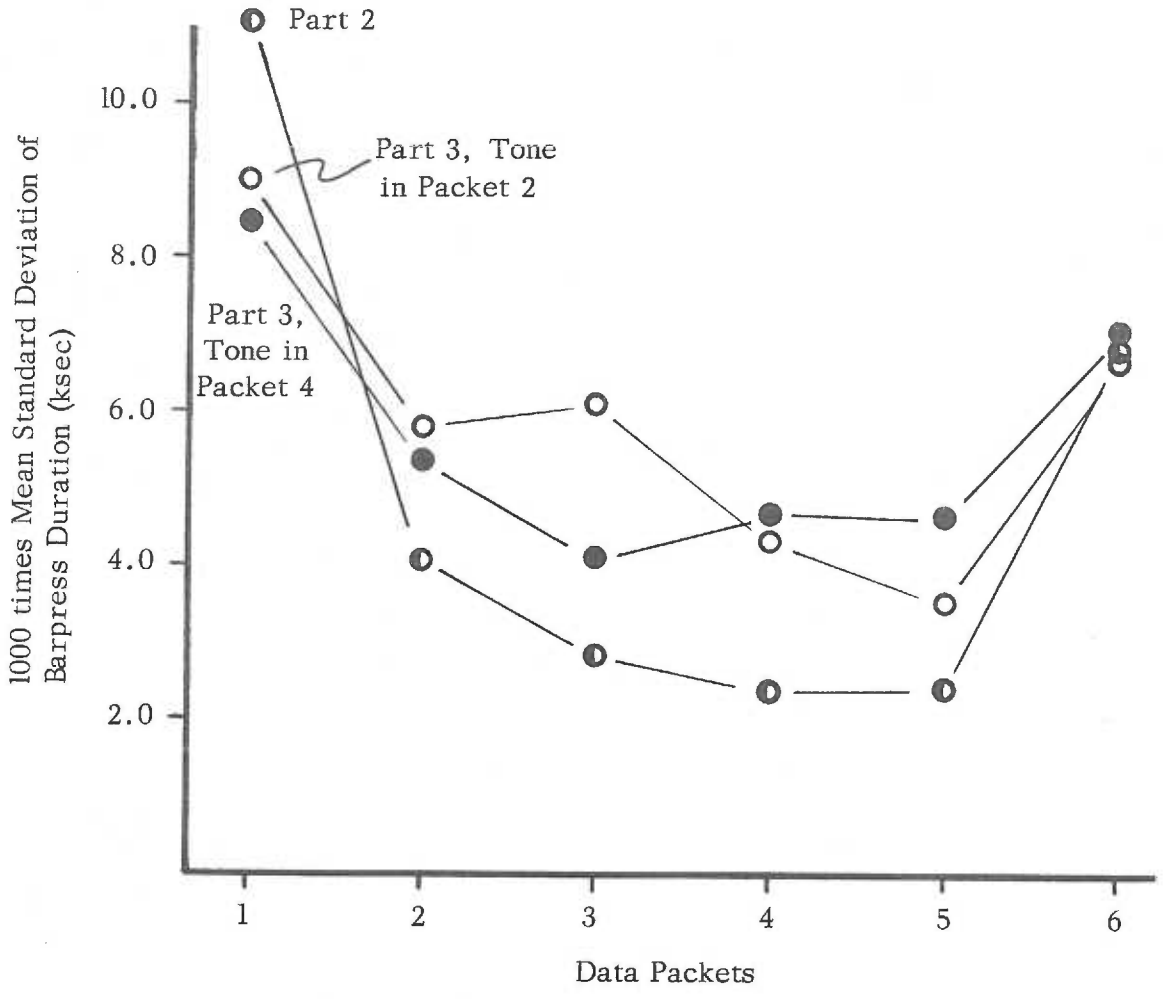

Figure C16. Average standard deviations of barpress durations in FR Sequences 4 and 5 (Part 2) and nonreinforced sequences (Part 3) of tests for conditioned frustration. BPAD values are multiplied by 1000 in this figure. Open sumbols indicate variability during sequences when the tone occurred in the second data packet; filled symbols are for sequences when the tone occurred in the fourth data packet.

Only a main effect of data packets was significant for the BPR measure. As can be seen in the upper line of Figure 14 rates in the third, fourth, and fifth packets were equivalent and higher than rates in the first and sixth packets. Also, rates in the second and sixth packets were higher than rates in the first packet.

The differences in rates between tone locations for the IBR measure in Part 2 are shown in Figure C15. With each tone location the rates in the first data packet were below rates in all other packets. When the tone occurred in the second packet rates increased across packets so that rates in the sixth packet were higher than rates in the second and third packets, and rates in the fourth and fifth packets were higher than rates in the second packet. However, when the tone occurred in the fourth packet rates in Packets 2-6 did not differ significantly.

The main effect of data packets which was significant for the BPAD measure can be seen in Figure C16. Average standard deviations were equivalent in Packets 2-5, and less in Packets 3-5 than in Packet 6, in which they were less than in the first data packet.

Nonreinforced sequences. For the FRR measure in Part 3 (Figure C13) the tone location by data packets interaction was owing to the fact that rates were higher in Packets 4-6 than in Packets 1-3 when the tone occurred in the second packet; but when the tone occurred in the fourth packet, rates in the third packet were higher than rates in the first two packets, and rates in the fifth and sixth packets were higher than rates in the first packet.

For the BPR measure the interaction is shown in Figure C14. When the tone occurred in the second data packet rates increased through the fifth packet, then slowed in the sixth packet, so that rates in the fifth packet were significantly higher than rates in all other packets except the fourth, rates in the fourth packet were higher than rates in the first three packets, and rates in the second, third, and sixth packets were higher than rates in the first packet. With the tone in the fourth packet rates in the third packet were higher than rates in the first, second, and sixth packets; rates in the fourth packet were higher than rates in the first and sixth packets; and rates in the second, fifth, and sixth packets were higher than rates in the first packet.

Figure C15 illustrates the interaction for the IBR measure during Part 3. With the tone in Packet 2, rates generally increased across packets so that rates in the sixth packet were higher than rates in the first four packets, rates in the fifth packet were higher than rates in the first three packets, and rates in the fourth packet were higher than rates in the first two packets. When the tone occurred in Packet 4, however, rates in the third, fifth, and sixth packets were higher than rates in the first packet and no other differences were significant.

The source of the tone location by data packets interaction for the BPADs can be described by indicating that the smallest average standard deviation within FR sequences with the tone in the second data packet occurred in Packet 5; whereas with the tone in the fourth data packet the smallest average standard deviation was in Packet 3.

Some general statements can be made about the results of testing for conditioned frustration. The factors of fluid consumed and conditioning contingency were not signigicant in any of the factorial analyses. Prior to this phase "fluid consumed" had been a within subjects factor, and analyses had often revealed it to be significant or to interact with other experimental variables. The failure of EtOH consumption to affect performance between subjects can most easily be accounted for on the basis of variability between subjects. Indeed, a check of mean square error terms for one series of analyses (12 four way analyses mentioned in the first paragraph of "FR Sequences with Tone Presentations") revealed that the between subject error terms averaged nearly ten times larger than within subject error terms. This between subject variability could also account for the failure to find an effect of conditioning contingency. In spite of the lack of a conditioning effect, CS presentations in both locations did have a reliable impact upon barpressing, as revealed by all four measures. The effect of the CS was to impede barpressing both by lengthening the intervals between barpresses and by lengthening the durations of discrete barpresses, and to increase the standard deviations of durations of discrete barpresses. Further, these effects of the CS were limited to a range of ten barpresses after onset of the 3-sec tones.

Conditioned Frustration Ratios

In an effort to counter the problems of between subject variability, conditioned frustration (CF) ratios were computed for each data packet

of the second and third parts on each of the four test days. These ratios were based upon mean durations for each of the dependent measures. Mean durations during the first three sequences of each session (Part 1) provided the standard against which durations in the second and third parts were "measured" for facilitation or suppression. For example, ratios were computed for each rat for each packet of Part 2 by dividing the mean duration in that packet in Part 2 by the sum of the mean durations in that packet in the first and second parts. Thus the same formula was used as had been used for similar ratios computed from data collected during primary frustration sessions: ratio = POST/(PRE + POST). Now, however, the PRE component was a mean duration from the first three FR sequences of a session, and the POST component was a mean duration from either the fourth and fifth sequences or the nonreinforced sequences. Ratios greater than .5 indicated that durations were longer in tone-containing sequences than in Part 1, and thus that rates were slower, or, for BPADs, that variability was greater. Ratios less than .5 indicated that durations were shorter and rates were faster, or, for BPADs, that variability was less in tone-containing FR sequences than in Part 1.

The ratios were averaged over the 4 days of testing for each rat and subjected to four way analyses of variance with between subjects factors of conditioning contingency (CF or UF) and fluid consumed (EtOH or SW) and within subjects factors of tone location (second or fourth data packet) and data packets (six levels). EtOH concentration (2% or 3%) and parts (Sequences 4 & 5 or nonreinforced sequences) were again

treated as separate replications, so that 16 analyses were conducted (four measures in each of four replications). Not any main effect of fluid consumed nor any interaction with that factor was significant except for the BPADs for 3% rats in Part 2, where the three way interaction of conditioning contingency by fluid consumed by tone location was significant [$F(1,20) = 12.25$, $p < .005$]. This interaction occurred because the ratios for CF rats with SW (averaged across all six data packets) were higher than those of their UF counterparts when the tone was in the second data packet. In fact, the ratios of CF rats with SW and the tone in Packet 2 were higher than those of UF rats under any conditions, indicating that the difference between average deviations in Parts 1 and 2 was greater under those conditions than any others. No other differences with regard to tone location, fluid consumed, or conditioning contingency were significant. These followup comparisons used a Tukey (a) procedure.

Subsequent analyses which excluded "fluid consumed" and included instead the between subjects factors of EtOH concentration (2% or 3%) and conditioning contingency (CF or UF), and the within subjects factors of tone location (two levels) and data packets (six levels) were completed for each measure in Parts 2 and 3 (eight analyses). The significant outcomes of these analyses are salient in Figures C17-C20. In every case except two there was a significant effect of data packets [all $Fs(5,220) > 4.5$, $p < .001$] and a significant interaction of tone location by data packets [all $Fs(5,220) > 7.0$, $p < .001$]. The exceptions both occurred in Part 2. For the analysis of ratios for BPRs neither the effect of

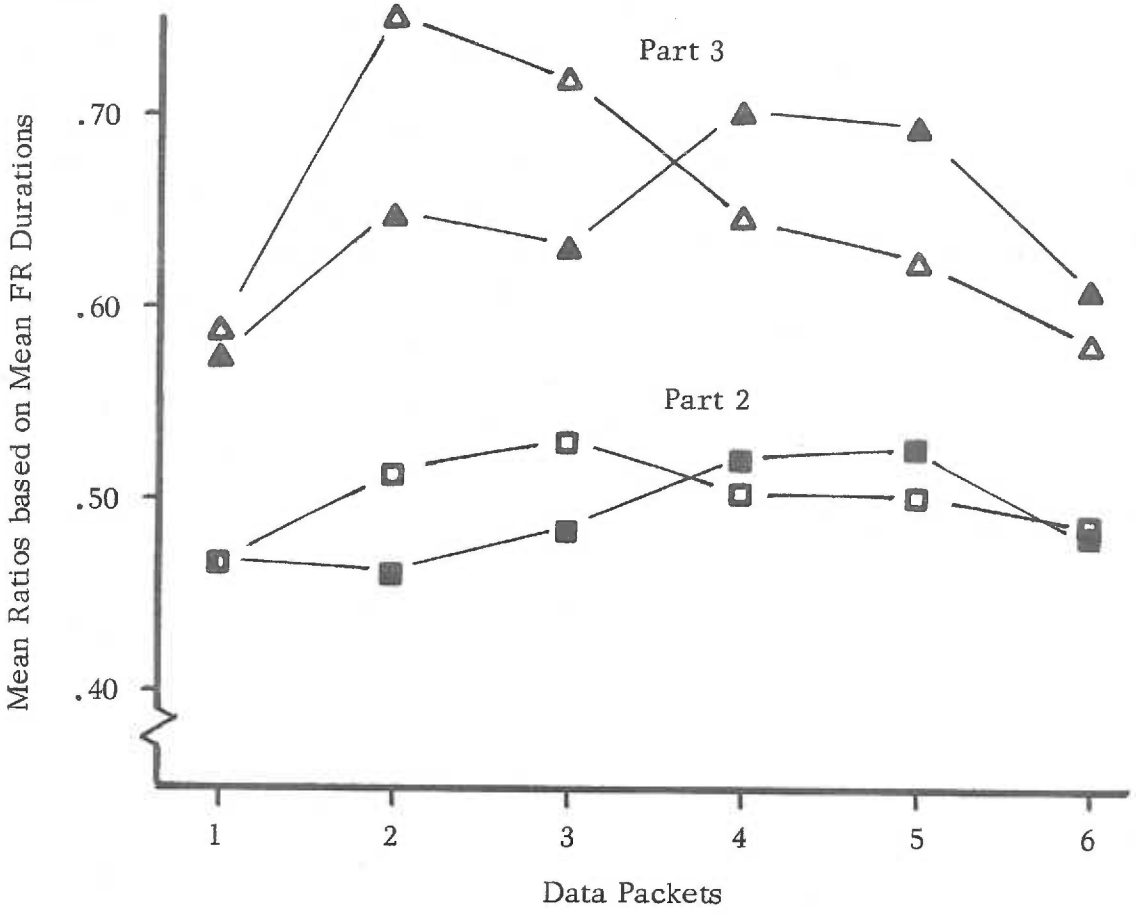

Figure C17. Frustration ratios based on FR durations during tests for conditioned frustration. Open symbols indicate FR sequences with the CS in the second data packet; filled symbols indicate sequences with the CS in the fourth data packet. Part 2 (□) comprised FR Sequences 4 and 5; Part 3 (△) comprised nonreinforced sequences.

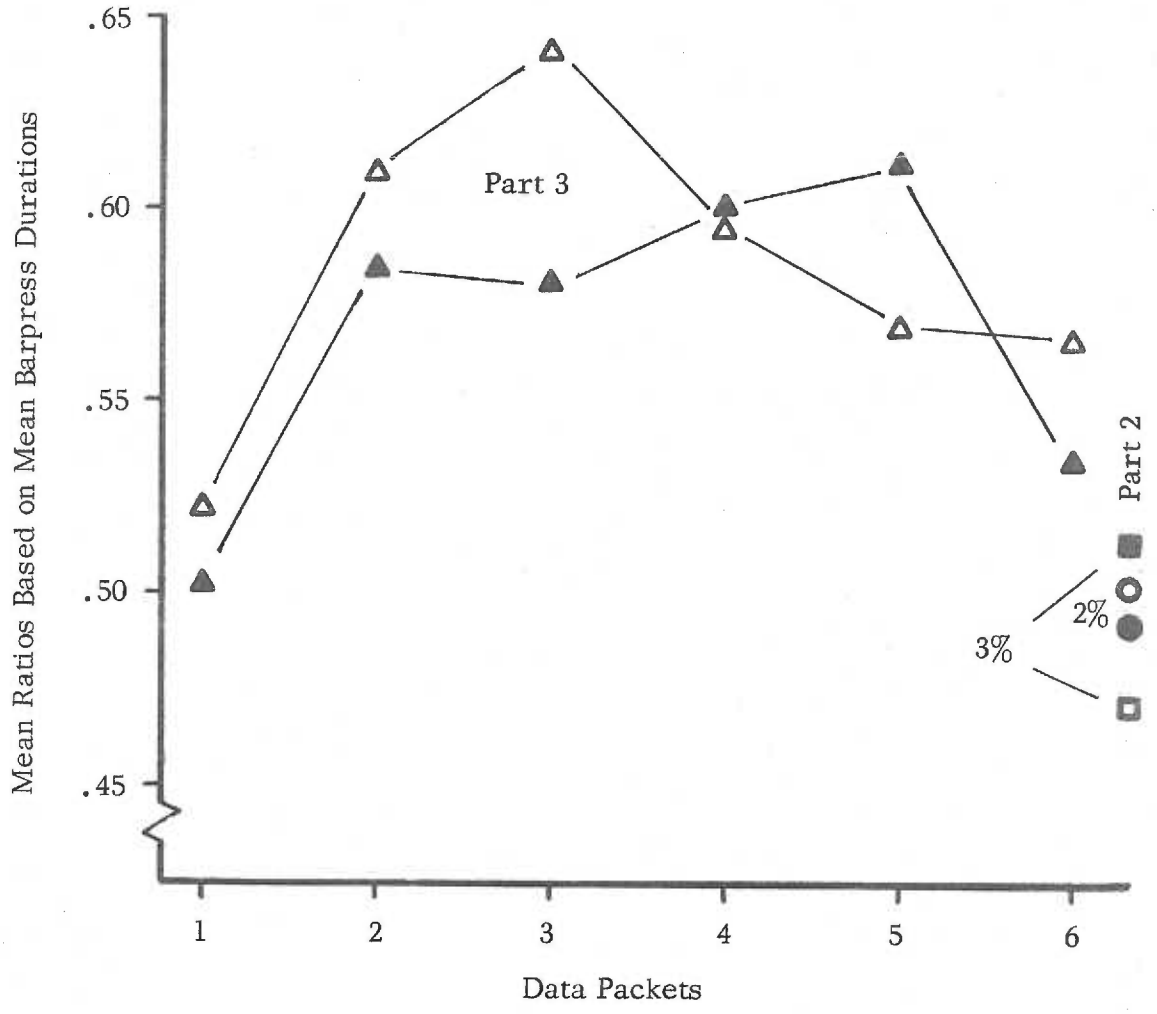

Figure C18. Interactions of tone location by data packets in Part 3 (△) and EtOH concentration by conditioning contingency in Part 2 (○, □) for suppression ratios based on barpress durations. Open symbols indicate FR sequences with the CS in the second data packet in Part 3, and in Part 2 indicate the UF subgroup. In Part 2 filled symbols indicate the CR subgroup, and in Part 3 they indicate FR sequences with the CS in Data Packet 4.

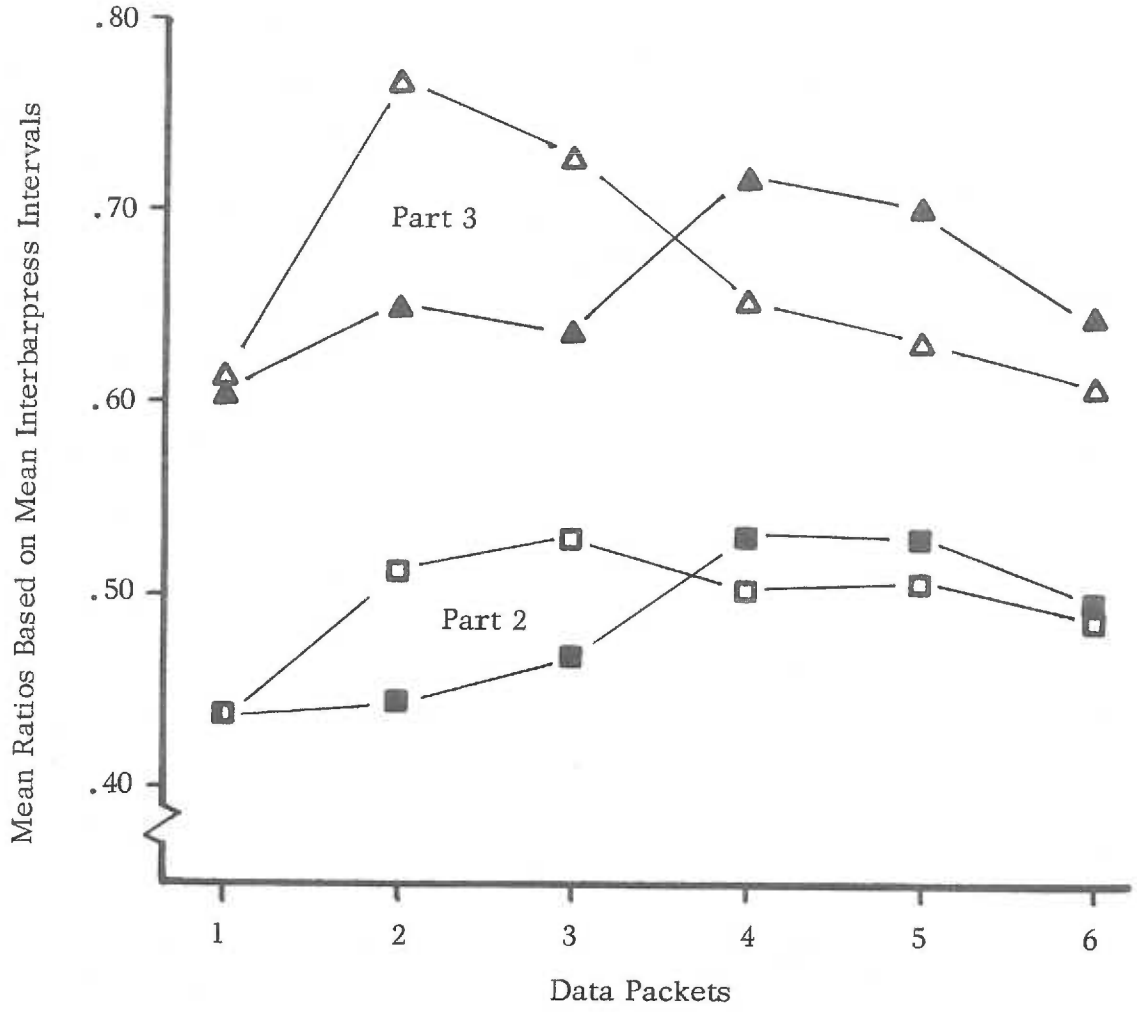

Figure C19. Suppression ratios computed with interbarpress intervals from sessions of testing for conditioned frustration. Open symbols indicate FR sequences with the CS in Packet 2; filled symbols indicate sequences with the CS in Packet 4. Part 2 (□) comprised FR sequences 4 and 5; Part 3 (△) comprised nonreinforced sequences.

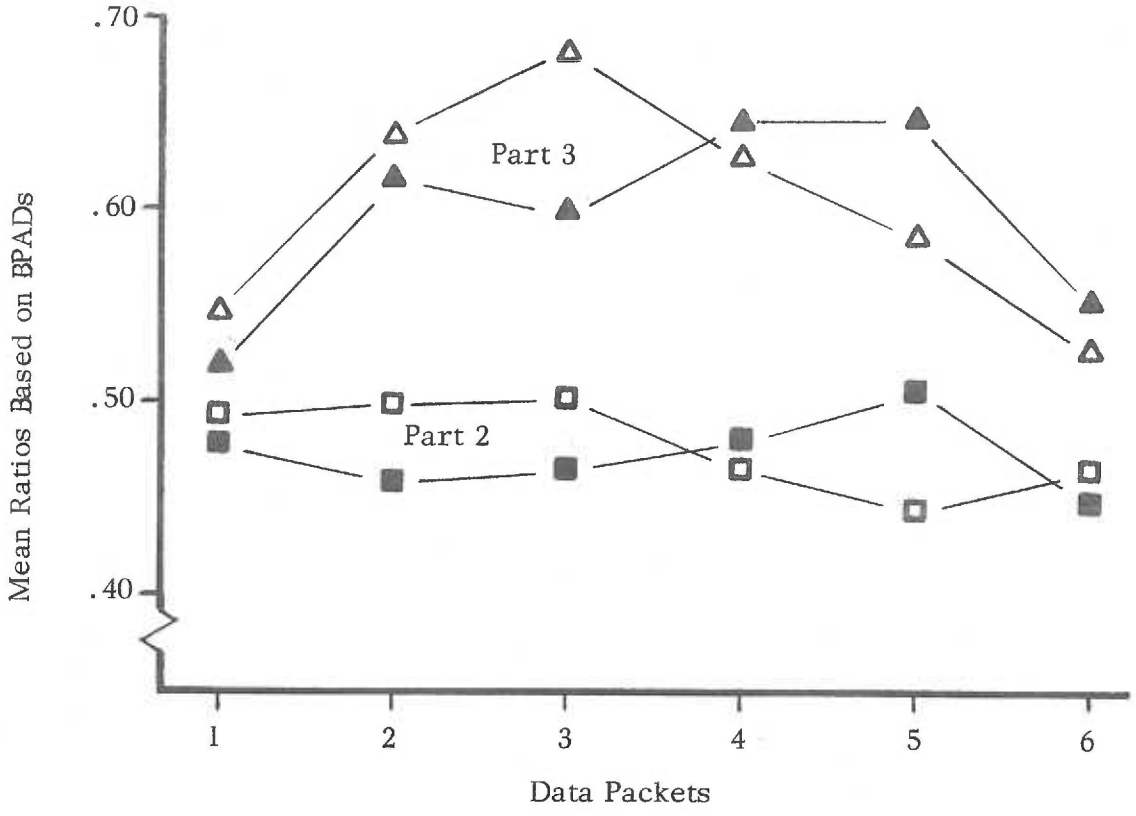

Figure C20. Suppression ratios based on mean standard deviations of bar-press durations during sessions of testing for conditioned frustration. Open sumbols indicate FR sequences with the CS in Packet 2; filled symbols indicate sequences with the CS in Packet 4. Part 2 (□) comprised FR Sequences 4 and 5; Part 3 (△) comprised nonreinforced sequences.

data packets nor its interaction with tone location was significant [Fs(5,220) = .66, 2.14, respectively], but the interaction was significant [F(1,44) = 7.99, p < .01]; For the analysis of ratios for BPADs the effect of data packets was not significant [F(5,220) < 1] but its interaction with tone location was [F(5,220) = 3.5, p < .01]. Followups of these interactions were accomplished with Tukey (a) tests.

FR Sequences 4 and 5. Ratios of suppression for FR durations in Part 2 are shown in Figure C17. When the tone occurred in the second packet ratios in the third packet were greater than ratios in the first packet. In addition, ratios in the second and third packets were greater than the respective ratios when the tone occurred in the fourth packet. Within FR sequences with the tone in the fourth packet, ratios in the fourth and fifth packets were greater than ratios in the first two packets.

The interaction of EtOH concentration by conditioning contingency for ratios of barpress durations in Part 2 is revealed by the isolated points at the right of Figure C18. The only significant difference was that ratios for 3% animals in the CF group were greater than ratios for 3% animals in the UF group. Apparently, then, the tone increased the average duration of discrete barpresses more than 3% rats if it had been paired with frustration during the conditioning phase than if it had been unpaired.

Ratios for the interbarpress intervals (see Figure C19) reveal a pattern very similar to that for FR durations but somewhat more pronounced. When the tone occurred in the second data packet, ratios in Packets 2-5 were greater than ratios in the first packet, and ratios in the second and third packets were greater than the respective ratios for sequences with the tone in the fourth packet. Within sequences with the tone in the fourth packet, ratios in the fourth and fifth packets were greater than ratios in the first three packets, and ratios in the sixth packet were greater than ratios in the first packet.

In Figure C20 the frustration ratios for BPADs are shown. A similar pattern to that of ratios for FR durations and interbarpress intervals is evident.

Nonreinforced sequences. Ratios for all three measures in Part 3 were obviously greater than ratios in Part 2 (Figures C17-C20) In addition, the effects of the CS seemed somewhat more dramatic. For FR durations (Figure C17), when the tone occurred in the second packet ratios in that packet were greater than ratios in all other packets except the third, where ratios were greater than those of the first, fifth, and sixth packets. Ratios in the second and third packets were also greater than the respective ratios of sequences with the tone in the fourth packet. In the sequences with the tone in the fourth packet ratios in the fourth and fifth packets were greater than ratios in the first and sixth packets, but did not differ significantly from ratios in the respective packets of sequences with the tone in the second packet.

Ratios for the barpress durations produced a slightly different pattern in Part 3 (Figure C18). With the tone in the second packet ratios in the third packet were greater than ratios in Packets 1 and 4-6, and ratios in Packet 2 were greater than those of the first, fifth, and sixth packets. With the tone in Packet 4 ratios in Packets 2-5 were greater than ratios in the first and sixth packets. Differences between FR sequences with the tones in different locations attained significance in both the third and fifth data packets.

In Figure C19 the uppermost two lines characterize the performances in Part 3 as revealed by the frustration ratios for interbarpress intervals. When the tone occurred in the second packet ratios in that packet were greater than ratios in all other packets except the third, where ratios were greater than those of the first, fifth, and sixth packets. Ratios in the second and third packets were also greater than the respective ratios of sequences with the tone in the fourth packet. In the sequences with the tone in the fourth packet, ratios in that packet were greater than ratios of the first and third packets, and ratios in Packet 5 were greater than ratios in the first packet.

A similar pattern occurred for BPADs, and is illustrated in Figure C20.

Number of Sequences Completed During Test Sessions

As a sort of "trials-to-extinction" measure, the number of FR sequences completed during each test session by each rat was used as a

datum in three way analyses of variance with between subjects factors of conditioning contingency (CF or UF) and fluid consumed (EtOH or SW) and a within subjects factor of days (four levels). For both 2% and 3% rats the results were limited to a significant effect of days [Fs(3,60) = 22.9, 28.8, respectively, $p < .001$]. An additional analysis with a between subjects factor of EtOH strength (2% or 3%) instead of fluid consumed (subjects per group increased from 6 to 12) revealed a single significant effect of days [$F(3,132) = 47.4$, $p < .001$]. That factor was significant because more FR sequences were completed on the first test day (24.5) than on the other days and more were completed on the second day (17.2) than on the third (13.0) and fourth (10.3) days, where the numbers completed were equivalent.

Drug Shift Results

For analyses of shift data, the 2% and 3% rats were considered as a single group. Half of these rats had consumed EtOH prior to sessions of testing for conditioned frustration and half had consumed SW. For examination of the effects of shifting drug conditions, half the rats that had had EtOH were switched to SW, and half those on SW were switched to EtOH.

The results of previous analyses indicated that the factor of conditioning contingency was not likely to be significant. Also, the CS was not presented during these drug shift days, so there was no reason to continue to exclude the data of the nine rats which had

been eliminated from consideration insofar as testing of conditioned frustration was concerned. Thus the data from those rats, and of the additional seven which had previously been eliminated to keep group sizes equal, were included in the analyses of shift data. This increased the total number of subjects to 64, and set the group sizes for the initial analyses at 16.

The number of FR sequences completed by each rat on each of these 2 days was determined and used as a datum in a three way analyses of variance with between subjects factors of drug condition (shifted or nonshifted) and fluid consumed during days of testing for conditioned frustration (EtOH or SW) and a within subjects factor of days. The only significant outcome of this analysis was a F ratio of 26.87 for the factor of days (df = 1,60; $p < .001$). On the first drug shift day the rats averaged 12.1 FR sequences completed. On the second drug shift day 8.5 FR sequences were completed on the average.

Duration measures were averaged across the 2 days and then converted to rates. Similarly, the standard deviations for barpress durations were averaged across days. In the few cases of missing data, when rats had completed fewer than six FR sequences on each of the 2 days, if a duration was not available then a rate of zero was used; if a standard deviation was missing then the overall average deviation of those that were available was used.

Four way analyses with between subjects factors of drug condition (shifted or nonshifted) and fluid consumed during testing (EtOH or SW)

and within subjects factors of parts (three levels) and data packets (six levels) revealed similar results for the four dependent measures. In every case the factors of parts [all $\underline{F}$s(2,120) > 12.9, $\underline{p}$ < .001] and data packets [all $\underline{F}$s(5,300) > 42.0, $\underline{p}$ < .001], and their interactions [all $\underline{F}$s(10,600) > 3.4, $\underline{p}$ < .001], were significant.

These main effects and interactions are shown in Figures C21-C24. In every case the measures in Parts 1 and 2 are alike, whereas those of Part 3 were either slower (rate measures) or greater (average standard deviations of barpress durations). In the case of FRRs (Figure C21) rates in Packets 3-5 were equivalent in Parts 1 and 2 and higher than all the other rates. Also in Parts 1 and 2, rates in Packets 2 and 6 were equivalent and higher than rates in the first packet. In every data packet rates in Parts 1 and 2 were higher than rates in Part 3. In Part 3 rates increased significantly from the first to the second packet and from the second to third packet, and were equivalent in the remaining packets.

In the case of BPRs (Figure C22), in Parts 1 and 2 the rates in Packets 2-5 were equivalent and higher than rates in the first and sixth packets, in which they were equivalent. In every data packet save the sixth rates were higher in Parts 1 and 2 than in Part 3. In Part 3 the rates were equivalent in Packets 3-6; in the second third, and sixth packets, and in the first and second packets (all other differences were significant).

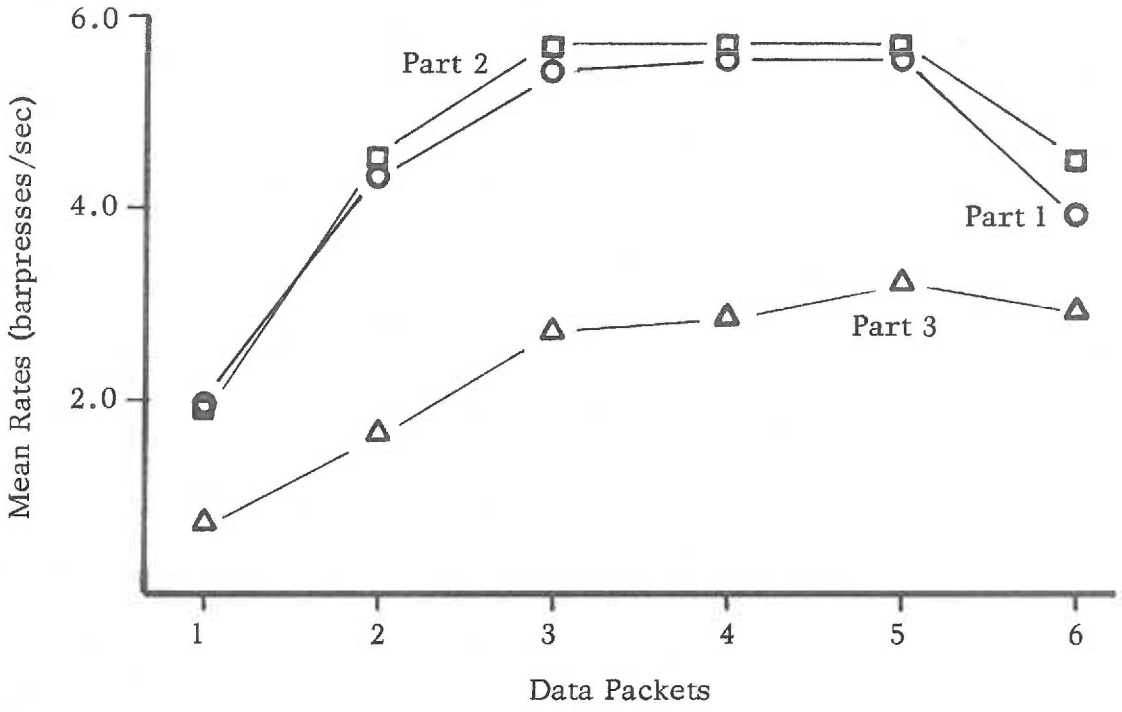

Figure C21. Rates of barpressing during drug shift days. Rates are shown for the first three FR sequences (Part 1: ○), FR Sequences 4 and 5 (Part 2: □), and nonreinforced sequences (Part 3: △).

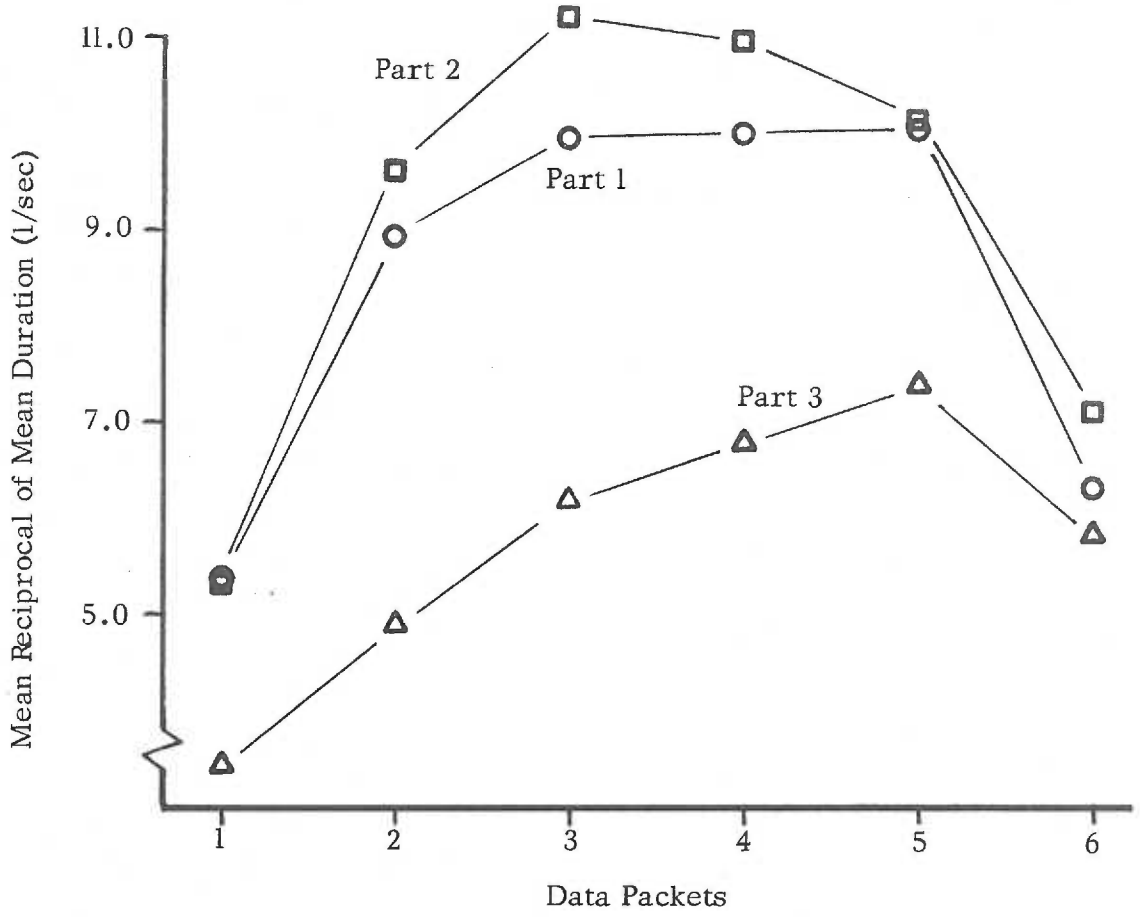

Figure C22. Reciprocals of mean barpress durations during drug shift days.

Interbarpress interval reciprocals differed between Parts 1 and 2 and Part 3 in every data packet. In all three parts speeds increased through the first three data packets, and were equivalent in Packets 3-6.

Only in the second data packet was the difference between standard deviations of the different parts significant--barpress durations in Part 3 were more variable than durations in Parts 1 and 2. The patterns within sequences were similar for each part: average deviations in the first and sixth packets were equivalent and greater than those of the other packets.

Ancillary Information

Body Weights

Throughout the experiment the body weights of the rats were monitored. These daily weights were grouped into blocks of 5 days each, and median weights were determined for each 5-day block. For purposes of analysing the body weights the days of the experiment were divided into three units. The first unit was the period from Apr 30 through Jun 8, which included the phases of deprivation adaptation, barpress shaping, and that portion of the FR training phase during which half the rats received the nominal 5% ethanol solution. The second unit commenced with Jun 9 and ended on Aug 1, and thus included most of the days of FR training. The final unit included the remaining days of the experiment (Sep 21-Oct 15), during which the refresher sessions, conditioning of frustration, primary frustration tests,

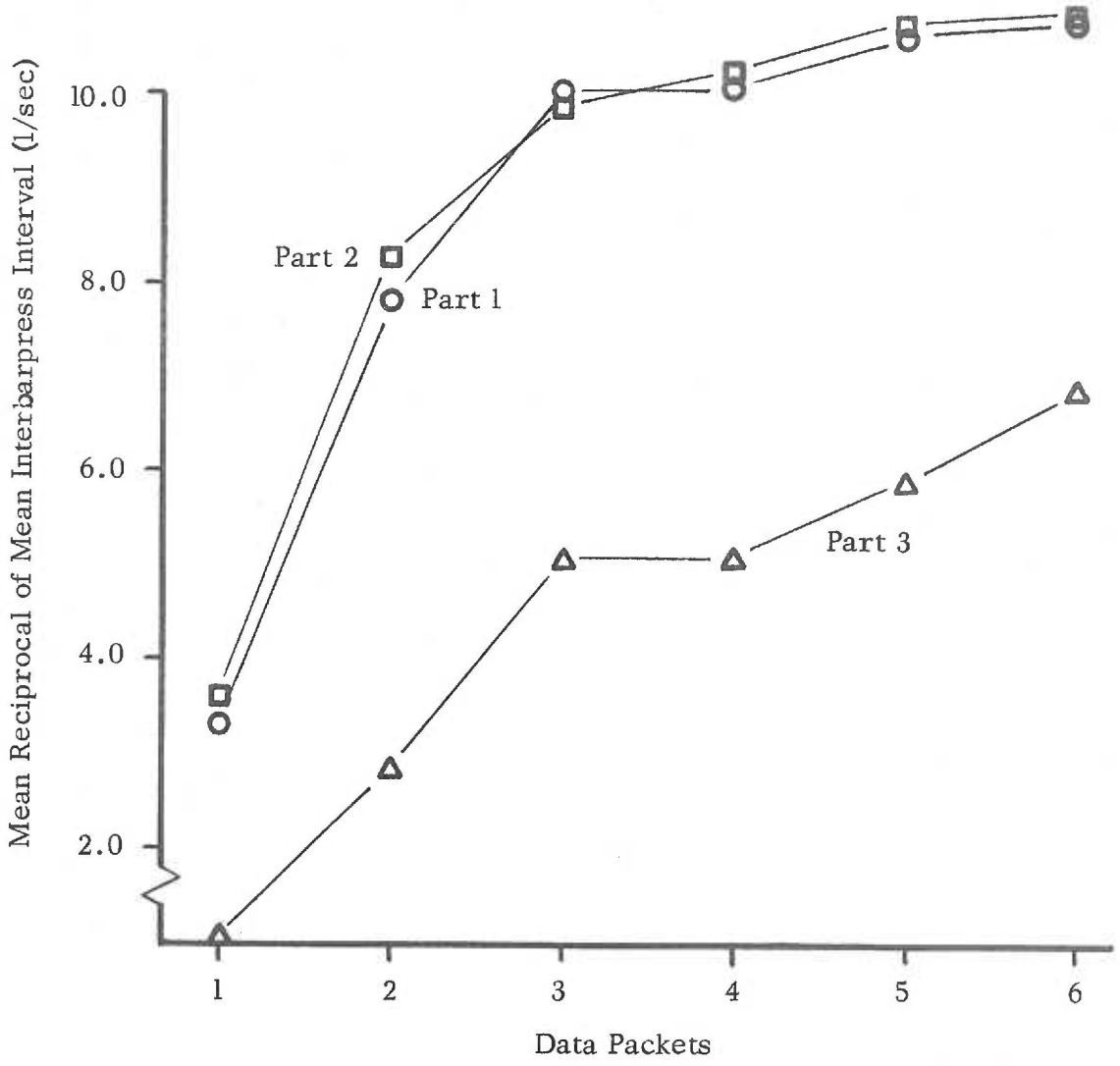

Figure C23. Interbarpress interval reciprocals during drug shift days.

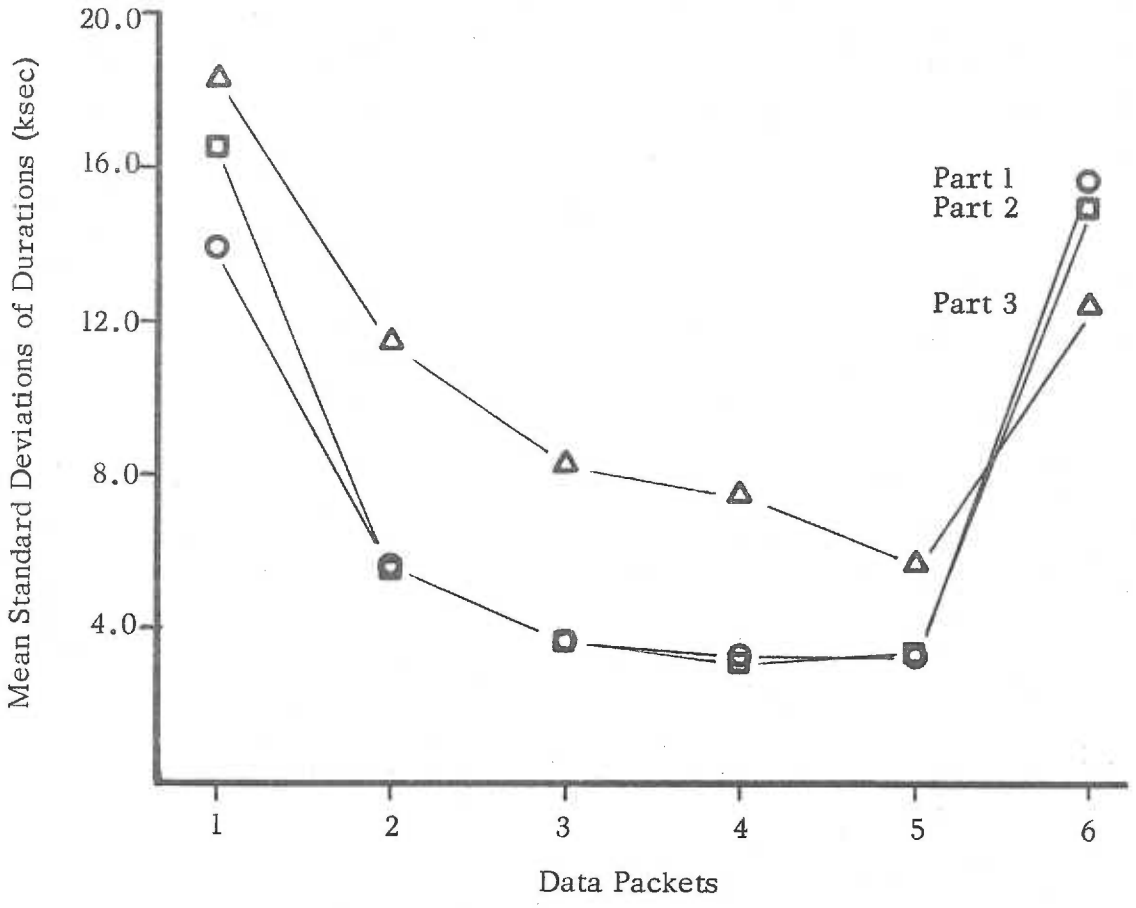

Figure C24. Average standard deviations of barpress durations during drug shift days. Values shown are multiples of 1000 of the actual mean standard deviations.

conditioned frustration tests, and drug shift tests occurred. Median weights for each rat throughout each of these units were subjected to three way analyses of variance with between subjects factors of EtOH strength and conditioning contingency, and a within subjects factor of blocks of 5 days. In each of the three analyses the factor of blocks of 5 days was significant [all $\underline{F}$s > 23.0, $\underline{p}$ < .001]. No other factor and no interaction was significant. As can be seen in Figure C25, the rats gained weight throughout the FR training phase, but lost some weight during the days of conditioning and testing. In addition, there was a marked weight gain during the period of respite from the beginning of August to Sep 21.

Ethanol Dosing

Ethanol was self-administered by the rats throughout the experiment. On each day that a rat drank ethanol solution, a dose was calculated based on the body weight of that rat and the amount and strength of the solution consumed. These doses were averaged so that for each rat 17 means of two doses were available. Recall that rats drank ethanol on only half the days of FR training, refresher sessions, conditioning of frustration, and testing of primary frustration. During those phases the means of two doses represented 4-day blocks. During testing for conditioned frustration and drug shift days, however, only half the rats drank ethanol solutions, but drank ethanol every day. Thus during those phases the means of two doses represented 2-day blocks.

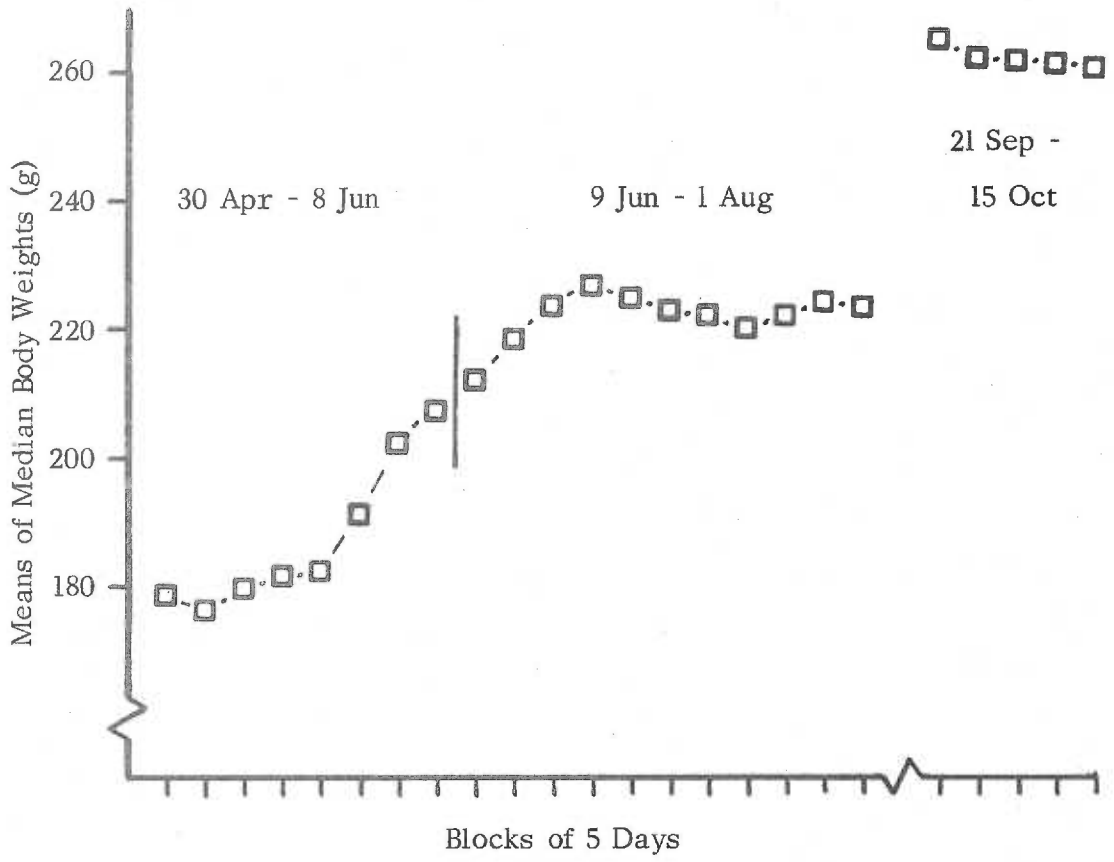

Figure C25. Means of median body weights over the course of the experiment.

These means of two doses were subjected to analyses of variance with factors which varied among experimental phases. The between subjects factors considered were EtOH strength, conditioning contingency, fluid consumed during testing for conditioned frustration, and drug shift condition. The only within subjects factor considered was two-dose blocks. These data were treated in six units. The first unit of two blocks included data prior to the change from 5% to 3% EtOH. The second unit included the seven two-dose blocks of FR training. The third unit included the four two-dose blocks of refresher sessions, conditioning sessions, and primary frustration testing. The fourth unit comprised the days of tests for conditioned frustration. The two final units were the doses of shift days and the doses of the days between drug shift and sacrificing the animals. The significant outcomes of these six analyses of variance are illustrated in Figure C26. In every analysis the factor of EtOH strength was significant (all $\underline{p}$s < .001). The factor of two-dose blocks was significant in the first three units (all $\underline{p}$s < .001) and approached significance in the fourth unit [$\underline{F}(1,20) = 6.14$, $\underline{p} < .025$]. In addition, the interaction of EtOH strength by two-dose blocks was significant in the second unit, the FR training phase.

Blood Ethanol Analysis

Plasma samples were analyzed in five separate batches (see Appendix B). For each batch of samples a separate regression line was

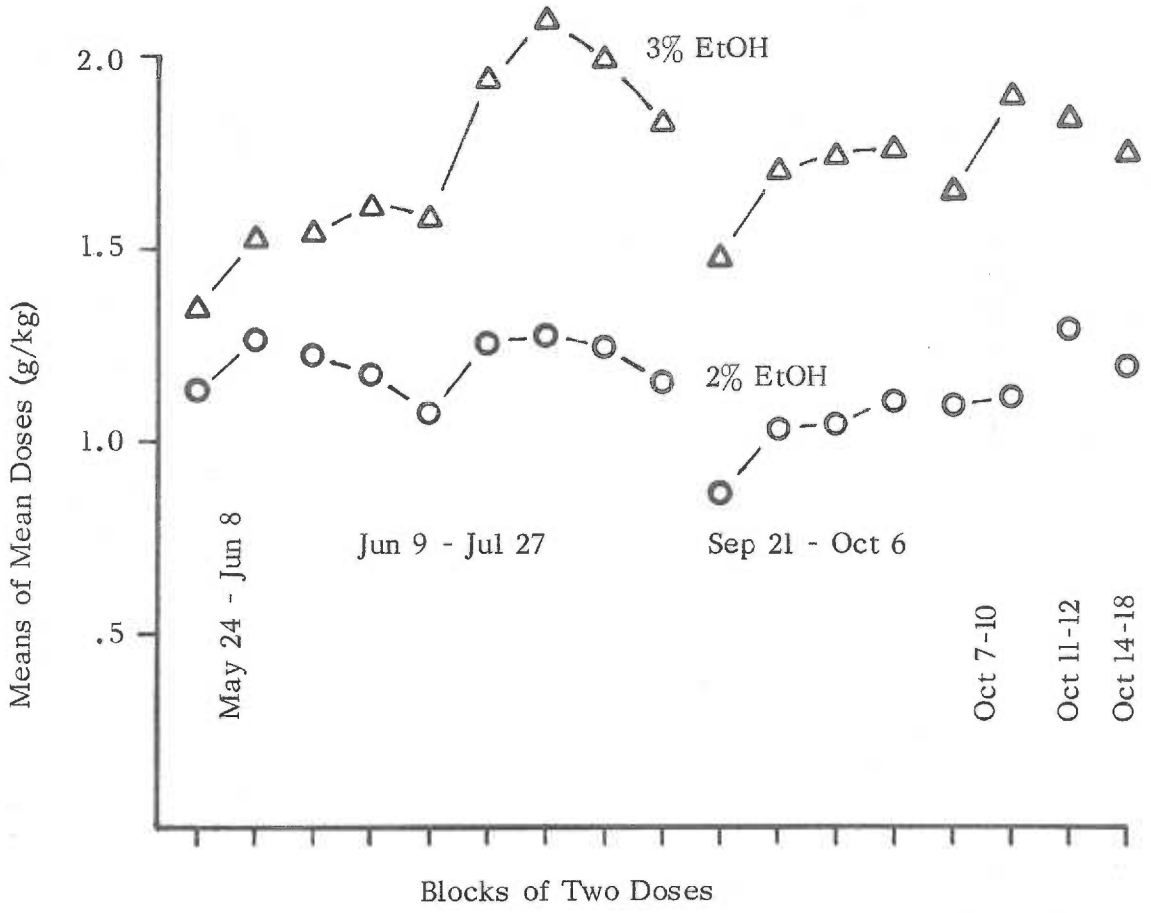

Figure C26. Ethanol dosing throughout the experiment.

derived, based on the median fluoromenter reading for each of the alcohol standards and the blank. The median blank reading was subtracted from each of the median standard readings, and a least squares line determined from the corrected fluorometer readings and known concentrations of the four standards. The equation for this least squares regression line was used to calculate ethanol concentrations for each of the plasma samples, using the corrected (raw score minus blank score) median fluorometer reading for that sample. In this fashion the ethanol concentration of each of the 64 plasma samples was determined.

A variety of doses had been self-administered by the rats so that at each of the time intervals after the beginning of the drinking period there was a range of blood alcohol levels. The doses and blood alcohol levels at each time interval were used to derive a least squares regression line at each of the intervals. These regression lines were used to generate Figure 7 (page 52), where blood alcohol curves at doses of 1.1g/kg, 1.6g/kg, and 2.5 g/kg are shown. Rats which drank the 2% EtOH during the drinking sessions prior to sacrifice self-administered doses with a mean of 1.1g/kg. The mean dose for rats drinking 3% EtOH was 1.6g/kg.