THE UNIVERSITY OF MANITOBA

CONTINGENCY CONTROL OF ALCOHOL DRINKING IN RATS

by

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has been approved

October 1971

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ABSTRACT

Four male albino rats were trained to lick a tube containing 10% ethanol or water for food reinforcement. The pattern of responding under a variable interval 30 seconds contingency (for either alcohol or water) did not resemble the typical slow steady rate, characteristic of operants reinforced on a variable interval schedule. On a variable interval 6.5 second schedule, the responding patterns for alcohol and water changed to a stable rate. When the mean reinforcement interval was reduced for licking the water tube, the volume of fluid consumed per session decreased. When the mean interval for alcohol consumption was reduced, alcohol consumption was equal to or greater than consumption under a larger interval. It seems that under some conditions alcohol consumption in rats resembles other operants under similar contingencies (Black & Martin, 1972), however, the present study suggests there are other variables controlling the response on a variable interval schedule.

ACKNOWLEDGEMENTS

I wish to express my appreciation to the members of my committee, Drs. Glen Lowther, Joe Pear and Gary Martin, for their co-operation and advice. I also gratefully acknowledge Tony Wawryko for his assistance in collecting the data for this research, and Greer Black for his helpful assistance in locating and integrating relevant sources of information.

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INTRODUCTION

Alcoholism, a major social problem, was once attributed to inner states such as a weak will, personality disorder, oral passivity, latent homosexuality and the like. More recently, medicine has defined alcoholism as a disease, probably with a physiological basis or possibly a result of some metabolic malfunction (Goth, 1970). A third alternative proposed recently is that alcoholism might be viewed as a functional or operant response (Kepner, 1964; Keehn, 1970; Martin, 1971).

The use of inner states as explanations of behavior has been an unproductive procedure in terms of uncovering relevant variables involved in an experimental analysis. The medical model of a physiological addiction has received considerable support. Goth (1970) stated, "alcohol is truly addictive as its sudden withdrawal produces withdrawal symptoms." These symptoms appear in acute cases as a variety of observable behaviors: the person is stuporous, or comatose; cold; clammy; he has dilated pupils and depressed respiration (Bergersen & Krug, 1969). In chronic cases the person may have a red face and nose, fatty liver, tremors, muscle weakness, hallucinations, delusions and

insomnia (Bergersen & Krug, 1969). Chronic alcoholics usually suffer from vitamin deficiencies as a result of poor diet. Goth (1970) stated that an evaluation of a physiological basis for alcohol addiction is difficult as alcoholics also suffer from nutritional deficiencies.

Jellinek (1960), formerly of the World Health Organization, conducted an intensive study on alcoholism, and devised a system of classification that describes five types or phases of alcoholism, each of which are described below. The types are not that clear-cut, and can overlap, thus no one person can really be labelled one type or another.

1. Alpha Alcoholism

This group represents a purely psychological dependence upon the effects of alcohol to relieve bodily or emotional pain. Alcohol consumption in this type reportedly causes absenteeism from work, friction in interpersonal relations, some nutritional deficiencies, but no signs of a progressive process.

2. Beta Alcoholism

This type of alcoholism involves complications; loss of appetite, vitamin deficiencies and skin lesions. More serious complications may develop; polyneuropathy, gastritis and cirrhosis of the liver.

3. Gamma Alcoholism

This phase is characterized by the loss of control over drinking and a state of "addiction" may have developed, and intoxication may continue for several days.

4. Delta Alcoholism

This type may be considered an extension of Beta Alcoholism, characterized by daily alcohol intake. After many years, the alcoholic becomes irritable and aggressive. If an attempt is made to stop drinking the withdrawal symptoms are severe, with gross tremors, gastrointestinal upsets, dehydration, psychomotor restlessness, sleeplessness, hallucinations and delirium tremors. The alcoholic may have organic disturbances, such as cirrhosis of the liver, peripheral neuropathics and chronic brain damage.

It is the opinion of this author that the role of vitamin deficiencies in the production of behaviors labelled withdrawal symptoms are not given sufficient weight in the formulation. The behavioral disruptions caused by a lack of the B vitamin complex correlate well with behaviors regarded as withdrawal symptoms.

According to Guyton (1966) vitamin B_1 deficiency causes degeneration of the myelin sheaths of nerve fibres in both the peripheral and central nervous systems; pain radiating along peripheral nerves, and in extreme deficiency, paralysis. Vitamin B_2 deficiency produces dermatitis, vomiting, diarrhea, muscular spasticity, and mental

depression. Vitamin B_{12} deficiency can cause demyelination of the large nerve fibres of the spinal cord; severe cases can cause paralysis. Vitamin B_6 deficiency causes fatty liver, dermatitis, mental deterioration, convulsions, nausea and vomiting. A lack of pantolhenic acid can lead to depressed metabolism of both carbohydrates and fats, fatty liver and other metabolic deficiencies. Biotin deficiency could have an adverse effect on the metabolic efficiency of the body. Inositol deficiency can cause fatty liver. Niacin deficiency causes muscle weakness, pathologic lesions to appear in many parts of the central nervous system, and "permanent dementia" or any of many different types of psychoses may result.

It seems reasonable to suppose that most of the behaviors called "withdrawal symptoms" could be due to vitamin deficiencies. Alcoholics classified in the gamma phase by Jellinek (1960) remain intoxicated for days using alcohol as their sole intake of food. Since alcohol is composed of the same elements as sugar, starch, and fat, it is energy rich (one gram of alcohol yields seven calories while one gram of sugar yields only four). Drinking undiluted beverages affects the mucosa lining of the stomach. This may produce vomiting, loss of appetite and less food intake. Cowgill developed a vitamin-calorie ratio based on the average American diet. According to his figures, the average American diet contains approximately 2,500 calories and 6,800 milligrams equivalent of vitamin B_1.

The ratio of vitamin B_1 over calories equals 2.7. If the ratio falls below 1.7 signs of vitamin B_1 deficiency will appear. If the alcoholic consumes alcohol for several days he will have a diet devoid of vitamins and develop behavioral disorders. Therefore, it seems logical that most of the withdrawal symptoms are due to bad diet.

The action of alcohol on the body is similar to that of a general anesthetic (Bergersen & Krug, 1969). The excitement stage is longer than a general anesthetic and toxic symptoms are present. Mild doses produce talkativeness and vivacity; moderate doses produce excitement, impulsive behavior, hilarity, even fighting. Large doses produce unconsciousness and eventually death due to respiratory depression. A general anesthetic produces an orderly change in behavior, generally classified or grouped into three stages (Bergersen & Krug, 1969). The initial stage begins with the first inhalation and lasts until the patient loses consciousness. It is characterized by excitement, respiration and pulse increase and a gradual loss of sensation. The second stage, called the excitement period, is usually characterized by a mild tremor, stretching of the extremities or irregularities in respiration; however, in habitual users of alcohol, there is great excitement and violent movements. This stage begins with movement of the arms, designed to push the mask away, or to enable the patient to rise. Then other muscles are used and the patient may struggle, sing, shout, laugh, swear, or talk. The

muscle tone of the body is increased and all reflexes are present. The final stage, called surgical anesthesia, is characterized by the disappearance of certain reflexes. If alcohol resembles the effect of a general anesthetic, it may mediate or suppress observable behaviors usually associated with mild vitamin deficiency in habitual alcohol users. Thus when this person is hospitalized, mild withdrawal symptoms may occur. If the person has consumed large amounts of alcohol over a long period of time, sudden withdrawal of alcohol may make the behaviors associated with vitamin deficiency appear in a dramatic manner; that is, the anesthetic properties of alcohol no longer dull the effects of vitamin deficiencies.

Popham (1970) stated that chronic intoxication with alcohol, barbiturates, and some central depressant drugs all induce physical dependence of a similar kind, which has been termed "dependence of the alcohol barbiturate type." Davis, Walsh and Yamanaka (1970) believe that alcohol addiction is linked biochemically with opiate addiction. They propose that alcohol dependence might result from alcohol-induced inhibition of the oxidation of 3,4-dihydroxyphenyl acetaldehyde from dopamine to 3,4-dihydroxyphenyl acetic acid. Instead of normal oxidation, large and continuous intake of alcohol causes the amine derived aldehyde to be metabolized by a normally unused pathway leading to tetrahydropapaveroline (THP or norlaudanosoline, and, in turn to morphine derivatives

with consequent addiction).

Several investigators believe alcoholism is a learned response and disagree with the belief that alcoholism is based on a physiological craving (Sobell & Sobell, 1972); Keehn, 1970). Keehn (1970) suggested that if we look at alcohol drinking as a high rate of response, we can examine it in terms of the relationships between schedules of reinforcement and patterns of response emission. He related studies in the animal literature that illustrate the manner in which unusual response rates are developed. For example, Findley and Brady (1965) shaped a chimpanzee to push a button 120,000 times per reinforcement by gradually reducing occasions on which reinforcement is delivered. Keehn suggested solitary drinking patterns in humans could be shaped in a similar manner. He suggested that the consequences of drinking that seemingly ought to reduce rate of occurrence but often fail to do so can be explained by a study of Azrin and Holtz (1966) which demonstrated that if punishment is paired with reinforcement, then punishment presented during periods of nonreinforcement produces an increase in response rate. Sobell and Sobell (1972) suggest alcoholism is a learned response to stress. They treated alcoholics at Patton State Hospital in San Bernadino, California. They allowed alcoholics to drink in a bar constructed in the hospital and delivered shocks randomly to the subjects through electrodes taped to their hands. To train social drinkers they allowed them to drink without

shock if they could make the drink last for twenty minutes. They claim to have made social drinkers out of 50% to 70% of the alcoholics. This finding is in direct contrast to the idea that the only cure for alcoholism is total abstinence. It suggests alcoholism may be attacked by examining the rates of alcohol drinking. Perhaps an alcoholic that has abstained from drinking completely seems compelled to drink heavily if he ever takes another drink because that first drink initiates large response chains built up under the influence of alcohol.

This collection of facts concerned with alcohol drinking as a learned response provides an organizational perspective in the investigation of alcohol effects in animals. This perspective will be described in the following literature review in which animal studies related to the above discussion will be outlined briefly in terms of consumption under aversive control, reinforcement, and as a schedule-dependent phenomenon.

CHAPTER II

REVIEW OF THE LITERATURE

The studies relevant to the conditioning of alcohol drinking may be classified as: (1) alcohol consumption under aversive control; (2) the reinforcement of alcohol consumption; (3) alcohol consumption as a schedule-dependent phenomena.

1. Alcohol consumption under aversive control.

The differential or dose-specific effects of alcohol could explain contradictory findings on the effects of alcohol on conflict and avoidance behavior. Masserman and Yum (1946) attempted to show that alcohol can mitigate neurotic behavior which arises from conflicts between shock avoidance and eating responses. Kaplan (1956) shocked rats in one compartment of a box. After animals had learned to escape from the shock compartment, one group was injected with water and a second group with alcohol. The alcohol group showed fewer escape responses in test trials. However, Kopmann and Hughes (1959) and McMurray and Jacques (1959) reported that alcohol did not affect their subjects' rate of shock avoidance. Reynolds and Van Sommers (1960) reported low doses of alcohol increase both responding and

avoidance responding, and high doses decrease avoidance responding. Goldman and Doctor (1966) reported that alcohol increased bar pressing both before and after the tone onset of a conditioned suppression paradigm in comparison to controls. Reynolds and Van Sommers (1960) suggested the effects observed in shock avoidance experiments may be dose-specific. The idea that alcohol produces "states" similar to an anesthetic with excitatory and analgesic effects may prove useful in interpreting the above results; that is, moderate doses would be expected to increase avoidance responding and resistance to extinction, whereas heavy doses would have the opposite effect.

2. The Reinforcement of Alcohol Consumption.

Senter, Smith and Lewin (1967) required rats in the first two phases to ingest a 7% ethanol solution to avoid shock, attain food and in a third phase allowed them to consume ethanol with no programmed consequences. The animals in the shock avoidance group were required to make a licking response of at least half a second duration to postpone shock for eight seconds. The animals in the food contingent group were trained to emit a sustained drinking pattern to obtain a 45 mg. food pellet. The duration of continuous drinking required for the delivery of a pellet was increased daily to a maximum of eight seconds. The animals in the group with no programmed consequences were exposed to a "yoked" procedure in which each animal was placed on 23

hours water deprivation and received the daily amount of alcohol consumed by a pairmate in the shock avoidance group, but no shock. The data reported were collected before (pre-ad lib) and after (post-ad lib) the experimental manipulations. The pre-ad lib and post-ad lib intakes of ethanol were similar for both the shock avoidance and the group with no programmed consequences. The group that received food reinforcement showed a significant increase in alcohol consumption following the conditioning period. The increase in alcohol ingestion was only temporary, and soon dropped to the pre-ad lib level. This study suggests positive reinforcement of drinking can increase consumption and provide a technique for studying "addiction."

Persensky, Senter and Jones (1968) performed a second experiment to provide a detailed description of the effect of positive reinforcement on alcohol consumption. The apparatus consisted of two juxtaposed boxes separated by a transparent guillotine door. The smaller start box was painted white and contained the lips of two drinking bottles projecting through one side. The second box called the "incentive box," contained stimuli known to be reinforcing to rats; food, blocks, balls, complex visual patterns on the walls. The start box contained a test solution, water choice. The rats were first placed on 23 hours food deprivation then allowed access to the "inventive" for half a minute for a total of 20 trials over two successive days. In the conditioning phase, the subjects were required to

drink 2 ml. or more of test solution (sucaryl or alcohol) within a five minute period to gain access to the incentive box. This conditioning phase lasted 27 days; each session lasted 45 minutes. In the final stage of the experiment, the subject was placed in the start box (extinction) for 15 minutes per day for 42 days.

They found that both groups showed an increased ingestion of test solution, however, their relative consumption index (volume of test solution consumed divided by total volume of water and alcohol consumed) remained virtually unchanged.

A study by Mello and Mendelson (1965) investigated the effects of a specific schedule of reinforcement. They trained seven rats to drink from a drinkometer for a liquid reinforcer presented by a dipper feeder. The delivery of the reinforcer was contingent on the emission of 64 licks within a specified time interval (slow responses were not counted toward the ratio). Alcohol and water were constantly available in the home cage. The rats were trained to drink a sucaryl solution for milk reinforcement, then a 10% ethanol solution was substituted for the sucaryl for 45 sessions. All rats drank alcohol for food reinforcement even though they were not food deprived. The number of slow responses were similar for six of the seven animals. The cumulative records showed that six of the seven subjects developed licking rates similar to the pattern characteristic of the fixed ratio (FR) schedule for at least part of the sessions.

A 10% ethanol solution was then substituted for milk as a reinforcer for 10 days. Under this condition six of the seven animals drank less ethanol and obtained fewer reinforcements. Milk was then reinstated as the reinforcer for 10 days in an attempt to replicate the performance of the previous milk reinforcement. However, only one subject earned as many reinforcers as during the training period.

The last manipulation in this was the removal of ethanol from the home cage. Alcohol drinking was reinforced by the production of ethanol by the dipper feeder. The number of reinforcements earned did not increase over the number earned when alcohol was available in the home cage. They concluded that the animals did not develop a dependency or tolerance for alcohol. This study was one of the first to reinforce drinking on a schedule.

Black and Martin (1972) exposed a drinking response to an FR 64 contingency. The animals were maintained at 85% of their ad lib weight and allowed constant access to ad lib water and 10% ethanol in the home cage.

The rats drank little alcohol in the ad lib condition, however, their consumption increased in both the home cage (HD) and Skinner box (SB) during magazine training and shaping. Both subjects showed stable drinking patterns in HC and SB (during FR 64). The ratio performance was a typical pattern. Two control rats were maintained at 85% body weight then returned to free feed, and then a reversal

was performed. Alcohol drinking (controls) seemed to be a function of deprivation as drinking increased rapidly during deprivation then returned to near zero under the ad-lib food condition.

The above study was extended by Martin (1971) in that his rats showed the same pattern of drinking on an FR 60. In addition, the rats consumed as much alcohol under the FR 60 condition as they did when pressing a bar for food reinforcement.

3. Alcohol Consumption as a Schedule-Dependent Phenomena.

Falk (1961) discovered that food deprived rats conditioned on a variable interval VI schedule to press a bar, consumed in a three-hour session, two to three times their normal daily free intake of water over many sessions even though they were never water deprived. This finding has been replicated frequently with water and alcohol (Lester, 1961; Holman & Myers, 1969). Thus it is possible for organisms to drink alcohol as a by-product of values of certain schedules of reinforcement of some independent response.

Martin (1971) systematically replicated Falk's procedure using FR schedules. Under an FR 30 for bar pressing the rats drank alcohol excessively. However, increasing the ratio to 60, 90 and 120 did not result in any further increase in milliliters consumed per session.

However, when the animals were returned to ad lib weight, alcohol consumption dropped rapidly. He found that although rats will consume the alcohol for caloric value the FR schedule had a greater effect on ethanol consumption.

In summary, rats can be conditioned to consume large volumes of alcohol by direct reinforcement or as a schedule-dependent phenomenon. In addition, alcohol drinking seems similar to other responses classified as operants, in terms of the relation of rate of response to the probability of reinforcement.

4. Possible Directions of Research.

The rationale and literature reviewed above suggest to this author several areas of investigation that may provide additional data on relevant variables involved in alcohol consumption.

One untouched area is the systematic investigation of the effects of vitamin deficiency on behavior. Diets could be restricted in such a manner that one vitamin was missing and the others present, and the behavioral effects evaluated on schedules of reinforcement or stimulus control. An investigation of this type would provide data on development of behavioral disruptions in the temporal pattern of an operant response. The question is, what effects will specific vitamin deficiencies have on behavior and how long will it take for them to develop? A related question is, will alcohol ingestion mediate or moderate the effects

relative to a control (vitamin-restricted, non-alcohol) group? In other words, if two groups are deprived of vitamins, will the behavioral disruptions of an alcohol treated group parallel the effects of a non-alcohol (vitamin-deprived) group?

The presentation of alcohol to an organism is an area that may provide an opportunity to increase the precision of the instruments used for investigation. Traditionally, alcohol is injected or the animal is reinforced for alcohol consumption. Perhaps alcohol drinking could be brought under stimulus control before the experiment proper or alcohol could be presented as a vapour. One possibility is the vapour delivery system, through the cage ventilation system with the aid of compressed air or oxygen. A vapour system would offer an advantage in that ether, alcohol or chloroform could be compared in terms of their effects on the same baseline; for example, an avoidance schedule.

In addition, dose response curves could be obtained. What effects will systematically increased drug doses have on a baseline rate? Perhaps the effect will parallel the action of a general anesthetic.

Many studies attempt to investigate the effects of stress on alcohol ingestion, however, they frequently produce conflicting results. Typically, shock or light is used as the stress or aversive stimulation. Part of the problem in such investigations could be the definition of

"stress." It may be misleading to interpret the consumption of alcohol in a shock avoidance situation as drinking to relieve stress, or, conversely, the lack of consumption as the failure of stress to produce drinking. Many types of "stress," for example, shock, light, restraint, chemical irritants, heat, could be examined systematically in conjunction with free access to alcohol.

Several studies have demonstrated that rats will drink alcohol for its caloric value when deprived of food. However, few studies have investigated alcohol consumption independent of deprivation. Perhaps alcohol drinking could be induced by electrical stimulation of the "drinking center" in the brain, or reinforced by stimulation of the medial forebrain bundle. This type of procedure would provide an evaluation of consumption in a non-deprived animal and provide further analysis of a physiological basis for addiction.

Another possible area of investigation is the comparison of alcohol drinking to operant responses. Alcohol consumption parallels other responses in terms of stimulus control and rate under different schedules of reinforcement, a strong case could be built up for a conception of alcohol drinking as an operant response. Alcohol drinking could be reinforced as one component of a multiple schedule with a "well studied" operant (bar pressing) in the other component. This method would allow the manipulation of schedule of reinforcement as an independent variable.

Ferster & Skinner (1957) stated that performances under various components of the multiple schedule are usually quite independent of each other and thus provide a technique for arranging control performances within a single subject and a single session. Studying these two responses in this manner would also provide a further analysis of Falk's (1961) polydipsia. The components could be reinforced on the same or different schedules and submitted to other traditional operant manipulations, for example, conditioned suppression or extinction.

CHAPTER III

STATEMENT OF THE PROBLEM

The purpose of this study was to examine the effects of VI food reinforcement on both the pattern and extent of ethanol drinking during daily sessions. A more general purpose was to examine alcohol drinking as an operant and compare the pattern to that of well studied operants (Ferster and Skinner, 1957) such as bar pressing in rats or key pecking in pigeons.

CHAPTER IV

METHOD

Apparatus

The apparatus consisted of standard Lehigh Valley programming and recording components, a Skinner Box containing a drinkometer attached to a calibrated bottle with a glass spout. The drinkometer was positioned by an adjustable clamp in the centre of, and 2 mm. behind a $1\frac{1}{4}$ inch square hole, two inches to the right of the magazine tray. A metal shield was placed over the square hole and provided a $1\frac{1}{4}$ inch by $\frac{1}{4}$ inch slot through which the rat could lick the tube. The shield was necessitated by the finding (Black and Martin, 1970) that rats would touch the drinking spout with their noses unless restrained by a shield. A red cue light was placed over a lever projecting into the experimental chamber left of the magazine tray. A 10% ethanol solution was prepared with tap water, by volume.

Subjects and Preliminary Procedures

Four naive, male albino rats designated S22, S23, S24 and S25, obtained from the Holtzman Laboratories, served as Ss. They were approximately five months old and

their ad lib weights were 469, 461, 481 and 483 gms. respectively. Four additional littermates served as a weight control group for approximating the normal growth curve of the experimental Ss.

The Ss were housed individually in 8" x 12" x 8" cages between sessions. All Ss were given constant access to a bottle of tap water in the home cage.

CHAPTER V

PROCEDURES AND RESULTS

A. The effects of VI 30 second food reinforcement for alcohol tube licking in the experimental chamber.

Procedure

The Ss were reduced to 85% of their free feeding weights (FFW) over a twelve day period, and were kept at this level for the first two manipulations. No baseline of alcohol consumption was taken as several studies have shown a general low level (1ml.) of consumption in one hour sessions (Black and Martin, 1970; Martin, 1971).

The Ss were then magazine trained by placing two food pellets in the food cup of the experimental chamber at the start of the session and then dispensing pellets on a variable interval one minute basis for the remainder of the session. In the following sessions, Ss were conditioned to lick the alcohol tube for food on a continuous reinforcement schedule. If a "non-licking" response, such as biting or nose touching the tube, occurred the glass spout was turned away from the opening. The spout was returned contingent on a licking response. This step took 6 sessions for S22, 8 sessions for S23, and 7 sessions for S's 24 and 25. After magazine training and shaping the

Ss were reinforced for alcohol tube licking on a variable interval (VI) 30 seconds.

The 36 minute sessions of VI 30 seconds continued for 21 days for S22, 22 days for S23 and 18 days for S's 24 and 25.

Results

The major effects of the influence of the VI 30 second contingency on alcohol tube licking would seem to be the following:

(1) All S's obtained approximately the same mean number of reinforcements per session (see Table I).

(2) All S's consumed moderate amounts of ethanol (12 - 17 ml.), and emitted a similar mean number of responses per session (within a range of 750 responses), see Table I and Figures 1, 2, 3 and 4.

(3) The drinking pattern for all S's was similar, although there are marked differences in overall rate, see Figures 5, 6, 7 and 8. S's 22 and 24 responded at a slower rate than S23 or 25. The slope of the record was not similar to the constant rate Ferster and Skinner (1957) described as characteristic of a variable interval contingency. All S's seem to respond at a high constant rate which abruptly changes to a slow steady rate, within and across sessions. S22 and S24 respond with smaller bursts after reinforcement but their pattern is almost identical to that of S23 and 25.

It was not possible to determine the effect of

the schedule contingency independent of the ethanol, on the pattern of responding. In order to assess the influence of the ethanol on responding, the following manipulation was initiated.

B. VI 30 second food reinforcement of water tube licking in the experimental chamber.

Procedure

The drinking tube was washed thoroughly to remove any trace of ethanol, then the tube was filled with water and the sessions conducted in the same manner as part A. The daily sessions continued for 19 days for S22 and 24 and 20 days for S23 and 25.

TABLE 1

Mean daily number of responses, number of reinforcements and alcohol consumption in the experimental chamber per experimental conditions for S22, 23, 24 and 25.

Subject	Condition	Mean Number of Responses	Mean Number of Reinforcements	Alcohol Intake per session in the experimental chamber (in ml.)
S22	VI 30", AL(Licks)	2,777.7	58.5	11.9
	VI 30", W(Licks)	4,695.1	62.9	28.1
	VI 6.5", W(Licks)	3,025.5	143.8	25.2
	VI 6.5",AL(Licks)	1,880.3	114.0	20.4
	VI 30" Bar Press	692.8	123.6	
	VI 15" Bar Press	1,070.3	72.3	
	VI 30" Bar Press	1,237.3	37.5	
S23	VI 30", AL(Licks)	3,136.8	59.6	14.9
	VI 30", W(Licks)	6,089.1	65.5	38.1
	VI 6.5", W(Licks)	4,763.2	166.9	33.0
	VI 6.5",AL(Licks)	4,200.7	164.1	26.4
	VI 30" Bar Press	773.5	122.0	
	VI 15" Bar Press	1,220.7	73.8	
	VI 30", Bar Press	1,189.0	36.6	
S24	VI 30", AL(Licks)	2,608.2	55.9	14.1
	VI 30", W(Licks)	4,397.9	62.3	31.2
	VI 6.5", W(Licks)	3,810.2	148.7	31.3
	VI 6.5",AL(Licks)	2,945.2	118.9	21.5
	VI 30", Bar Press	361.7	85.8	
	VI 15", Bar Press	484.3	63.0	
	VI 30", Bar Press	544.4	34.0	
S25	VI 30", AL(Licks)	3,531.8	58.7	17.6
	VI 30", W(Licks)	7,070.9	66.4	41.2
	VI 6.5", W(Licks)	4,617.3	177.8	37.4
	VI 6.5",AL(Licks)	3,924.6	165.0	27.6
	VI 30", Bar Press	872.3	129.1	
	VI 15", Bar Press	1,275.3	76.1	
	VI 30", Bar Press	1,283.0	36.9	

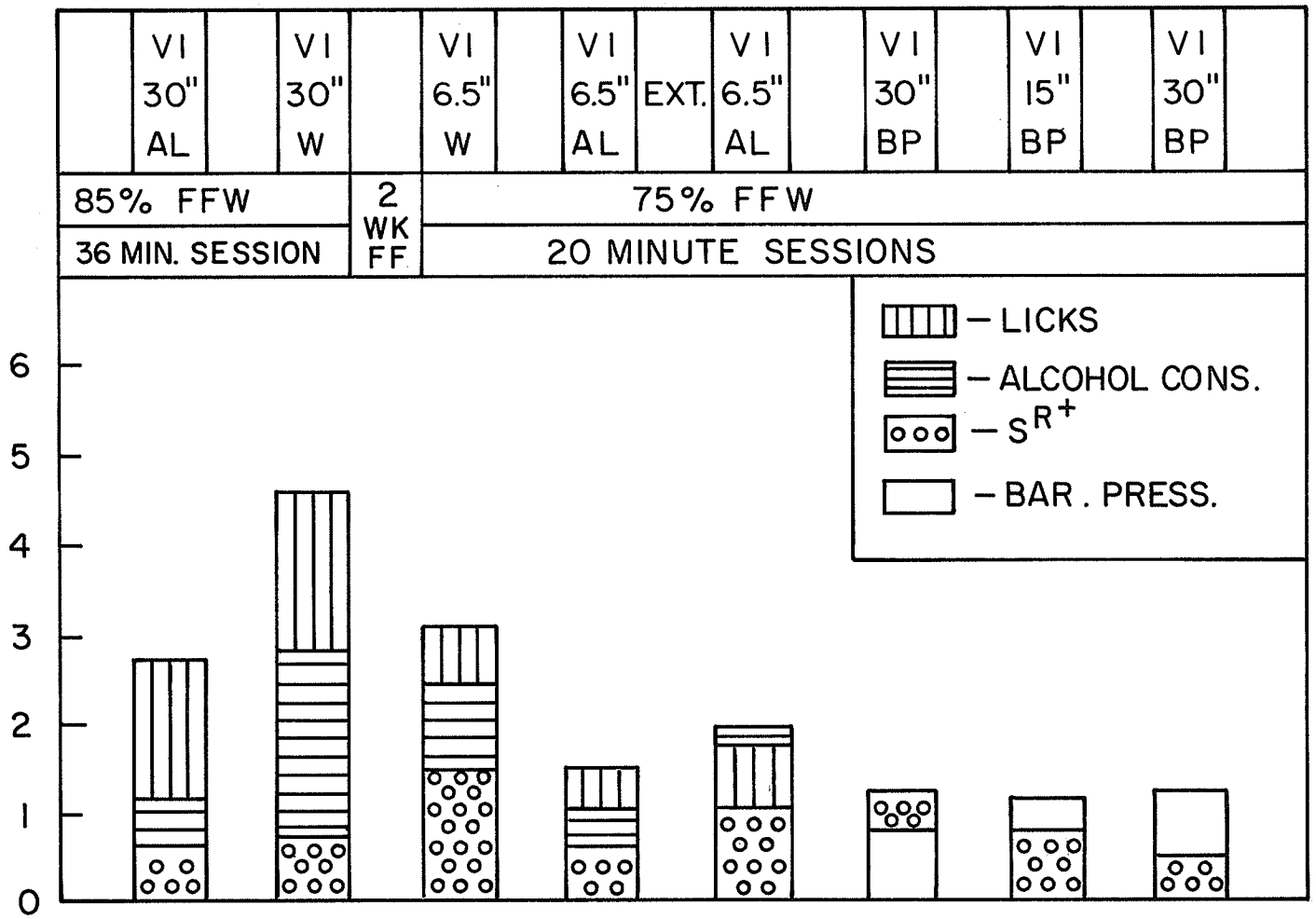


Figure 1. Mean daily number of responses (X 1,000), number of reinforcements (X 100), and alcohol consumption (X 10) in the experimental chamber per experimental condition for S22.

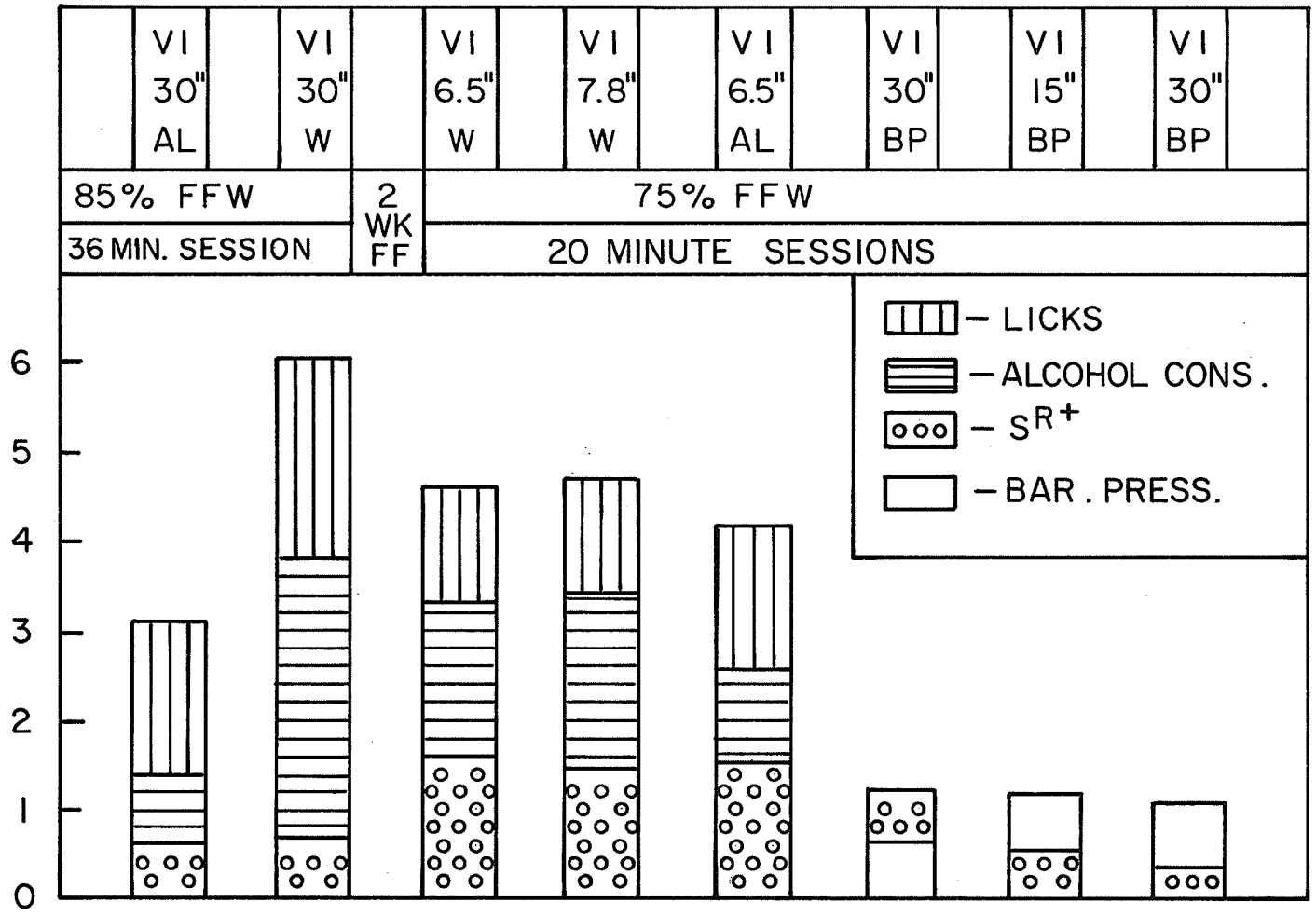


Figure 2. Mean daily number of responses (X 1,000), number of reinforcements (X 100), and alcohol consumption (X 10) in the experimental chamber per experimental condition for S23.

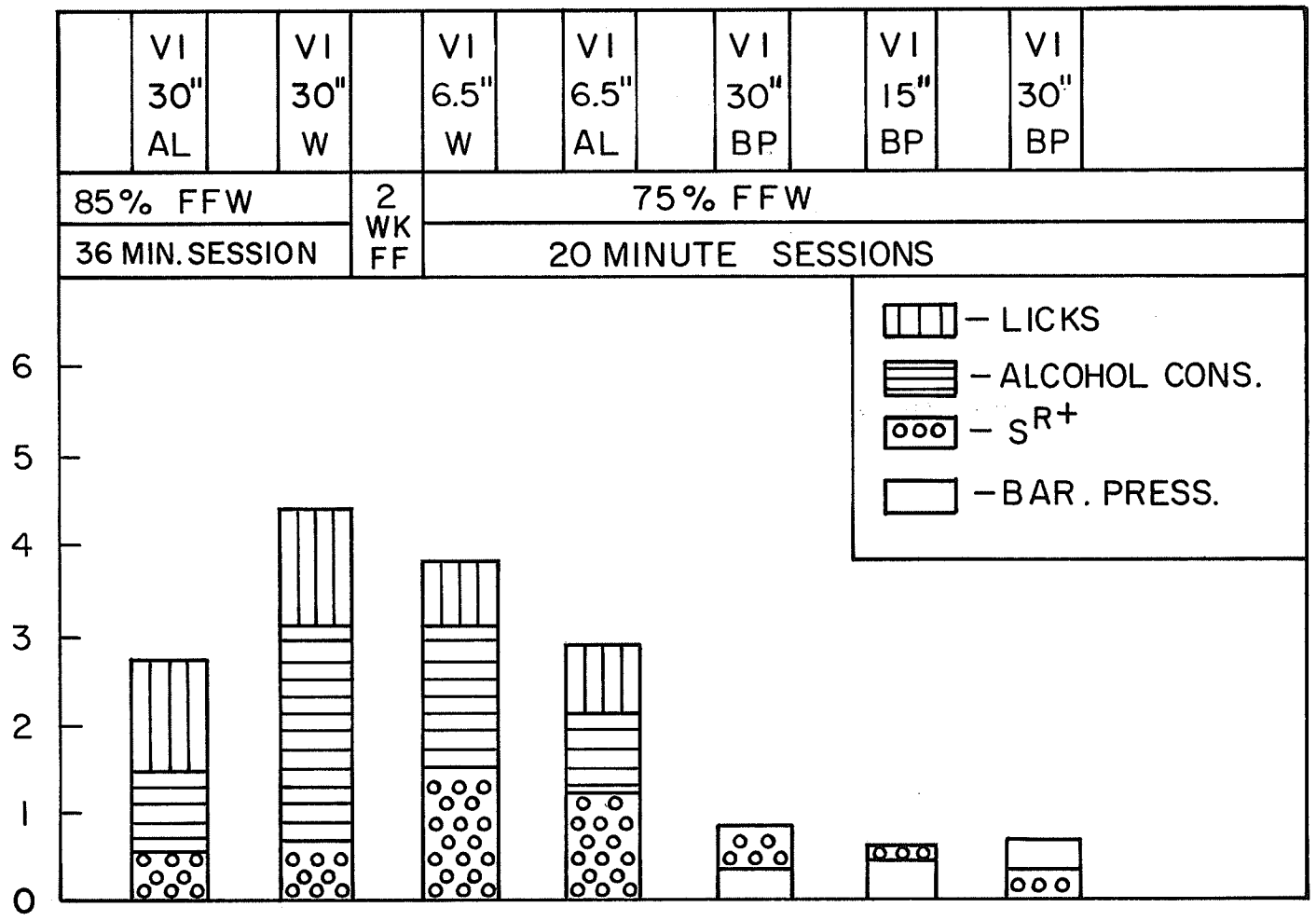


Figure 3. Mean daily number of responses (X 1,000), number of reinforcements (X 100), and alcohol consumption (X 10) in the experimental chamber per experimental condition for S24.

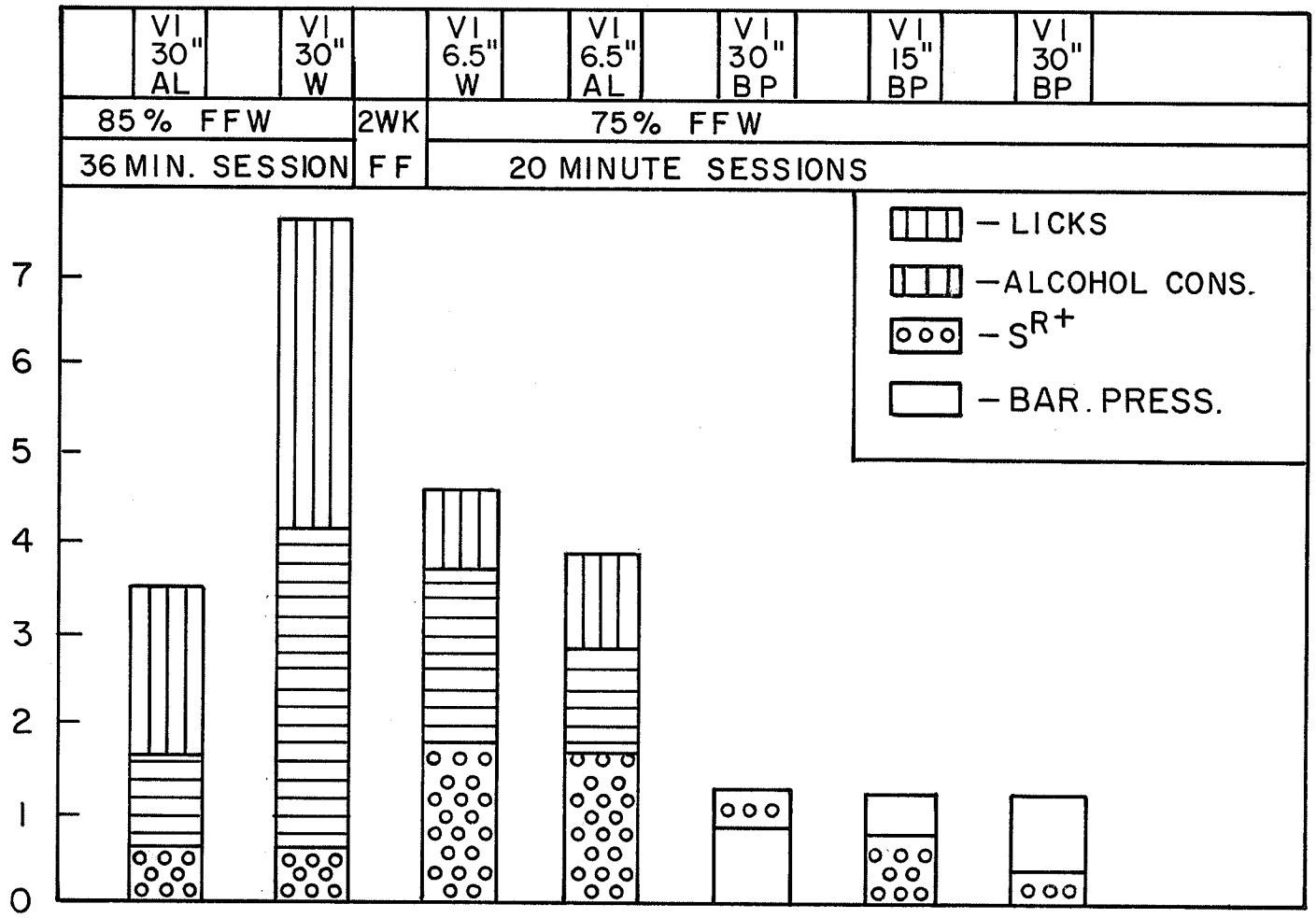


Figure 4. Mean daily number of responses (X 1,000), number of reinforcements (X 100), and alcohol consumption (X 10) in the experimental chamber per experimental condition for S25.

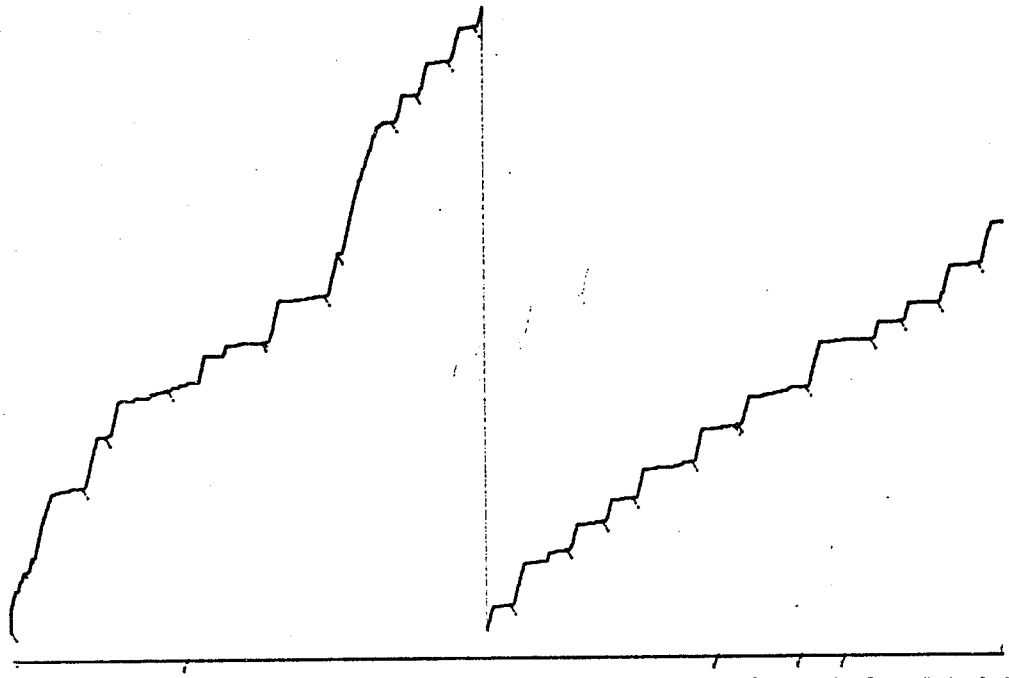


Figure 5. Cumulative record of S22's alcohol-tube licking under conditions of VI30-second food reinforcement. The record represents the first twenty minutes of a session.

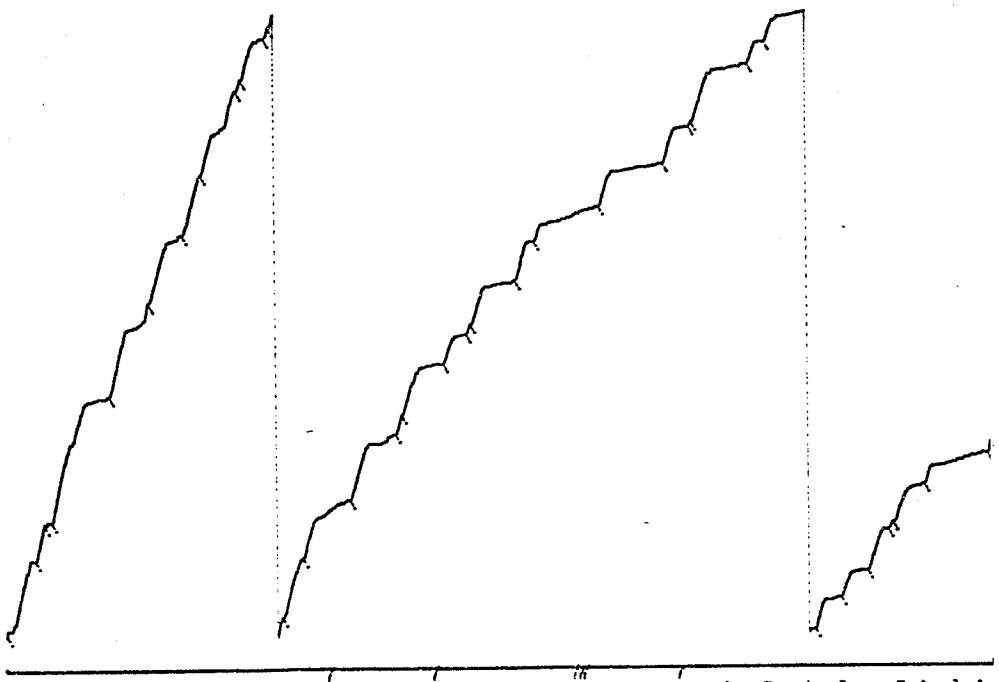


Figure 6. Cumulative record of S23's alcohol-tube licking under conditions of VI30-second food reinforcement. The record represents the first twenty minutes of a session.

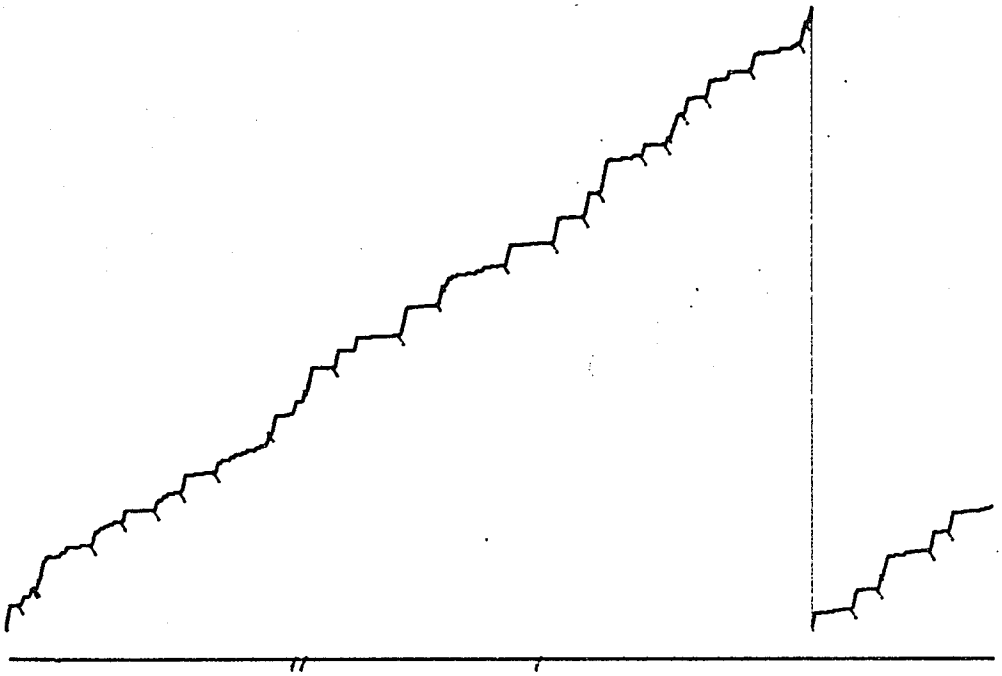


Figure 7. Cumulative record of S24's alcohol-tube licking under conditions of VI30-second food reinforcement. The record represents the first twenty minutes of a session.

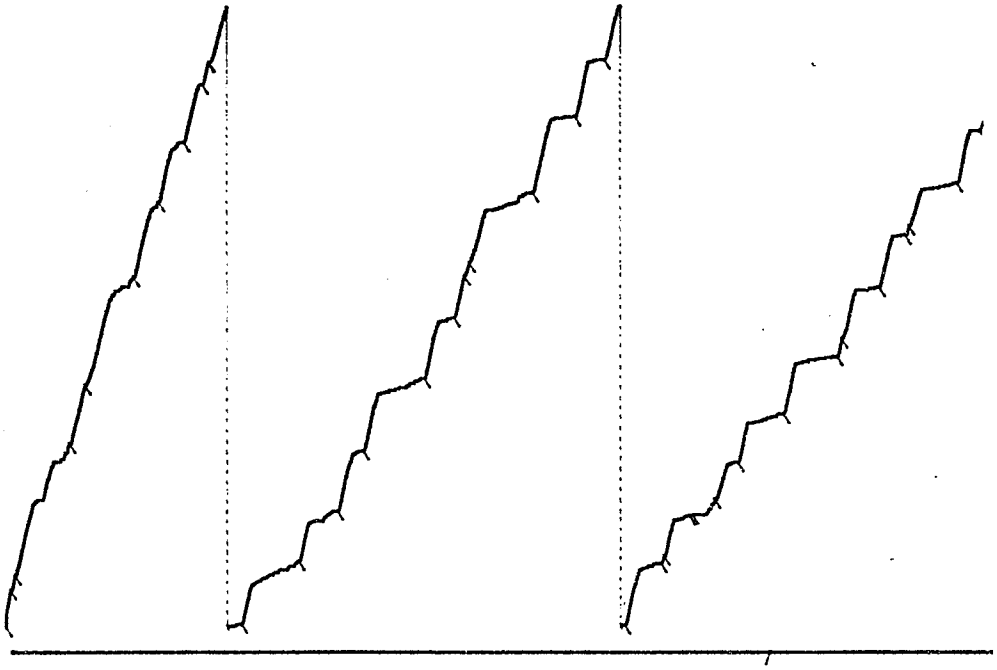


Figure 8. Cumulative record of S25's alcohol-tube licking under conditions of VI30-second food reinforcement. The record represents the first twenty minutes of a session.

Results

All Ss showed an increase in the mean number of licks and volume of fluid consumed per session (see Table I). The number of reinforcements obtained increased slightly (5 or 6 reinforcements per session). The increase in number of responses and fluid intake, when compared to phase A, probably reflects the removal of the aversive taste of the ethanol; or removal of the intoxicating effects of alcohol.

The pattern of responding showed two major changes from part A. First there was an overall rate increase as shown in Figure 9, Figure 10, Figure 11 and Figure 12 in comparison to Figures 5, 6, 7 and 8. Secondly, the pattern still retained the high constant rate following reinforcement, however the transition to a slower rate is not as abrupt. The pattern during this phase was not a typical VI (constant rate). The bursts of drinking following reinforcement were longer and the slow rate preceding reinforcement was higher than the slow rate shown in the records of part A.

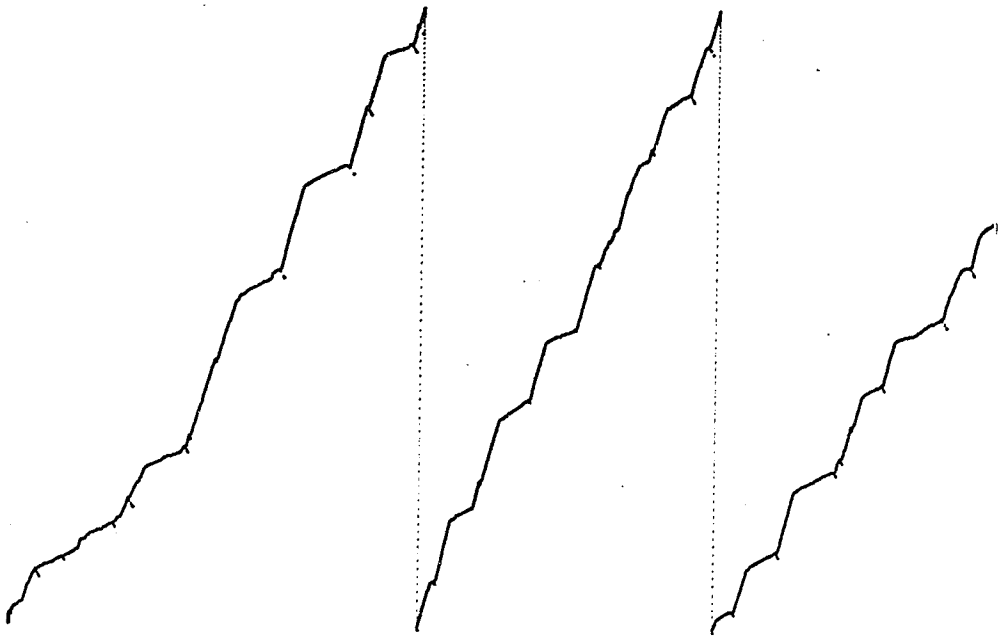


Figure 9. Cumulative record of S22's water-tube licking under conditions of VI30-second food reinforcement. The record represents the first twenty minutes of a session.

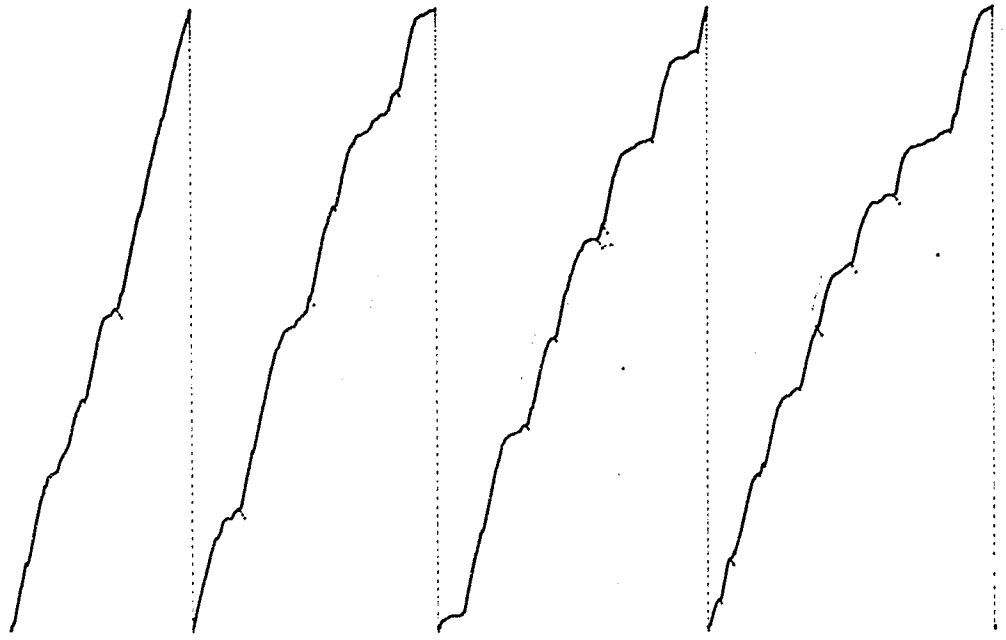


Figure 10. Cumulative record of S23's water-tube licking under conditions of VI30-second food reinforcement. The record represents the first twenty minutes of a session.

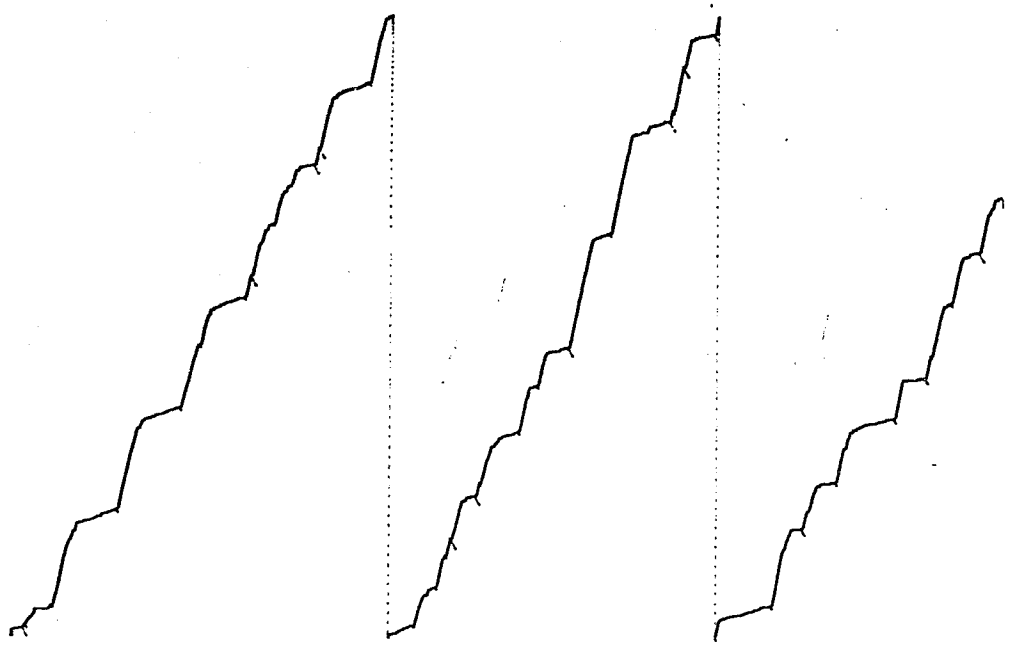


Figure 11. Cumulative record of S24's water-tube licking under conditions of VI30-second food reinforcement. The record represents the first twenty minutes of a session.

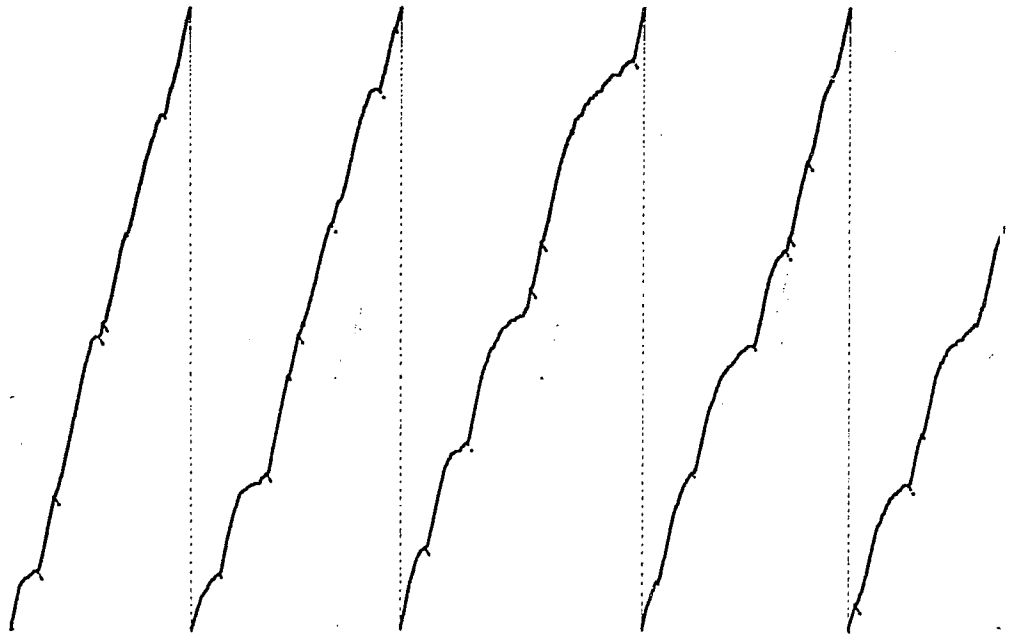


Figure 12. Cumulative record of S25's water-tube licking under conditions of VI30-second food reinforcement. The record represents the first twenty minutes of a session.

Discussion of parts A and B

In summary, the response patterns showed a high constant rate following reinforcement with a change to a slower rate preceding reinforcement under alcohol and water. The change in rate was not as abrupt and the rate preceding reinforcement was not as low as the alcohol condition. One possibility is that drinking or a licking response in rats does not follow the same laws as other operants. A second possibility is that the licking response has a unique conditioning history, when compared to other operants like bar pressing in the rat or key pecking in a pigeon. Upon close examination of figures 5, 6, 7, 8, 9, 10, 11 and 12, it seems that whenever a reinforcer was presented during the initial high constant rate following a reinforcer, a local constant rate developed. (See figures 6, 8, 10 and 12). It seemed logical that if each reinforcement were programmed, so that the mean interval was less than the drinking burst intervals shown on the cumulative records of parts A and B, a constant rate would be maintained. The next step was designed to investigate the above possibility.

C. VI 6.5 second food reinforcement for water tube licking in the experimental chamber.

Procedure

There was a two week break from the end of part B to the initiation of part C. During this time, all Ss were

returned to free feed. The FFW was redetermined and they were deprived to 75% body weight. As the mean reinforcement interval was extremely low the Ss could obtain a large number of reinforcers in a short period of time, thus it seemed logical to use a shorter session time and a lower body weight to offset the effects of rapid satiation. The sessions were conducted in the same manner as part B. The sessions of VI 6.5 seconds water tube licking continued for 21 days for S22, 16 days for S23, 19 days for S24, and 20 days for S25.

Results

All Ss responded at a high rate and obtained at least double the number of reinforcements they had received in Parts A and B (see Table I). The rate of responding for all Ss was very close to a constant rate, (see Figures 13, 14, 15 and 16). Again Ss 22 and 24 responded at lower rates than Ss 23 and 25. It seems that reinforcement must occur within a post reinforcement burst to produce a constant rate of response. The volume of fluid intake remained high (see Table I).

The results of part C raised two additional questions:

(1) Could the short VI be extended and the constant rate maintained?

(2) Would the constant rate of part C remain intact if alcohol was substituted for water at the short interval.

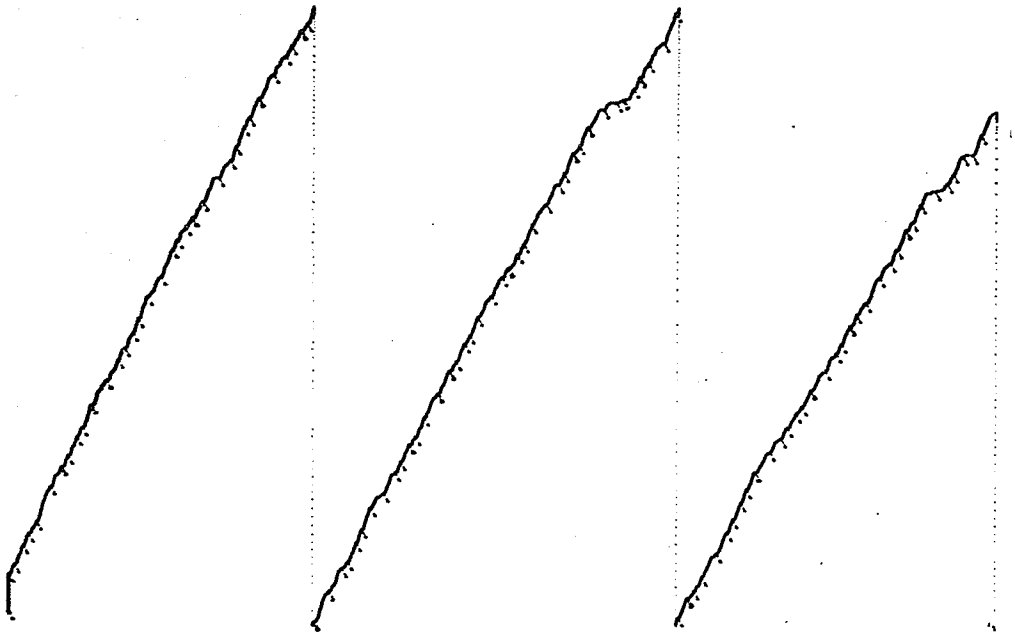


Figure 13. Cumulative record of S22's water-tube licking under conditions of VI6.5-seconds food reinforcement. The record represents the complete session.

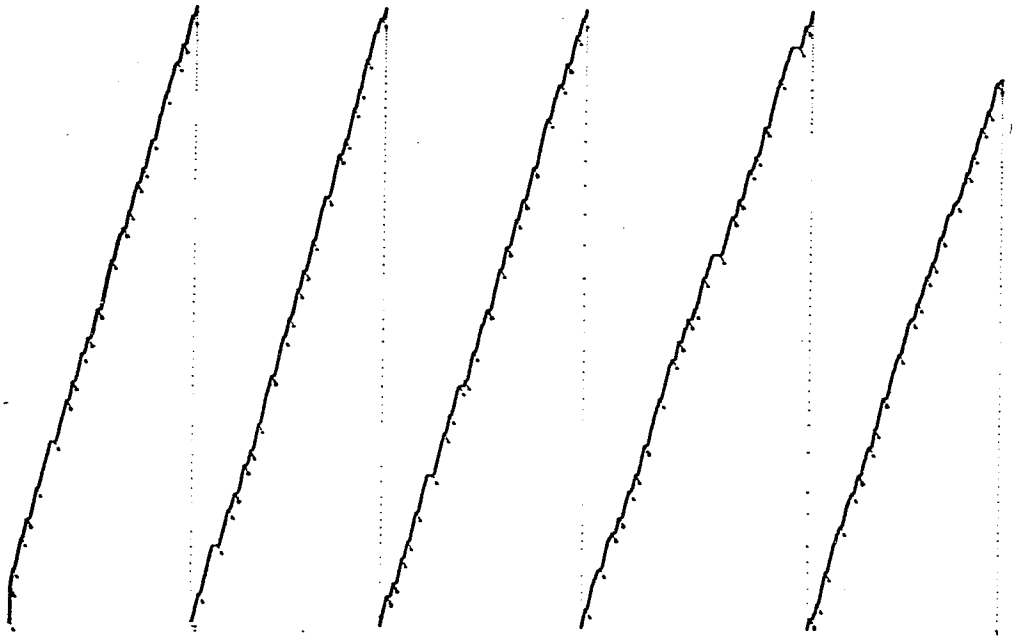


Figure 14. Cumulative record of S23's water-tube licking under conditions of VI6.5 seconds food reinforcement. The record represents the complete session.

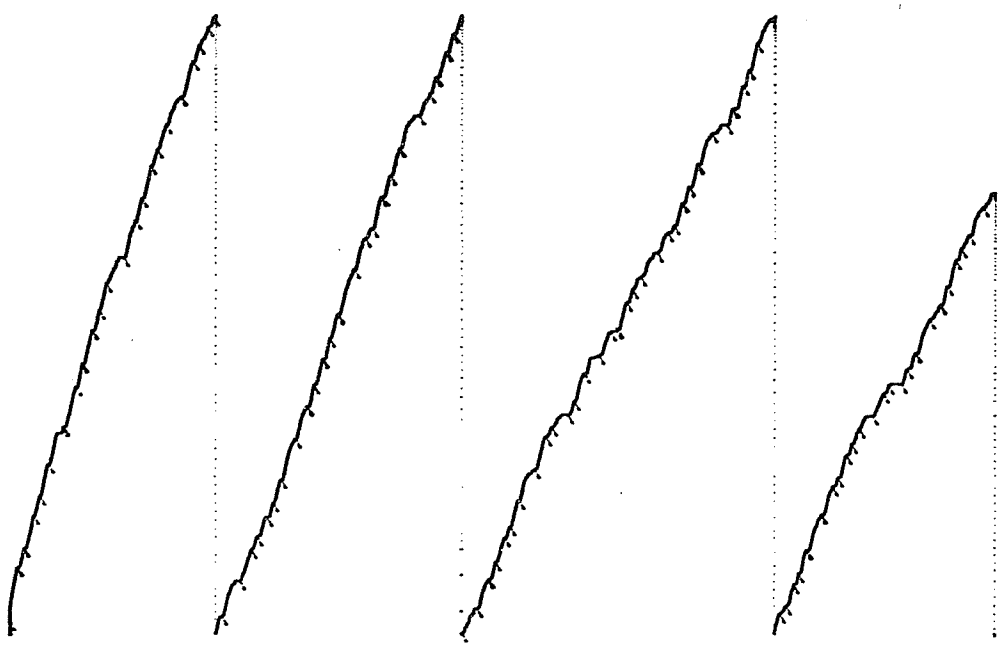


Figure 15. Cumulative record of S24's water-tube licking under conditions of VI6.5-seconds food reinforcement. The record represents the complete session.

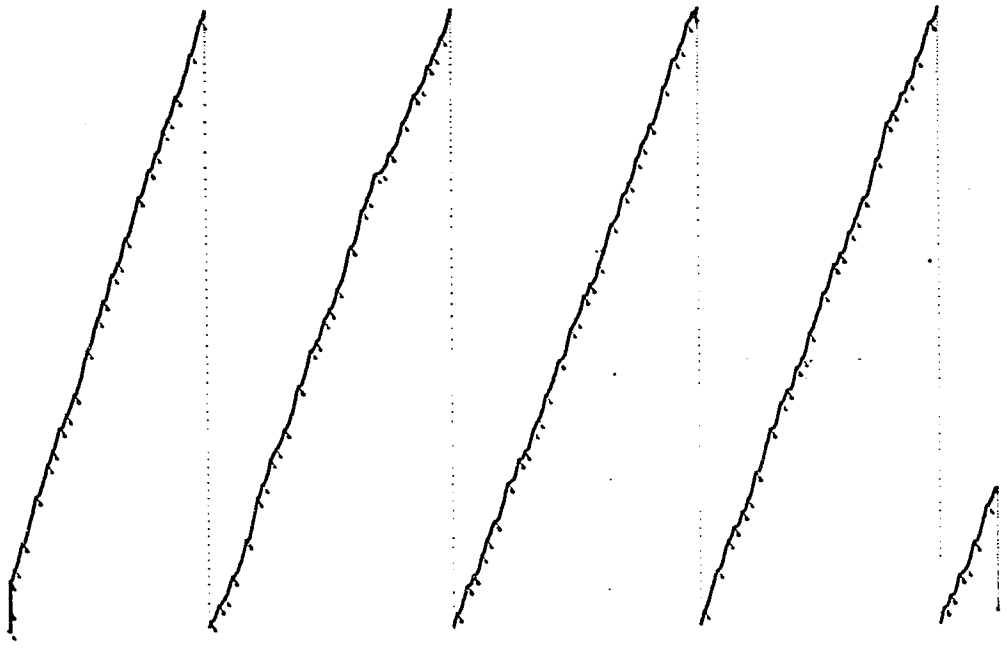


Figure 16. Cumulative record of S25's water-tube licking under conditions of VI6.5-seconds food reinforcement. The record represents the complete session.

In order to answer these questions the manipulations of part D were initiated.

D. (1) VI 7.8 second food reinforcement of water tube licking.

(2) VI 6.5 second food reinforcement of alcohol tube licking.

Procedure

S23 was exposed to a 7.8 second VI for water tube licking for 5 days. All Ss were submitted to a schedule of alcohol tube licking on the same schedule as part C. The sessions of VI 6.5 second food reinforcement for alcohol tube licking continued for 21 days for Ss 22, 24 and 25 and 22 days for S23. S22 started biting the tube and was put on extinction for 2 days then reshaped to a VI 6.5 second schedule for alcohol.

Results

1. There was little or no change in any of the dependent variables when the interval was raised to 7.8 seconds (see Figure 2).

2. There was a decrease in the number of responses per session. Three Ss showed a decrease in the number of reinforcements obtained while S23 showed a slight increase. S22, 24 and 25 showed a general decrease in overall rate, while S23 showed a very slight decrease in rate. All Ss maintained a constant rate of responding, extending the generality of the results of part C. S22 and S24 once

again responded at a lower rate than S23 and S25 (see Figures 17, 18, 19 and 20.)

Discussion of Parts C and D.

A constant rate was maintained for all Ss under alcohol and water conditions. There was a decrease in the average number of responses from the water condition. All Ss consumed less alcohol than water under comparable contingencies of reinforcement. The number of responses for S23, 24 and 25 under part D exceeded the number in part A, although the sessions in part D were considerably shorter (see Table I). The volume of alcohol consumed in part D exceeds the consumption during part A.

Parts C and D demonstrated that a constant rate could be generated on an extremely short schedule, however, the unusual pattern at longer intervals (30 seconds) could not be explained. Ferster and Skinner (1957) stated that a variable interval schedule of reinforcement produces a constant rate by not permitting any feature of the birds' behavior to acquire discriminative properties. However, in fixed interval and fixed ratio schedules the fixed pattern establishes a correlation between behavior and reinforcement. It seemed logical that the programming apparatus used for longer intervals may have approximated a fixed pattern and allowed the licking behavior to acquire discriminative properties. In order to investigate this possibility the following manipulation was initiated:

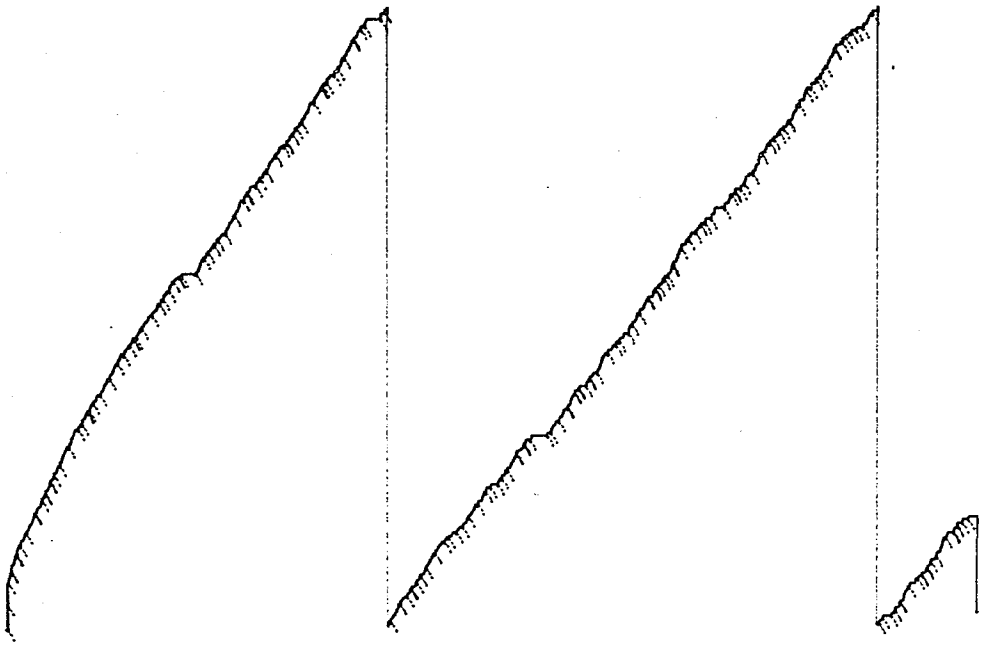


Figure 17. Cumulative record of S22's alcohol-tube licking under conditions of VI6.5-seconds food reinforcement. The record represents the complete session

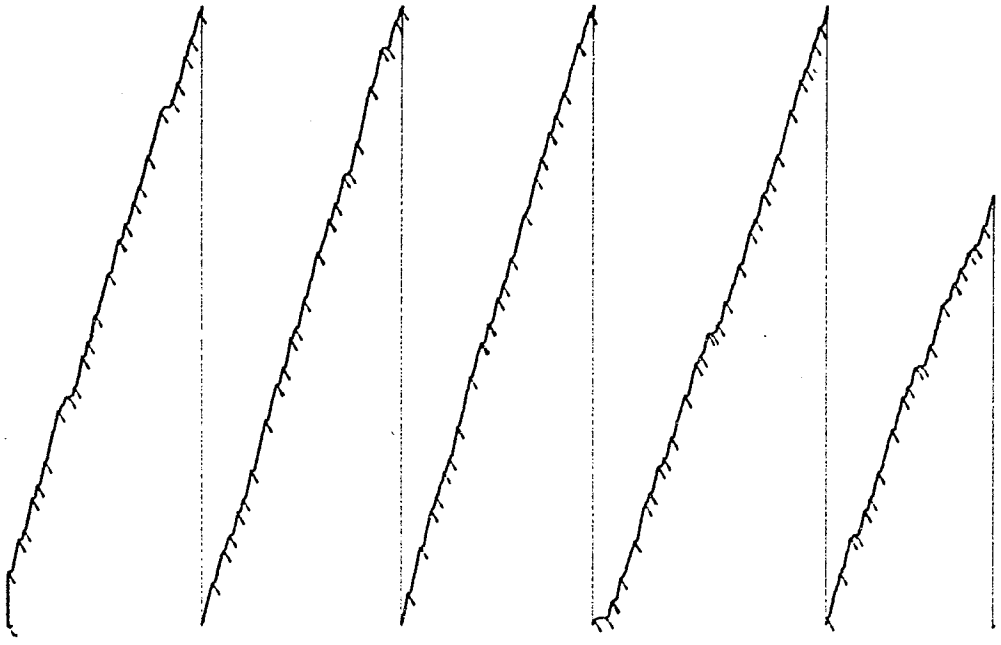


Figure 18. Cumulative record of S23's alcohol-tube licking under conditions of VI6.5-seconds food reinforcement. The record represents the complete session.

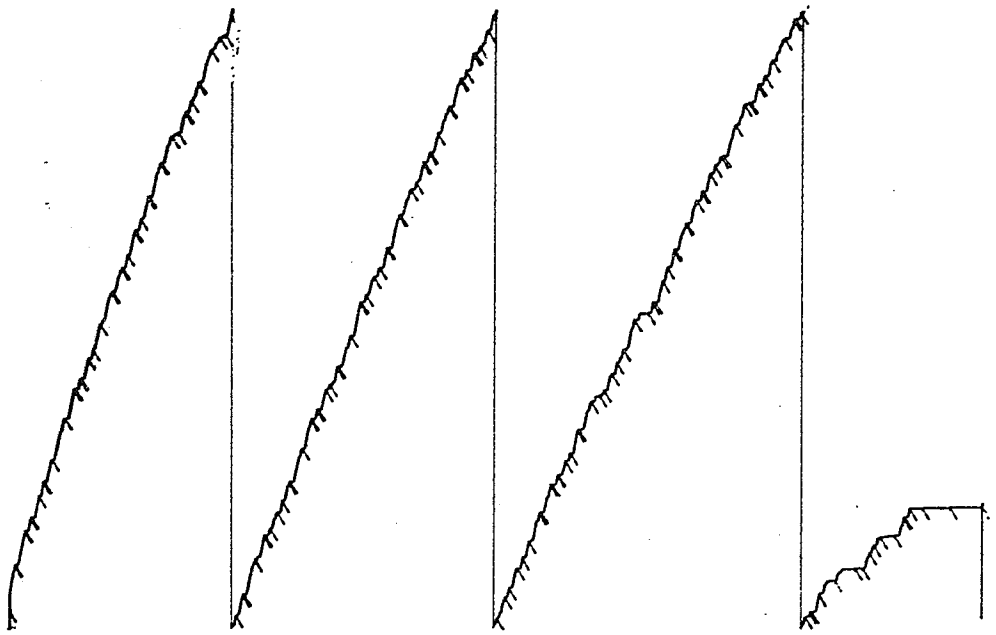


Figure 19. Cumulative record of S24's alcohol-tube licking under conditions of VI6.5-seconds food reinforcement. The record represents the complete session.

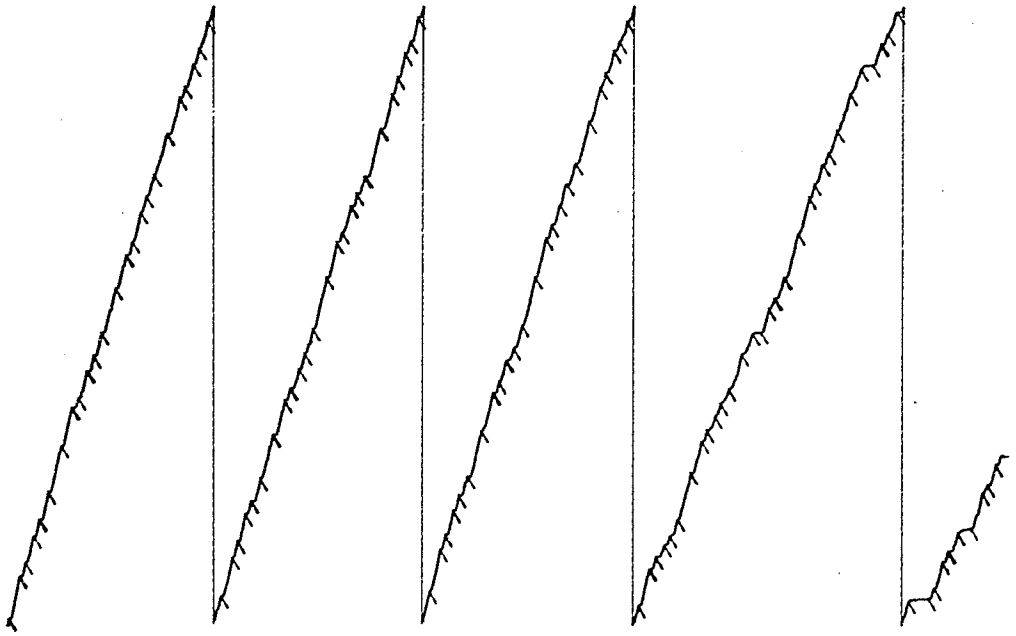


Figure 20. Cumulative record of S25's alcohol-tube licking under conditions of VI6.5-seconds food reinforcement. The record represents the complete session.

E. The effect of VI reinforcement of bar pressing.

The numerous systematic replications of bar pressing studies indicate that a constant rate develops from variable interval schedules of reinforcement. If the bar pressing pattern mimicked the licking pattern at longer intervals, then the programming apparatus would be suspect; that is, the apparatus must have allowed the behavior under its control to develop discriminative properties.

1. VI 30 second food reinforcement of bar pressing.

Procedure

The alcohol tube was removed from the experimental chamber and the opening was covered with a metal plate. All Ss were shaped to press the bar on a continuous reinforcement schedule. They were then placed on a VI 30 second schedule. This step lasted 12 days for Ss 22, 23 and 25, and 6 days for S24. (S24 developed a foot infection and had to be returned to free feed and given antibiotics for several days.)

Results

The bar pressing rates for all Ss were relatively constant (see Figures 21, 22, 23 and 24). S23 showed a low rate in relation to the other 3 Ss; however, S23 was still recovering from an infection during this stage. The rates of S22, 23 and 25 had similar slope in contrast to the differential overall slopes shown in Part A (see figures 5, 6, 7 and 8). There were no abrupt local rate changes

that appeared in the records of the alcohol tube licking. The averages shown in Table I for this condition and in Figures 1, 2, 3 and 4, include the transition from continuous reinforcement to VI 30 seconds and as a result early sessions with low response rates and high reinforcement frequency distort the mean values for that condition. The records for this condition are from the eighth day of this 12 day condition. In order to evaluate changes in rate as a function of interval size the following manipulation was performed.

2. VI 15 second and VI 30 second food reinforcement of bar pressing.

Procedure

All Ss were exposed to a VI 15 second schedule for six days and then a VI 15 second schedule for six days and than a VI 30 second schedule for seven days.

Results

The overall rates are roughly constant and the slopes, with the exception of S24 are similar, (see Figures 25, 26, 27 and 28). When the contingency was changed to a VI 30 seconds there was very little change in the response pattern, as shown by Figures 29, 30, 31 and 32. Figures 1, 2, 3 and 4 show a marked decrease in the frequency of reinforcement while the average number of responses per session remained relatively constant.

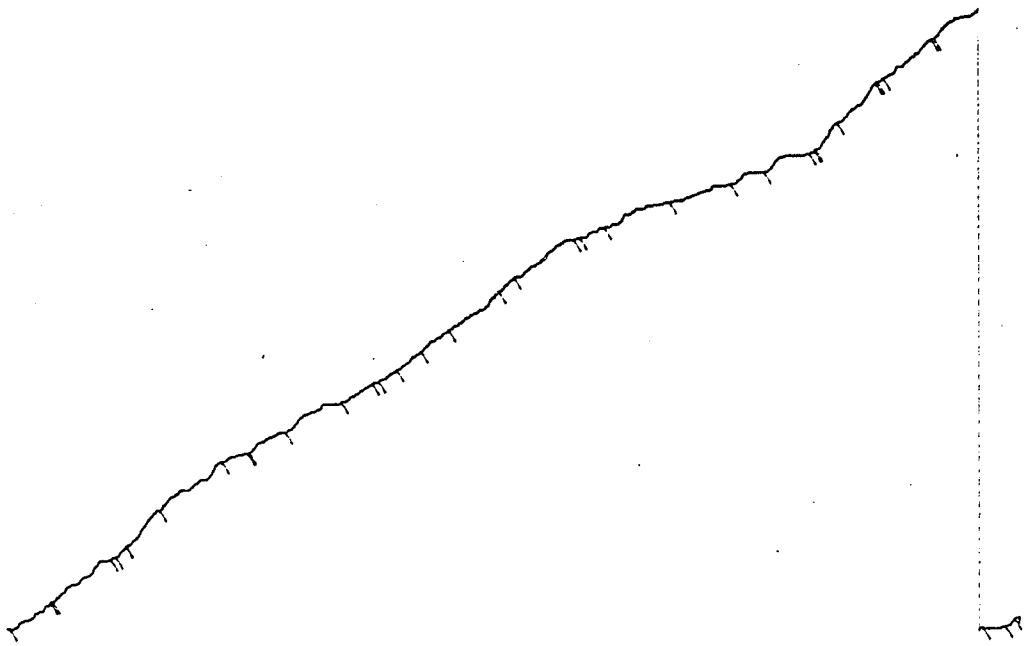


Figure 21. Cumulative record of S22's bar pressing under conditions of VI-30 seconds food reinforcement. The record represents the complete session.

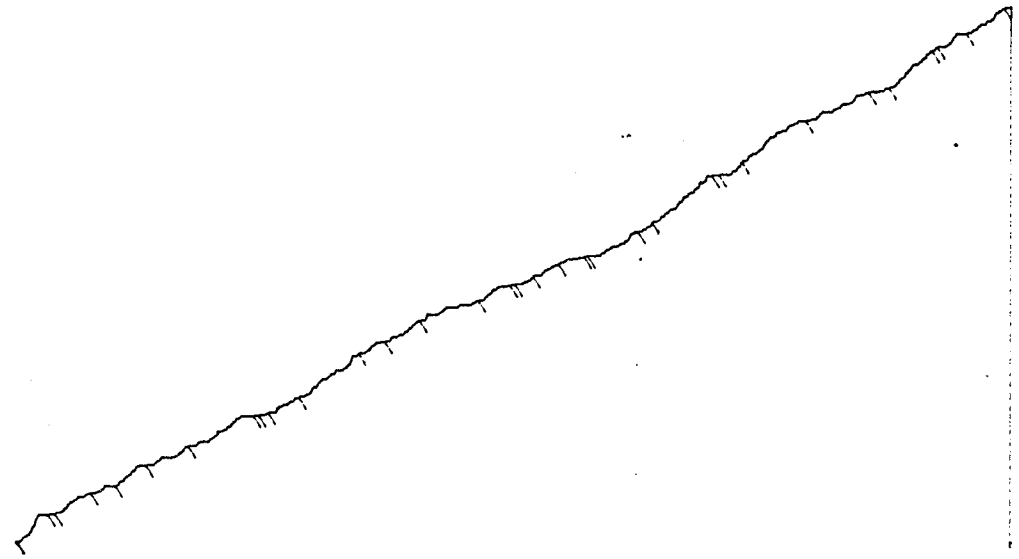


Figure 22. Cumulative record of S23's bar pressing under conditions of VI-30 seconds food reinforcement. The record represents the complete session.

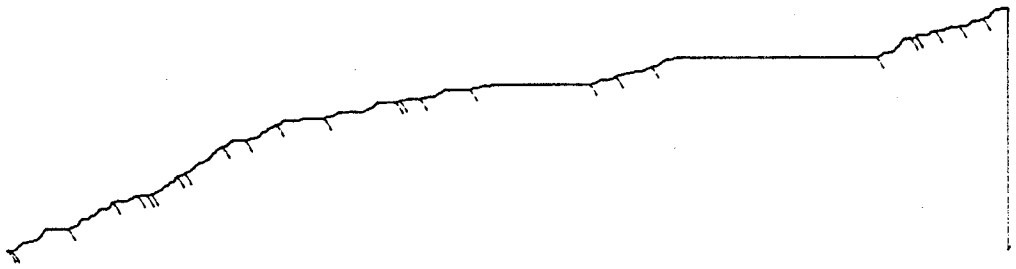


Figure 23. Cumulative record of S24's bar pressing under conditions of VI-30 seconds food reinforcement. The record represents the complete session.

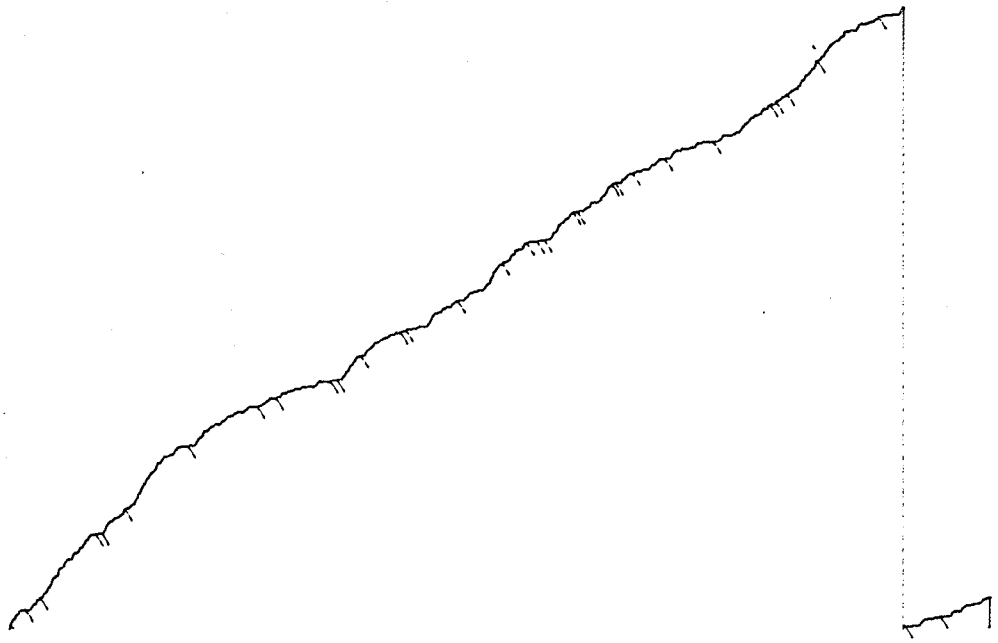


Figure 24. Cumulative record of S25's bar pressing under conditions of VI-30 seconds food reinforcement. The record represents the complete session.

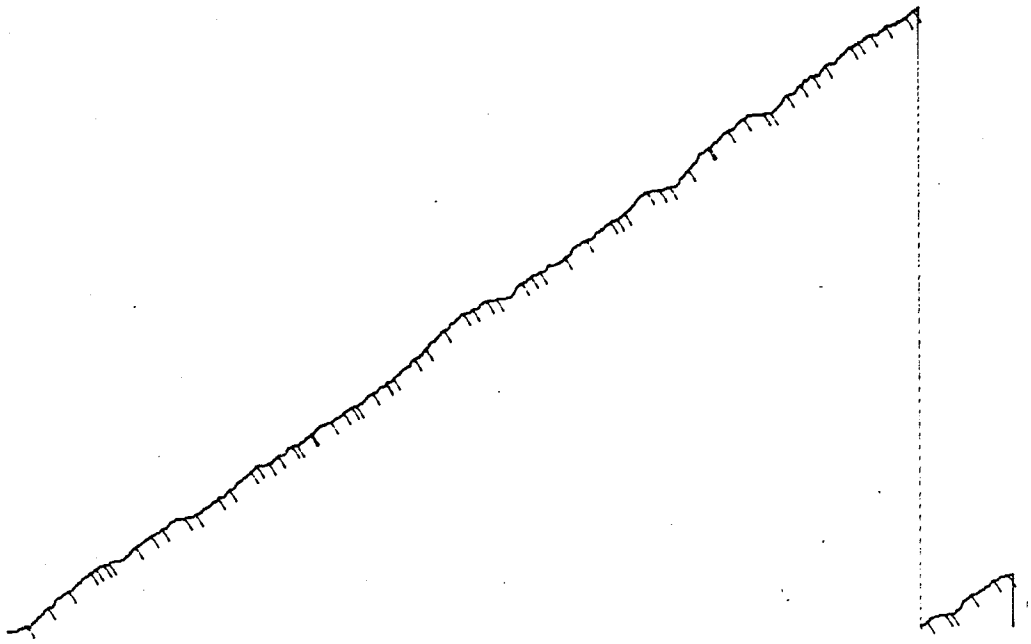


Figure 25. Cumulative record of S22's bar pressing under conditions of VI-15-seconds food reinforcement. The record represents the complete session.

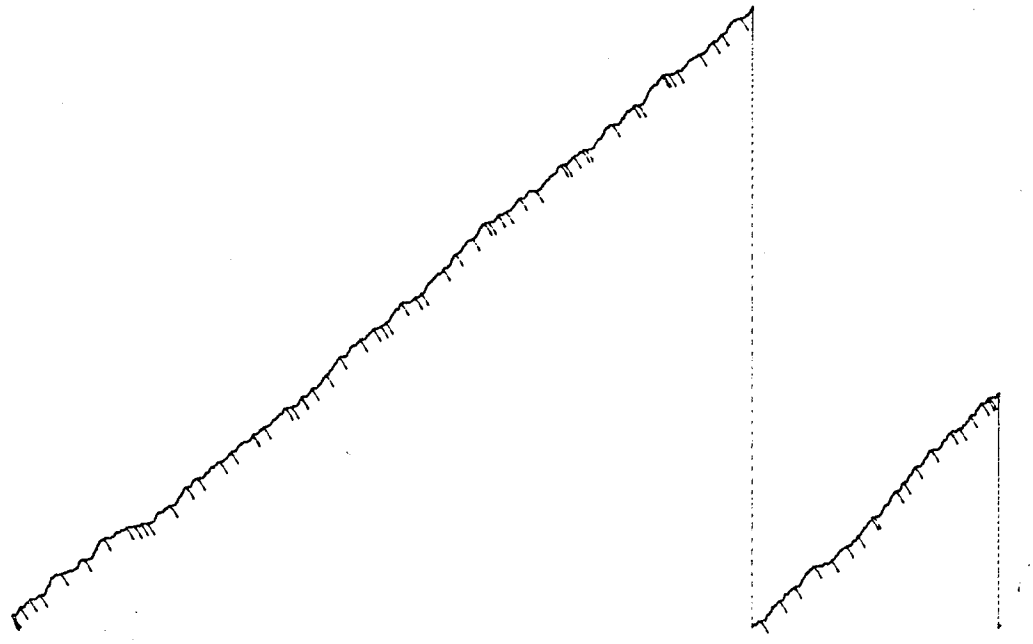


Figure 26. Cumulative record of S23's bar pressing under conditions of VI-15-seconds food reinforcement. The record represents the complete session.

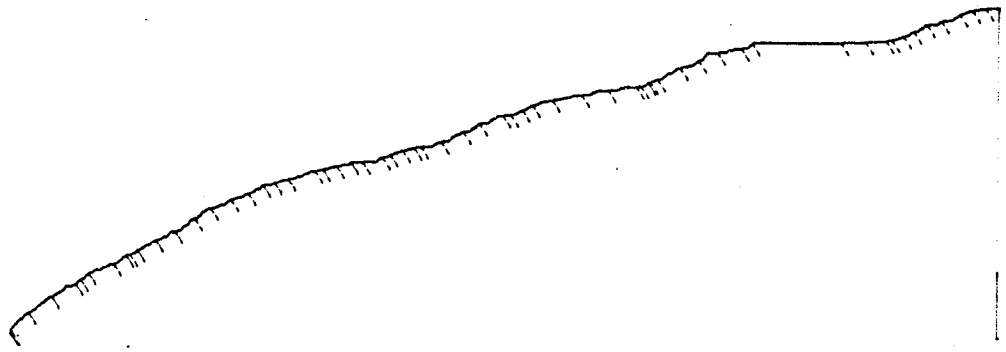


Figure 27. Cumulative record of S24's bar pressing under conditions of VI-15-seconds food reinforcement. The record represents the complete session.

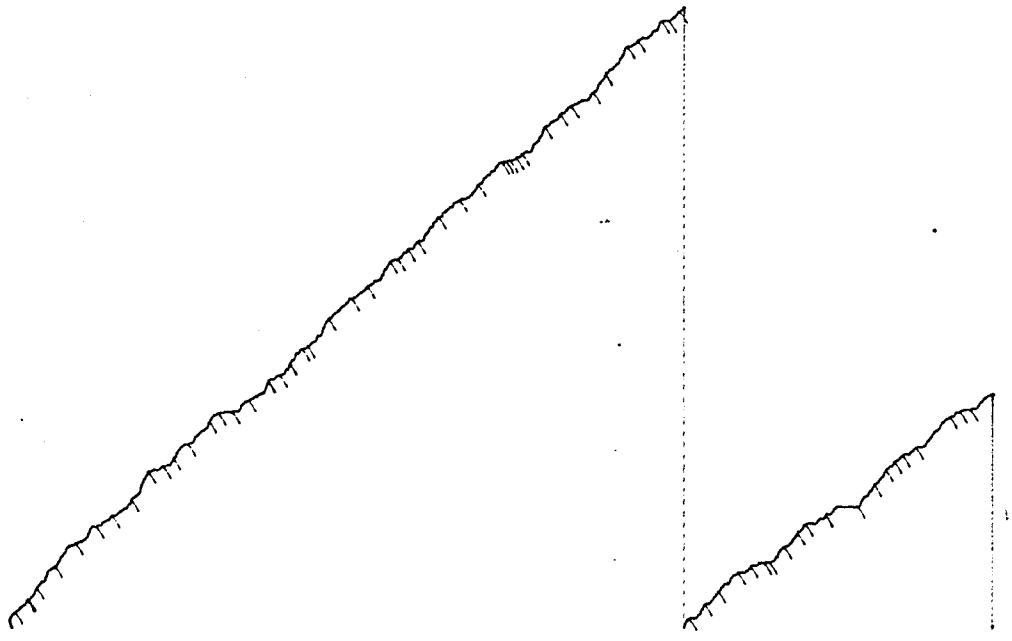


Figure 28. Cumulative record of S25's bar pressing under conditions of VI-15-seconds food reinforcement. The record represents the complete session.

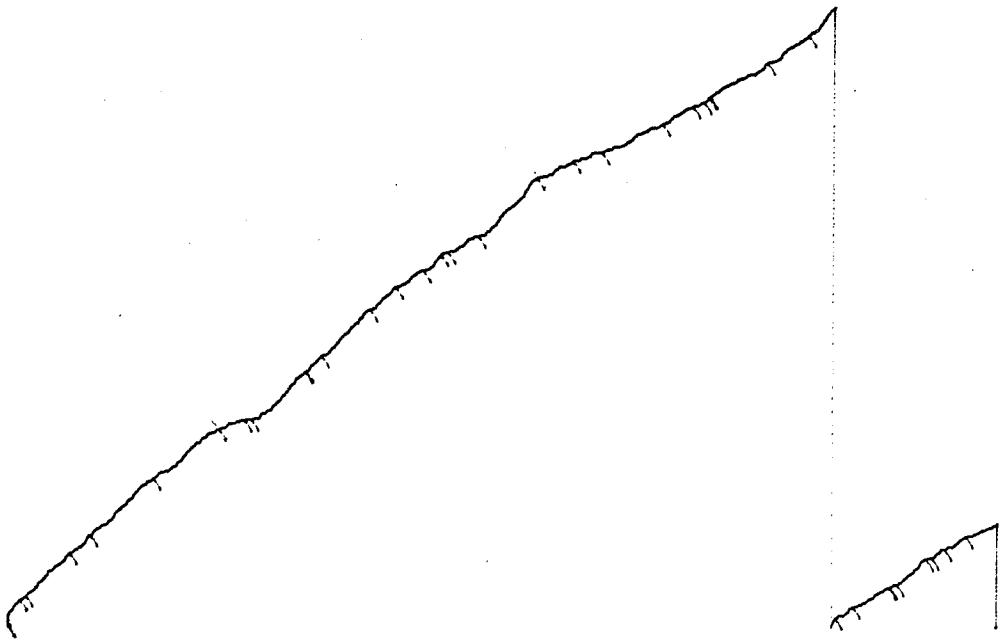


Figure 29. Cumulative record of S22's bar pressing under conditions of VI-30 seconds food reinforcement. The record represents the complete session.

Figure 30. Cumulative record of S23's bar pressing under conditions of VI-30 seconds food reinforcement. The record represents the complete session.

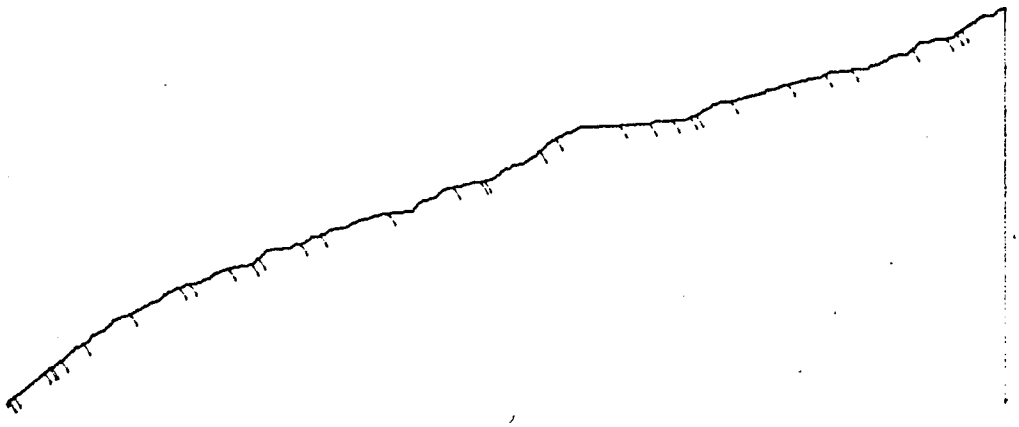


Figure 31. Cumulative record of S24's bar pressing under conditions of VI-30 seconds food reinforcement. The record represents the complete session.

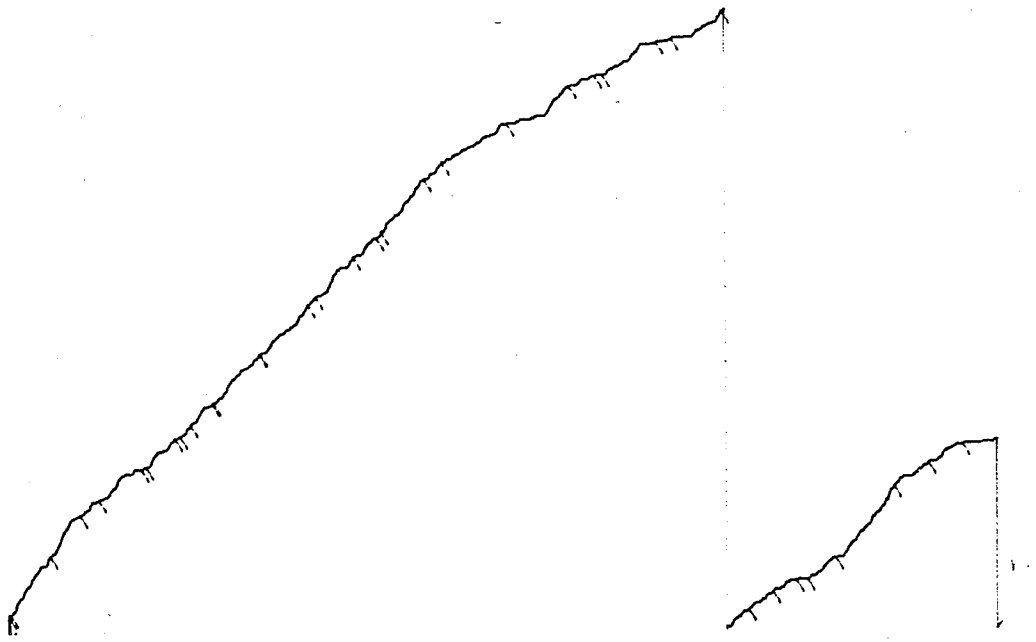


Figure 32. Cumulative record of S25's bar pressing under conditions of VI-30 seconds food reinforcement. The record represents the complete session.

CHAPTER VI

DISCUSSION

The present study was designed to analyse the alcohol drinking response in rats. The results indicated that under certain conditions the licking response functions like any other operant and under some conditions it does not. Martin (1971) found that under conditions of FR reinforcement for alcohol drinking, the tube-licking looked very much like the rate of other operant responses on FR schedules. He also demonstrated that rats consume ethanol because of its caloric value, however, FR reinforcement had much greater effects on alcohol intake than did the caloric variable. Black and Martin (1971) found similar results with a smaller FR value. They found that alcohol tube licking extinguished rapidly after the contingency was removed. The present study partially supports the results of the above experiments and in addition raises some questions of the generality of the same studies. The present study found that a constant rate of response can be generated and maintained with an extremely short VI Schedule; suggesting additional support for the hypothesis that alcohol consumption functions as an operant response. However, when the mean interval exceeded a certain value

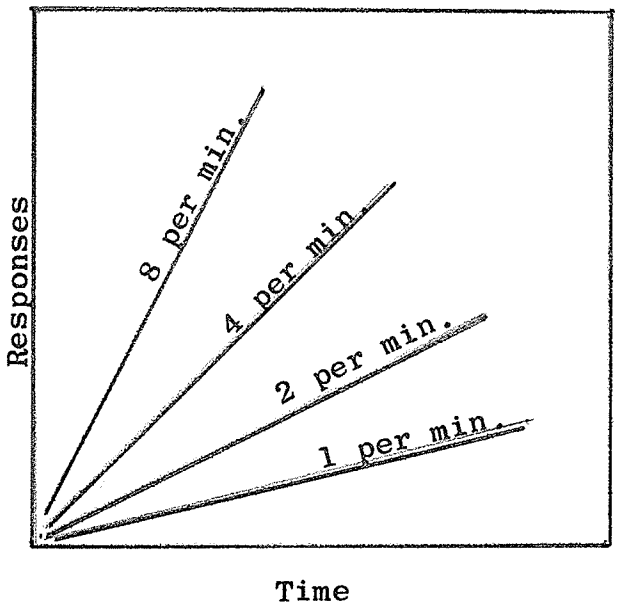
the pattern broke down. The departure from a constant rate was not due to the alcohol itself or an anomaly in the apparatus. This author suggests that the presentation of a reinforcer following the emission a certain number of responses, after reinforcement, is critical in maintaining a constant rate. The studies of Martin (1971) and Black and Martin (1971) should have used a larger range of values of an FR schedule. They may have found that the pattern will change beyond a critical ratio. On the other hand, the pattern developed by an FR may shape up discriminative properties in the behavior itself and enable the pattern to maintain its integrity as the schedule parameters increase. It suggests to this author that an attempt should be made to establish the same response under FI and VR control. This author would predict that an FI schedule would produce results similar to the present study while the VR would produce results similar to Martin (1971) and Black and Martin (1971).

The licking response as an operant is unique in terms of its phylogenic or ontogenic conditioning history. The drinking response is unlike a bar press as the tube licking response has a long history of reinforcement prior to the experiment in question. The licking response is similar to the pecking response in pigeons but not entirely; the former involves consumatory behavior while the latter is a prehensile response; that is a pigeon pecks at something but doesn't consume it. It is possible that a rat

brings with it to an experiment a learned drinking pattern; for example, licking in a certain burst (45 responses). Thus on a variable schedule, the mean reinforcement interval must be within this "natural" burst to maintain a constant rate, or discriminative properties of the behavior must be shaped from lower values that have inter-reinforcement times within the "natural" drinking burst. One further implication of this analysis is, that a constant rate VI cannot be shaped for large intervals (30 seconds) with a licking response.

This type of analysis is valuable in studying alcohol intake in man and animals. No one has been able to establish an alcohol "addiction" in animals and this author doubts the existence of a physiological addiction to alcohol. The study of the environmental consequences of behavior has led to behavioral control techniques that have been used to treat many behavioral disorders that were once attributed to malfunctions within the organisms. The study of alcohol consumption in laboratory animals may provide behavioral control techniques to treat human "addiction" as a behavioral disorder.

APPENDIX



Each slope represents the number of responses per minute.

REFERENCES

Azrin, N. H. and Holz, W. C. Punishment in Honig, W. K. (ed.) Operant Behavior: Areas of Research and Application, New York: Appleton-Century Crofts, 1966.

Bergersen, B. S. and Krug, E. E. Pharmacology in Nursing, St. Louis: The C. V. Mosby Company, 1969.

Black, E. L. and Martin G. L. Extinction of alcohol drinking in rats following acquisition on a fixed ration schedule of reinforcement. Psychonomic Science, 1972, Vol. 29 (3).

Davis, V. I. and Walsh, J. J. and Yamanka, Y. Data link alcoholism and opiate addiction. Chemical and Engineering News, Feb., 1970.

Falk, J. L. Production of polydipsia in normal rats by an intermittent food schedule. Science, 1961, 133, 195 - 196.

Ferster, C. B. and Skinner, B. F. Schedules of reinforcement. New York: Appleton-Century Crofts, 1957.

Findley, J. D. and Brady, J. V. Facilitation of large ratio performance by use of conditioned reinforcement. Journal of Experimental Analysis of Behavior, 8: 125 - 129, 1965.

Franks, C. M. Behavior Therapy Appraisal and Status, McGraw-Hill Inc., 1969.

Goldman, P. S. and Doctor, R. F. Facilitation of bar pressing "suppression" of conditioned suppression in cats as a function of alcohol. Psycho-pharmacologia (Berl.), 1966, 9, 64 - 72.

Goth, A. Medical Pharmacology. St. Louis: The C. V. Mosby Company, 1970.

Guyton, A. C. Textbook of Medical Physiology. Philadelphia: W. B. Saunders Company, 1966.

Holman, R. B. and Myers, 1969. Ethanol consumption under conditions of psychogenic polydipsia. Pharmacology and Behavior, 1968, 3, 369 - 371.

Jellinek, E. M. The Disease Concept of Alcoholism. New Haven, Conn.: College and University Press, 1960.

Kaplan, H. S. Effects of alcohol on fear extinction, Dissertation Abstracts, 1956, 55, 571 - 572.

Keehn, J. D. Reinforcement of alcoholism; schedule control of solitary drinking, Quarterly Journal of Studies on Alcohol, 1970, 28 - 39.

Kepner, E. Application of learning theory to the etiology and treatment of alcoholism. Quarterly Journal of Studies on Alcohol, 1964, 25, 279 - 291.

Kopmann, E., and Hughes, R. W. The potentiating effect of alcohol on tranquilizers and other central depressants. A.M.A. Archives General Psychiatry, 1959, 1, 7 - 11.

Lester, D. L. Self-maintenance of intoxication in the rat. Quarterly Journal of Studies on Alcohol, 1961, 22, 223 - 231.

Martin, G. L. Schedule-induced and contingency-maintained alcohol drinking by rats. Unpublished doctoral dissertation, Arizona State University, 1971.

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

McMurray, G. A. and Jacques, L. B. The effects of drugs on a conditioned avoidance response. Canadian Journal of Psychology, 1959, 13, 186 - 192.

Mello, N. K. & Mendelson, J. H. Operant drinking of alcohol on a rate-contingent ratio schedule of reinforcement. Journal of Psychiatric Research, 1965, 3, 145 - 152.

Michael, J. Laboratory Studies in Operant Behavior. New York: McGraw-Hill Book Company, Inc.

Perensky, J. J., Senter, J. J. and Jones, R. B. Induced alcohol consumption through positive reinforcement. Psychonomic Science, 1968, 11, 109 - 110.

Popham, R. E. Alcohol and Alcoholism. Toronto: University of Toronto Press, 1970.

Reynolds, C. S. and Van Sommers, R. Effects of ethyl alcohol on avoidance behavior. Science, 1960, 132, 42 - 43.

Senter, R. J., Smith, F. W. and Lewin, S. Ethanol ingestion as an operant response. Psychonomic Science, 1967, 9, 291 - 292.

Sobell, L. C., Sobell, M. B. and Chestlam, W. C. The Myth of "One Drink," Behavior Research and Therapy, 1972.

Sidman, M. Tactics of Scientific Research. New York: Basic Books, 1960.