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Voluntary Consumption of Beverage Alcohol by Vervet Monkeys: Population Screening, Descriptive Behavior and Biochemical Measures

FRANK R. ERVIN,*† ROBERTA M. PALMOUR,*†[1] SIMON N. YOUNG,*
CARLOS GUZMAN-FLORES‡ AND JORGE JUAREZ‡

**Department of Psychiatry, and †Centre for Human Genetics*
McGill University, 1033 Pine Avenue West, Montreal, Quebec, Canada H3A 1A1
and ‡Instituto Investigaciones Biomedicos, Universidad Nacional Autonoma de Mexico, Mexico D.F. 20

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ERVIN, F. R., R. M. PALMOUR, S. N. YOUNG, C. GUZMAN-FLORES AND J. JUAREZ. *Voluntary consumption of beverage alcohol by vervet monkeys: Population screening, descriptive behavior and biochemical measures.* PHARMACOL BIOCHEM BEHAV **36**(2) 367–373, 1990.—Seventeen percent of 196 feral vervet monkeys *(Cercopithecus aethiops)* spontaneously drank appreciable quantities of beverage alcohol in 3% sucrose in preference to 3% sucrose alone. Ethanol consumption increased over time, as did the concentration of ethanol tolerated. Willingness to select ethanol was stable over a three-year period, as measured by periodic retesting. Individual patterns of drinking and behavioral responses to ethanol were quite variable. Upon occasion, some animals drank to ataxia and unconsciousness; signs of withdrawal, including tremulousness, pacing, irritability and increased aggression, followed the abrupt discontinuation of ethanol availability. A variety of changes in social interaction, including increased orientation to external stimulus, increased incidence of stereotyped aggression and of other stereotyped behaviors and decreased frequency of affiliative behaviors were observed during ethanol periods, as compared to baseline scoring periods. In a small number of alcohol-preferring animals, CSF amine metabolites (5-hydroxyindoleacetic acid and homovanillic acid) were raised by drinking alcohol. These studies suggest that the alcohol-selecting vervet monkey may be complementary to established primate models of alcoholism.

Alcohol Vervet monkeys Social behavior CSF amines

IN spite of the problems in developing primate models of alcoholism (6, 8, 18, 19), this area of research has produced much interesting data. Among the models developed are the intravenous self-administration models (20,21), the schedule-induced polydipsia model (12, 20, 26) and paradigms in which drinking is stimulated by various psychosocial stressors such as repeated separation from a pair-bonded conspecific (15,16). In all these models, rhesus monkeys will consume reasonably large quantities of alcohol and will continue drinking (or self-administration) until a state of relative dependence ensues. Kraemer (16) has emphasized that baseline neurochemical status differentiates those animals most vulnerable to separation distress and to increased alcohol consumption. By contrast, in schedule-induced polydipsia and self-administration studies, most of the exposed individuals will develop a pattern of consumption which increases over time. Thus, these models emphasize direct pharmacologic reinforcement and are less relevant to individual, social or biological predilection for drinking (12, 20, 26). In man, excessive consumption occurs in a minority of the exposed population and is not limited to persons in acute psychosocial distress. Several studies show that chronic intake of excess alcohol occurs disproportionately in individuals with strong family histories of similar behaviors (30–80% of DSM-III "alcoholics"), compatible with the hypothesis that a predisposition to alcohol abuse is conferred in part by genetic factors.

In studies of baboons, rhesus monkeys, pigtailed macaques and chimpanzees, there has often been mention of the "atypical" animal which voluntarily consumed large quantities of ethanol without any obvious behavioral or nutritional coercion (9–11, 13). In all but one of these investigations, fewer than 10 animals were studied. Because most laboratories have access to only a few primates at any one time, a systematic screening of large numbers of monkeys seemed appropriate.

An experimental colony of vervet monkeys *(Cercopithecus aethiops)* housed in stable social groups, and drawn from a large, isolated and nonendangered Caribbean population, has now been

[1]Requests for reprints should be addressed to Roberta M. Palmour, Department of Psychiatry, McGill University, 1033 Pine Avenue West, Montreal H3A 1A1, Canada.

studied behaviorally and biochemically for a number of years. The feral population from which these animals came has lived for 300 years in an environment of sugar cane, burned cane and fermented cane. Locally, there are stories of catching wild monkeys by supplying rum and molasses in coconut shells, then picking up the drunk animals. The present communication describes a strategy for screening these animals for alcohol preference, and presents evidence suggesting that 17% of these vervet monkeys select vehicle plus ethanol (as homemade rum) over vehicle alone. Some physiological and behavioral correlates of alcohol ingestion are also described.

METHOD

Animal Subjects

Vervet or African green monkeys *(C. aethiops)* were housed outdoors in social groups, typically comprising 1 or 2 adult males, 3–6 adult females and 3–8 juveniles and infants. Purina Primate Chow (Formula 308) was available ad lib, as was fresh water from a piped central supply. Diet was supplemented with fresh fruit and produce several times weekly. Food was supplied once daily between 11 a.m. and noon. Housing and sanitary conditions met the guidelines of the Canadian Council on Animal Care.

Population Screening

An initial screen of 6 groups of animals (n = 52) used the following protocol: After habituation to the presence of a behavioral observer (two 2-hour periods beginning at 7 a.m. and 4 p.m.), Ancare drinking bottles containing 3% w/v sucrose (vehicle) and 3% sucrose solution with graded concentrations of local rum (vehicle + ethanol) were presented twice each day 30 minutes after the initiation of behavioral observation. The initial concentration of ethanol was 7.5% (v/v) and this formula was presented 4 days in succession. Animals which repeatedly chose vehicle + ethanol were housed separately for more detailed investigation of the volumes and concentrations which would be consumed.

More recently, this protocol has been expanded to incorporate 3 days of presentation of 7.5% ethanol, followed by 3 days each at 10%, 15% and 20% ethanol, with vehicle alone available at all stages. A further group of 144 animals was screened using this procedure, for a total of 196 animals.

Volumes and Concentrations Consumed by Alcohol-Preferring Vervets

In order to determine the maximum concentration of alcohol which would be freely ingested, a pilot study was performed. A small number of animals showing a preference for alcohol on the preliminary screen (n = 34) were housed individually and given measured quantities of increasing concentrations of ethanol in vehicle (beginning at 10%, with a 2.5% increment per day to a maximum of 25%) until a concentration was reached at which consumption was 100 ml or less per day for each of 3 days.

In a subsequent study, each of these 34 alcohol-perferring animals was offered 10% ethanol in vehicle ad lib for 3 days, then 15% for 3 days, then 20% (if tolerated; 15% if not) for 7 days. The total daily intake of ethanol was computed [after analysis of the ethanol content of local rum, using an enzymatic diagnostic assay (Sigma, St. Louis, MO)] and normalized as g alcohol/kg body weight/day (mean of 4 days consumption). This protocol was repeated at yearly intervals for a total of 3 years to assess the stability of alcohol preference.

Behavioral Characterization: General Observations

The effects of alcohol consumption on individual behaviors were documented in social groups which had been allowed to stabilize for several weeks before behavioral study. Using trained behavioral observers, each cage was recorded for 16 social and individual behaviors (3,7) during peak morning and afternoon activity periods (6–8:30 a.m.; 3:30–6 p.m.). Basal observations extended over a three-week period.

For the next three-week period, calibrated bottles containing vehicle alone or vehicle + 15% ethanol (2 bottles of each solution) were placed on the cage at 7 a.m. and 4 p.m.; solutions were renewed throughout the day as consumed, so that ethanol was available for most of the 24-hr period. Behavior was recorded as described above, as was the volume consumed by the group. During this period, the behavioral observer scored frequency and duration of individual drinking to provide a rough estimate of individual consumption and differences in patterns of drinking (e.g., steady, small dose drinking vs. high volume, short duration drinking). Special note was made of ataxia, nystagmus, uncoordinated movements during jumping, playing, falling off perches, and various atypical acrobatic maneuvers. Withdrawal symptoms were scored according to suggestions of Majchorowicz (18).

Behavioral Characterization: Quantitative Analyses of Behavior in the Context of a Social Group

Social interactions were studied in two newly established groups of animals, each of which consisted of one adult male and five females. These groups were first observed for a baseline period of one month, during which time social group dynamics were established and the animals became habituated to the presence of an observer. Following this period, social behaviors were recorded using sequential time analysis for one hour daily in the absence of alcohol. Next, alcohol (10% in 3% sucrose) was presented along with the vehicle (3% sucrose) for one hour. The two males did not select alcohol, but all of the females, at one time or another, did select alcohol. Social and individual behaviors were recorded during the one hour of access to alcohol and for two further hours after removal of the drinking bottles. For the purposes of this analysis, social behaviors were grouped as agonistic or affiliative, while individual behaviors included maintenance activities, level of arousal and idiosyncracies, such as stereotypy. These categories are listed in Table 1.

Amine-Related Compounds in CSF of Vervet Monkeys

CSF samples were taken on two occasions from alcohol-selecting monkeys. The animals studied were two males (2.95 and 5.30 kg) and six females (2.8–4.95 kg), all of which were in a stable social group. All had been shown to be alcohol-selecting animals and the group had been exposed to alcohol continuously for three months. At the end of the three months, alcohol was removed. After a further month of no alcohol exposure, CSF samples were taken. Alcohol was then reintroduced and was available continuously for a further 10 days. At the end of this period, a second CSF sample was taken. When alcohol was reintroduced, all animals selected alcohol and showed behaviors seen before at the peak of alcohol consumption. However, it was not possible to measure individual consumption without disrupting the social group. Both CSF samples were taken at 4 p.m. because this was the time of maximum alcohol intake in this group. Thus, the monkeys were studied on and off alcohol and at the time of maximum intake. A social group of random untreated animals who had not been exposed to alcohol was studied as controls. In this group, CSF was taken at 4 p.m. from three males (2.65–3.75 kg) and nine females (2.25–4.25 kg).

Blood Alcohol Levels in Vervet Monkeys

The pharmacokinetic clearance of ethanol in vervet monkeys

TABLE 1

CATEGORIES OF SOCIAL AND INDIVIDUAL BEHAVIOR

Social Behaviors	Individual Behaviors
Agonistic (Aggressive and Defensive)	Maintenance
Displace	Eat
Threat	Drink
Slap, hit	Self groom
Bite	Masturbate
	Self play
Affiliative Behavior	Arousal
Groom	Excited
Huddle	Orienting out (Vigilant)
Join	Alert
Play	Drowsy
Sex	Sleep
	Unconscious
Idiosyncratic or Stereotyped	Idiosyncratic or Stereotyped
"Stereotyped aggression"	Stereotypy
Incomplete behavior	Ataxia
(see text for examples)	Abnormal posture
	Piloerection

Each of these self-evident terms is operationally defined. For example, join = approach another animal and remain within arm's reach >30 seconds. Interobserver reliability on these measures was >0.90. Behaviors are defined in previous publications (3,7), and further details are available on request.

was determined in a group of animals not previously exposed to alcohol. Graded doses of ethanol (0, 1.25, 2.5 or 5 g/kg body weight) in a total volume of 20 ml 150 mM NaCl were administered nasogastrically to 40 male fasted monkeys previously anesthetized with ketamine (10 mg/kg IM). Blood samples were drawn and prepared, as described below, before intubation and 30, 60 and 90 minutes after intubation. These experiments were carried out starting at 7 a.m.

Biological Samples

Venous blood samples were taken by transcutaneous femoral puncture under ketamine anesthesia; ketamine reportedly has minimal effects on stress-related hormone levels in primates (4,14). Cisternal CSF (1–1.5 ml) was obtained by transcutaneous puncture using a 26-gauge needle, also under ketamine anesthesia. Samples for ethanol determination were deproteinized (1 M perchloric acid), then centrifuged. All samples were frozen immediately and shipped to Montreal in liquid nitrogen for laboratory analysis.

Biochemical Measures

Blood alcohol concentrations were measured by a modification of the colorimetric enzyme-linked assay described by Mello *et al.* (22,23), using a kit supplied by Sigma (St. Louis, MO). Tryptophan, tyrosine, homovanillic acid (HVA), 5-hydroxyindoleacetic acid (5HIAA) and 3-methoxy-4-hydroxyphenylethylene glycol (MHPG) were measured in CSF using high performance liquid chromatography (HPLC) with fluorometric and electrochemical detection (1,2).

RESULTS

Population Screening

Using the methods described above, we have screened 196 vervet monkeys, well-acculturated to captivity and to a specific social group, for willingness to drink beverage alcohol. Thirty-four (17%) of these animals repeatedly drank more than 200 ml/day of 15% ethanol in 3% sucrose in preference to 3% sucrose alone (Table 2). About twice this number of animals drank small quantities of 15% ethanol and larger quantities of lower alcohol concentrations, but did not continue drinking as the alcohol concentration was increased.

The age, sex and periodic alcohol consumption of alcohol-preferring vervet monkeys is presented in Table 2. Not surprisingly, young animals drink ethanol in sucrose more readily than do older animals, just as they are the first to try new foods and explore new situations. Most of the confirmed drinkers were subadult males or subadult or young adult females at the time of first

TABLE 2

CHARACTERISTICS OF ALCOHOL-PREFERRING VERVET MONKEYS AND STABILITY OF DRINKING BEHAVIOR

Monkey No.	Age/Sex	1985	1986	1987	1988
N452-3	SA/M	2.62	3.87	9.43	Yes
NL1525	A/F	3.85	6.93	15.06	Yes
OL1790	SA/F	3.85	8.74	2.09	Yes
0824-1	J/M	5.71	7.36	8.25	Yes
13B	J/M	6.63	7.57	6.39	Yes
02-1-2	J/M	7.02	9.35	8.66	Yes
OL1709	SA/M	7.85	6.75	12.43	Yes
OL1720	SA/F	8.85	16.50	14.38	Yes
0624-1	J/M	9.31	10.47	12.33	Yes
NL1526	SA/M	9.72	15.43	12.96	Yes
N454-1	SA/F	10.55	22.13	2.18	Yes
9-1	SA/M	11.76	8.07	12.36	Yes
NL1786	J/M		3.53	6.08	7.89
0854-1	SA/F		3.86	20.01	14.35
B2	A/F		4.96	6.33	8.17
N461-1	J/M		5.44	6.35	3.93
N459-2	J/F		5.59	7.85	12.73
OL1743	SA/F		6.95	11.48	10.21
NL1120	A/F		7.55	8.54	3.39
NL1712	A/F		7.56	5.34	2.86
OL1701	SA/M		8.02	12.35	16.65
N233-1	J/F		Yes	10.37	9.65
N489-1	J/F		Yes	3.65	8.42
0632-1	J/M		Yes	10.37	8.42
0704-2	J/F		Yes	14.85	18.36
OL1555	A/F			3.86	6.75
N476-1	J/F			3.87	9.54
OL1830	SA/F			5.45	9.13
OL1664	J/M			7.02	12.32
01028	A/F				7.96
OL1810	SA/F				7.78
NL1746	SA/M				10.67
OL1558	SA/M				6.54
L2035	J/M				7.23

Alcohol consumption is expressed as the mean of g ethanol/kg/day over a test period of 4 days, during which animals were individually housed and offered 15% ethanol in 3% sucrose or 3% sucrose. A designation of Yes indicates that the animal was seen to drink actively in a group cage, but that individual consumption could not be measured without interfering with social observations. Ages reflect the ages of animals at first testing.

J = juvenile, SA = subadult (adolescent), A = sexually mature adult.

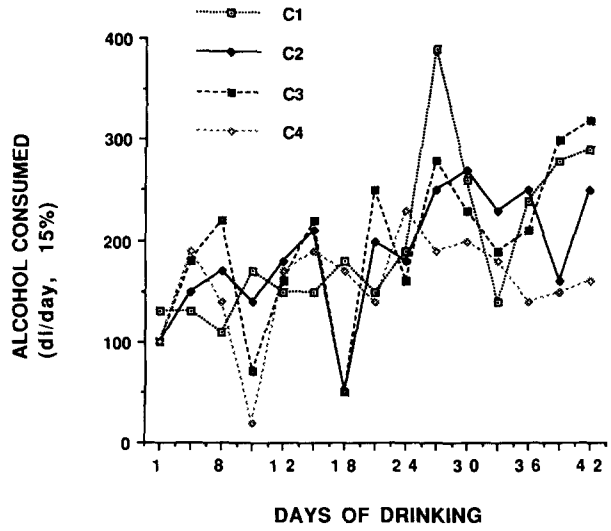

FIG. 1. Average consumption of ethanol per day by 4 monkeys given increasing concentrations of beverage alcohol (local rum) in 3% (w/v) sugar water. Data are expressed both as deciliters consumed and as g ethanol. Arrows indicate the day on which the concentration of ethanol was increased. Nominal concentrations are 7.5%, 10%, 12.5%, 15% and 20% (v/v); a 10% solution was found to contain 8.6 g ethanol/100 ml by enzymatic analysis. Standard errors ranged from 8–15% of the mean, but are not shown for the sake of clarity.

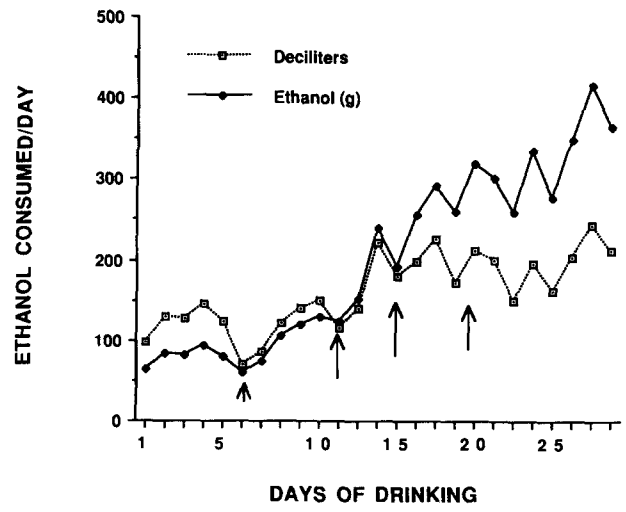

FIG. 2. Patterns of consumption of 15% ethanol by each of 4 alcohol-preferring monkeys studied over a 42-day period.

drinking. In general, neither sexually mature males nor dominant females drank substantial quantities of alcohol. However, males who began drinking as juveniles or subadults continued to drink into mature adulthood if alcohol were available. A number of females of reproductive age select ethanol in sucrose. Several pregnant and/or lactating females have drunk to intoxication, and in at least one instance, a female killed her infant while intoxicated.

Quantities and Patterns of Alcohol Consumption

Although some effort was made to estimate individual consumption in the group situation, animals were removed from the group and placed in individual cages for an accurate determination of the total volumes consumed ad lib and of the maximum ethanol concentration which would be tolerated. Of 34 animals studied in this fashion, 100% tolerated 15% ethanol and most drank substantial volumes of higher concentrations of alcohol. When an increased concentration of ethanol was presented, total alcohol consumption (determined as total volume consumed × % ethanol in the solution) dropped for 1 or more days (Fig. 1). Then consumption would increase over a period of a few days until the original consumption was exceeded. During these periods, a relatively constant fluid intake was maintained by drinking greater quantities of vehicle.

There is substantial individual variation with respect to the total consumption of ethanol by alcohol-preferring monkeys (Table 2). Despite individual differences, however, a rather regular pattern of consumption is observed with ad lib exposure (Fig. 2). Typically, consumption increases over 3 (± 1) days, drops some on the next day, then begins another ascending phase. Some few animals have a steadier daily consumption and increase at a constant and more gradual rate.

Stability of Drinking

Maximum alcohol intake in 18 monkeys has been measured once per year for three successive years (Table 2), using the protocol described in the Method section. A single male monkey (not shown in Table 2) refused to consume 15% ethanol on the third trial.

Behavioral Effects of Ethanol: General Observations

If housed singly, 20–25% of alcohol-preferring animals occasionally drank to ataxia, while 5–8% drank to unconsciousness on at least one occasion. Typically, a vervet which drank to unconsciousness one day did not drink alcohol the next; it huddled quietly in one corner and seemed hypersensitive to abrupt noises. After 3 weeks of constant access to alcohol (gradually increasing concentrations up to 20% for the last week), abrupt withdrawal led to restlessness, cage pacing, voluminous consumption of vehicle, hyperirritability to sound or observer intrusion, tremulousness, signs of autonomic discharge and repeated approaches to the drinking bottle together with handling, rattling and banging of the drinking bottle. These effects all occurred in isolated animals and were not dependent upon social reinforcers. In a group, aggression and displacement were increased, and affiliative behaviors decreased. We did not see withdrawal seizures in any animal.

In the group, drinking patterns were quite similar to those displayed by individually caged animals. Some animals drank steadily, while others drank intermittently. There were also animals in the group which drank whenever the bottle was available, but due to low status in the hierarchy had little access to a steady supply of alcohol unless three or more alcohol bottles were present. Most alcohol-preferring vervets did not drink appreciable amounts of 3% sucrose when it was presented simultaneously, while alcohol-shunning monkeys often drank large amounts of 3% sucrose in preference to water.

The behavioral response to alcohol intake was also highly individual. When intoxicated, one type of animal became very active in mostly solitary play, jumping to the perch, performing acrobatics, falling off the perch, occasionally playfully interacting with some individual by pulling the tail, etc. Another responded with increased initiation of affiliative behaviors, joining, grooming, inviting play and so on. Still another withdrew from the group, sat at the bottle or in the corner, and either did not respond to social overtures or showed mild aggression. Male-male play

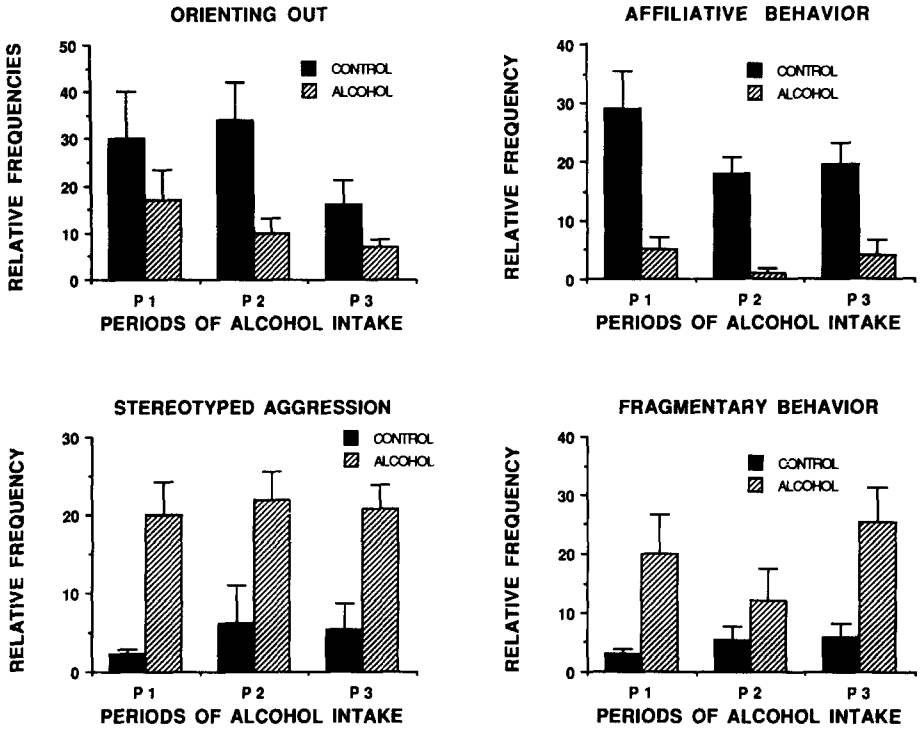

FIG. 3. Changes in distribution of social behaviors in two social groups of vervet monkeys (6 animals/group) during the process of habituation to ethanol consumption. Control bars represent the average of 1-hour observation on each of four days just prior to the presentation of alcohol. "Alcohol" represents the similar period following the removal of alcohol after one hour of access. P1 is four days taken after one month of socialization and habituation to the observer, at the beginning of alcohol exposure. P2 is taken after stabilization of alcohol intake. P3 is taken later during the experimental month on four random days on which the group was perturbed by presenting a limited supply of highly preferred food (mango) just before starting observation. The abscissa represents the relative frequency (±SEM) of behaviors normalized to events/monkey/hour.

bouts more frequently terminated in aggression and separation than usual. Occasional animals became very hyperactive, racing around the enclosure and pacing frantically back and forth. The consistent changes after drinking were ataxia, the adoption of postures never observed normally, a striking slowing of climbing and walking, and the appearance of repetitive incomplete behaviors (vide infra). At low doses, despite significant behavioral effects, there was not a striking increase in aggression, with the exception of mild conflict at the drinking bottle if there were limited numbers of spouts. Although on occasion two monkeys of similar size and rank drank simultaneously from the same bottle, the normal patterns of displacement pertained just as they would

TABLE 3

CSF AMINO ACIDS IN ALCOHOL-PREFERRING AND CONTROL VERVET MONKEYS

Metabolite (ng/ml)	Control Monkeys	Alcohol-Preferring Monkeys (No Alcohol)	Alcohol-Preferring Monkeys (Alcohol)
Tryptophan	384.5 ± 121.7†	677.5 ± 92.9	712.5 ± 79.3
Tyrosine	1405.2 ± 117.5‡	2628.5 ± 257.9	3234 ± 184.7
5HIAA	64.15 ± 9.2	76.55 ± 67.7	103.4 ± 10.5*
HVA	322.5 ± 36	248.2 ± 17.6	335.6 ± 28.8*
MHPG	32.7 ± 3.4	25.75 ± 3.6	18.58 ± 5.6

CSF was drawn from alcohol-preferring monkeys after 1 month of withdrawal from ad lib alcohol (off alcohol condition), then after 10 days of ad lib alcohol (15%, v/v) in sugar water (3%, w/v). All samples were collected between 1600 and 1620 hr. Data are expressed as mean ± SEM. As shown, tryptophan and tyrosine differed between groups in the no alcohol condition, while 5HIAA and HVA differed as a function of the alcohol/no alcohol conditions in the alcohol-preferring group. *$p<0.05$; †$p<0.01$; ‡$p<0.001$ by two-tailed Student's t-test, or paired t-test, as appropriate.

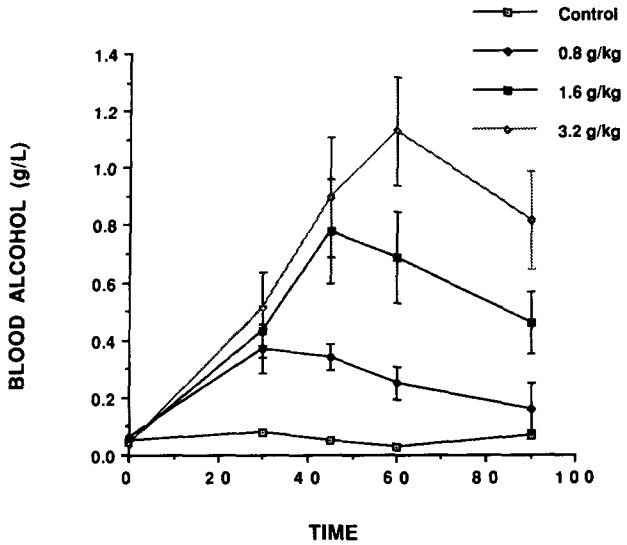

FIG. 4. Blood alcohol concentrations after the nasogastric administration of 0, 0.8, 1.6 or 3.2 g/kg ethanol in 0.15 M NaCl. Alcohol was administered and blood samples were drawn under light ketamine anaesthesia. All animals used in this study were alcohol-naive. Data are presented as mean ± SEM; n = 10 animals per group.

with other valued resources. When the bottle was empty, drinking monkeys often attacked the bottle and pulled the drinking tube off entirely.

Behavioral Effects of Ethanol: Quantitative Analysis of Individual Social Interaction

During the control hour before presentation of alcohol, the group as a whole showed significant attention to the external environment and showed anxious attention to stimuli, such as the presence of the observer (to whom they had previously shown habituation), other monkey cages, etc. During and after the period of alcohol consumption, this "orientation out" waned markedly (Fig. 3). Figure 3 also shows the shifts in patterns of social behaviors (relative frequencies) observed during the pre- and postdrinking conditions at three different times. (See caption for more experimental detail.) Although alcohol consumption increased the total number of interactions, there was a striking decrease in affiliative behaviors such as grooming and huddling. The increase was accounted for by fragmentary and inappropriate behaviors. That is, an animal might make a play invite, then walk away rather than accepting the response. The same pattern was striking in regard to aggression. There were many "aggressive" overtures, including threats, slapping at, physical displacement, which were neither responded to nor followed up by the initiator. We scored these not as aggression but as "stereotyped aggression" and the frequency quadrupled during the period of alcohol consumption (Fig. 3, panel D).

Biochemical Measures

CSF amino acids and amine metabolites were studied in 8 alcohol-preferring monkeys (2 males, 6 females) and in 10 control animals (2 males, 8 females). As shown in Table 3, CSF levels of tryptophan and tyrosine were significantly lower in control animals than in alcohol-preferring animals in the no alcohol condition, while CSF 5HIAA and HVA were significantly raised by drinking alcohol (in alcohol-preferring monkeys for the alcohol vs. no alcohol condition).

Blood ethanol levels achieved after the administration of acute bolus loads of 0, 0.8, 1.6 and 3.2 g/kg ethanol are depicted in Fig. 4. For this experiment, we used ketamine-anesthetized alcohol-naive monkeys. The relatively low blood alcohol levels achieved after large loading doses are compatible with the high daily intake of alcohol seen in alcohol-preferring monkeys and with the high rate of glucose metabolism previously documented in rhesus and in vervet monkeys (13,23).

DISCUSSION

Thirty-four of 196 feral vervet monkeys derived from an isolated Caribbean population voluntarily consumed substantial quantities of beverage alcohol both in social group settings and when housed individually. In either setting, alcohol consumption increased over time, and withdrawal signs followed removal of alcohol. Differences in patterns of drinking, in amount consumed and in behavior when intoxicated were noted over a 6-month period. Subadult animals of both sexes and low-ranking adult female monkeys are over-represented among drinkers.

In this report, we provide evidence that willingness to select alcohol is stable over time, and that alcohol-preferring monkeys voluntarily consume very large absolute amounts of alcohol. However, the blood alcohol concentrations achieved after the bolus administration of graded alcohol doses suggest that ethanol is metabolized very quickly in this animal, in keeping with previous estimates of the kinetics of glucose metabolism (14,25).

Although some of the expected behavioral consequences of alcohol intake—clumsiness, ataxia, increased social interaction—were observed, the most striking finding was the highly individual response to alcohol, as described above. In general, social drinking served to intensify a given monkey's normal behavioral pattern. Thus, an evaluation of behavior during alcohol presentation requires a detailed knowledge of normal baseline behavior for each animal. For the group, two important generalizations concern decreased levels of affiliative behaviors during the drinking period and increased levels of aggressive behaviors during the withdrawal period. A detailed analysis of both individual and group behaviors will be presented subsequently (Guzman-Flores *et al.*, unpublished data).

Alcohol-preferring individuals, all of whom were group-housed, were not subjected to any identifiable behavioral stress which would distinguish them from their peers. Although additional characterization is essential, these animals might provide a model of voluntary alcohol consumption which differs from other important primate models (15, 16, 21, 22) in that no social stress or behavioral training is required for the initial elaboration of drinking behavior. In particular, because individual animals show differences in the rate and magnitude of change from steady state drinking to high consumption, they provide an opportunity to examine the vulnerability to increased consumption and the concomitant biological changes.

There are some obvious differences between our drinking monkeys and alcohol abuse in humans. First, the monkeys progress very rapidly to high levels of alcohol consumption. Second, adolescent male monkeys and females low in the social hierarchy are over-represented among alcohol-preferring animals. Our preliminary observations suggest that heavy drinking adolescent males usually continue drinking into early adulthood. Thus, with the passage of time, we may find a larger proportion of adult males within our colony. Third, the proportion of animals which ingest no alcohol (and show active distaste) is larger than that seen in humans. Nonetheless, a major asset of the vervet monkey in studies of alcohol abuse is that most monkeys do not drink to excess, and that those which do drink do so spontaneously. This enables studies of biological, psychological and social factors which modulate drinking behavior and in particular determine the

transition from intermittent drinking to chronic high level intake. Thus, the vervet might be a useful addition to other animal models, which have strengths in different areas.

In this preliminary study, we have demonstrated one type of biological factor which can be studied. The CSF measurements have great potential, as we have established previously that there are marked similarities between CSF indices of brain biogenic amine metabolism in vervets and humans (28). That tryptophan and tryosine are elevated in the CSF of alcohol-preferring monkeys is an interesting finding. Further work will be needed to determine whether this is due to prior exposure of the monkeys to alcohol or whether it reflects inherent differences between alcohol-preferring and control animals. Both tryptophan and tryosine are catabolized primarily in the liver. If there is a decline in the rate of catabolism of tryptophan and tyrosine, this is unlikely to be due to a general decline in liver function in view of the relatively short prior exposure of the vervets to alcohol. Alternatively, previous alcohol ingestion may have altered the uptake of aromatic amino acids by the brain. Whatever the explanation, it is significant that the elevated tryptophan levels did not lead to increased CSF 5HIAA, as might have been expected. Possibly CNS tryptophan hydroxylase could have been reduced in alcohol-preferring animals, thereby compensating for the elevated 5HT synthesis rate which resulted from high tryptophan levels.

Ingestion of alcohol for ten days resulted in significant increases in brain 5HT and dopamine metabolites. These data are consistent with the theories that promote potentiation of 5HT or dopamine functions as important factors in the reinforcing properties of alcohol (5, 15, 17, 24).

In summary, we have shown that a proportion of vervet monkeys spontaneously select alcohol and drink it to intoxication. These traits are associated with altered brain biochemistry. The alcohol-preferring vervet has advantages complementary to the established animal models of alcoholism and may provide a useful means of studying some of the factors which lead to alcohol abuse in man.

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