Pharmacology Biochemistry & Behavior, Vol 24, pp 271–280, 1986 © Ankho International Inc Printed in the U S A 0091-3057/86 $3 00 + 00

Stress and Conflict Conditions Leading to and Maintaining Voluntary Alcohol Consumption in Rats

MARJORIE A. CAPLAN AND KATHLEEN PUGLISI

Department of Psychology, Adelphi University, Garden City, NY 11530

Received 9 October 1984

CAPLAN, M A AND K PUGLISI *Stress and conflict conditions leading to and maintaining voluntary alcohol consumption in rats* PHARMACOL BIOCHEM BEHAV **24**(2) 271–280, 1986 —Four experiments were conducted to investigate the effects of unavoidable shock, conflict conditions, taste, and food deprivation on the voluntary consumption of alcohol by rats Experiment 1 showed that when rats were given unavoidable shocks for one hour every day, those living in their home cages consumed greater amounts of a 5% ethanol solution than did rats living in the shock chambers Experiment 2 revealed that this increased alcohol consumption was maintained and further elevated when these same rats were subjected to conflict, and it did not decrease when the conflict conditions were terminated When the unavoidable shock conditions were repeated in Experiment 3 with naive rats and the fluid choice consisted of a plain sucrose solution and one containing alcohol, rats in both the shock box and safety cage living conditions consumed very little of the sucrose-plus-alcohol solution Rats living in the aversive environment even decreased consumption of the plain sucrose solution Experiment 4 showed that simple food deprivation can also result in an increased intake of an alcohol solution The tension reduction hypothesis cannot account for these results they demonstrate that deprivation can influence alcohol consumption, and indicate that an aversive environment can interfere with drinking of any solution The results also demonstrate both the positive and negative properties that alcohol can have

Unavoidable shock Punished responding Alcohol consumption

A number of studies have shown that repetitively subjecting an organism to various kinds of aversive stimulation will increase alcohol consumption in animals that initially show an aversion to it, other studies have indicated no effect [2,14] Powell, Kamano and Martin [15] showed that rats of both sexes subjected to periodic uncontrollable shock five times daily increased alcohol consumption following a period of forced ethanol intake, this increased intake remained elevated during the two-week stress-free after period A number of other investigators have demonstrated that voluntary ethanol consumption increases during the stress-free period that follows shock exposure The classic result here is that of Casey [4] who found no increase in alcohol consumption by rats during the period when they were being subjected to inescapable shock Ethanol consumption increased following termination of the stress conditions and was maximal 16 days after the last shock When rats were subjected to random presentation of unavoidable shock during the same 12 minutes of every hour for five days, Mills, Bean and Hutcheson [11] found that increased alcohol consumption occurred specifically in the temporal interval immediately following shock occurrence

Since these results indicate that stress-induced alcohol consumption follows stress exposure, Volpicelli, Tiven and Kimmel [22] hypothesized that a post-shock safety period is necessary in order to observe increased alcohol consumption They posited that the absence of a stress-free period was the reason that Myers and Holman [12] failed to find an increase in alcohol intake when uncontrollable and unpredictable footshock was administered to rats one or six times per hour for 14 days Volpicelli *et al* tested the hypothesis that animals would drink more ethanol in a safe environment following termination of inescapable shock than they would if they were maintained in the aversive shock chambers During the stress period, all rats were placed in the shock chamber, one at a time, and received 60-1 0 mA inescapable shocks of two sec duration delivered on a fixed-time 60-second schedule Volpicelli *et al* found that rats housed in their home cages consumed more alcohol in the shock-free periods than did those housed in the experimental chambers Their procedure insured an adequate sampling of alcohol prior to the shock fluid-choice phase there were two shock periods preceding this phase during which only water (Phase I) or alcohol (Phase II) was available to the animals at all times

Anisman and Waller [1] found that voluntary consumption of alcohol increased in rats when inescapable shock was presented, and there were no differences in consumption during stress and rest periods Alcohol consumption did not increase when the rats were in a conflict situation when they could avoid shock by not responding The usual interpretation of these results is that organisms engage in the voluntary consumption of ethanol because it reduces the anxiety and fear induced by uncontrollable aversive stimulation According to Anisman *et al* , control over aversive shock stimulation is an important determinant of alcohol consumption be-

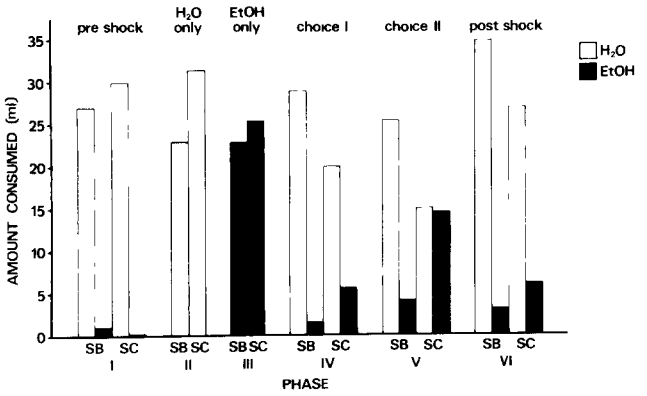

FIG 1 Median ethanol intake (ml) during the daily 23-hour stress-free intervals of rats living in their home cages (SC) or in the shock chambers (SB) during the designated phases

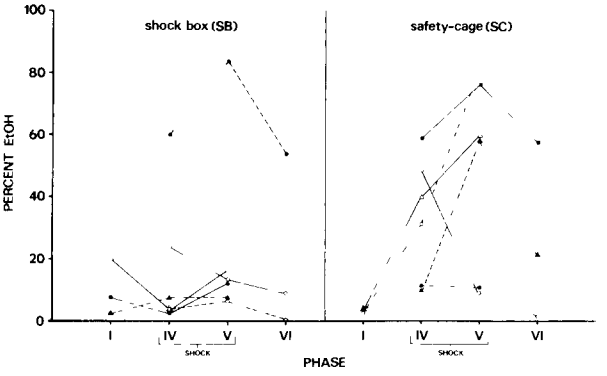

FIG 2 Percent ethanol intake of individual rats in the SB and SC living conditions when a choice of water and a 5% ethanol solution was available to them

TABLE 1

MEDIAN VOLUME (ml) AND QUANTITY (g/kg) OF 5% ETHANOL CONSUMED BY THE SHOCK-BOX (SB) AND SAFETY-CAGE (SC) RATS IN EACH PHASE OF THE UNAVOIDABLE SHOCK-STRESS CONDITIONS (EXPERIMENT 1)

		Amount of Ethanol Consumed			
		(ml)		(g/kg)†	
Phase	No and Gender of Subjects	SB	SC	SB*	SC*
Pre-shock	2m, 1f	1 00	0 00	0 09 (0 00–0 08)	0 00 (0 00–0 20)
EtOH Only	4m, 2f	23 00	25 50	2 06 (0 71–3 13)	2 58 (1 31–3 23)
Choice I	4m, 2f	1 50	5 50	0 13 (0 00–2 23)	0 56 (0 00–2 73)
Choice II	4m, 2f	4 00	14 50	0 36 (0 00–6 61)	1 46 (0 00–3 23)
Post-shock	2m, 1f	3 00	6 00	0 27 (0 00–1 34)	0 61 (0 00–4 45)

*Median ad-lib body weight (g) SB=441 5, SC=390 5
†Range is in parentheses

cause when an adequate coping method is available, the organism does not need alcohol to reduce the stress Lazarus [7] has also emphasized the controllability of aversive stimulation as being a main factor in the determination of what kind of stimulation will be stressful to the organism

The first experiment to be reported here was conducted to replicate Volpicelli *et al* 's procedure and results, it also included two alcohol-water baseline phases, one preceding and one following the stress period to provide a measure of alcohol consumption before and after stress exposure The second experiment examined alcohol consumption when these rats were minimally food-deprived (95% ad lib body weight) and subjected to an approach-avoidance conflict The question of interest was whether or not having control over shock occurrence would result in a decrease or cessation of alcohol consumption in alcohol-experienced rats during the conflict period

Since taste has been shown to be a factor controlling the voluntary consumption of alcohol, Experiment 3 was conducted to see if flavoring the alcohol solution with sucrose would influence its consumption in the unavoidable shock conditions of Experiment 1 when the choice solution consisted of plain sucrose Investigators have shown that when a sweet caloric solution is one of the fluids available to the animal, choice of it can override consumption of any others [8,11] Mills *et al* also found that when the sweet solution did not contain calories equivalent to the ethanol solution, stressed animals decreased saccharin intake in favor of the 5% and then a 10% ethanol solution They attributed these results to changes that occur with increasing exposure to stress, taste simply begins to play a less important role in fluid selection Experiment 4 was conducted to see which sucrose solution would be preferred when the animals were reduced to 95% ad lib body weight as they were in Experiment 2 Waller, McBride, Lumeng and Li [24] have shown that both food restriction and sugar flavoring of an alcohol

TABLE 2

MEDIAN VOLUME (ml) AND QUANTITY (g/kg) OF 5% ETHANOL CONSUMED BY MALE AND FEMALE RATS IN THEIR HOME CAGES DURING SHUTTLE-BOX CONFLICT CONDITIONS (EXPERIMENT 2)

	Amount of Ethanol Consumed			
	(ml)		(g/kg)†	
Phase	Males	Females	Males*	Females*
Approach I	6 79	17 75	0 61 (0 00–1 98)	2 52 (0 96–3 20)
Conflict	18 25	26 13	1 64 (0 00–3 69)	4 18 (2 24–6 24)
Approach II	17 57	22 55	1 58 (0 00–3 87)	3 61 (1 76–7 04)
Post-shuttle-box	29 33	21 25	2 64 (0 27–4 32)	3 40 (2 56–5 44)

*Median 95% body weight (g) Males=438 0, Females=246 5, n=8 males and 4 females in each phase

†Range is in parentheses

solution result in the greatest increase in alcohol consumption under non-stress conditions

EXPERIMENT 1

METHOD

Animals

Twelve Sprague-Dawley rats (8 males, 4 females) obtained from Blue Spruce Farms, Altamont, NY, were run in two squads of six rats each (4 males, 2 females) At the start of the experiment, the first and second squads of animals were 140 and 90 days old, respectively and weighed between 244 (f) and 542 (m) grams Median weights of the rats are presented in Tables 1 through 4 All were housed individually under a 12-hour light/dark cycle, with food and liquid freely available This liquid consisted of water and/or a 5% ethanol solution prepared from 100% ethanol and tapwater (v/v)

Apparatus

Two kinds of living conditions were provided for each squad of animals Three rats in each squad were housed in their home cages in the vivarium (the safety-cage group-SC), the other three in each squad were housed in the shock chambers (the shock-box group-SB) Ad lib food was available to all of the animals from a food hopper that hung on one of the walls of their cages Fluid was available from one or two inverted 100 ml graduated cylinders mounted side by side on the cages to the right of the food hopper Drinking spouts protruded 2 5 cm into the cage and hung 3 0 cm above the floor

The shock box living conditions consisted of three identical chambers (25×30×30 cm), each encased within a sound-attenuating chamber Adequate circulation of air was provided by a fan, and a white noise generator provided low-level masking noise during the shock sessions The side walls were constructed of stainless steel and the top, front, and rear panels consisted of clear Plexiglas A food hopper hung on a side panel outside a square hole (5×7 cm) covered by wire mesh 4 5 cm above the floor from which the subjects could obtain food ad lib One or two inverted 100 ml graduated cylinders hung on either side of the food hopper, drinking spouts protruded 2 0 cm into the shock box and hung 7 0 cm from the floor The floor of the shock box consisted of stainless steel grid bars 0 5 cm in diameter, spaced 1 5 cm apart center to center Scrambled shock was delivered through the grid floor and side walls by a constant voltage, fixed impedence shock source [5] Shock was programmed via electromechanical equipment and an interval tape programmer in an adjacent room

Procedure

The experiment consisted of six phases, each of seven-days duration All animals were run through four shock phases (II, III, IV, and V) For the first five days of each shock phase, each subject was placed into the shock chamber for one hour, and received 60 uncontrollable 1 0 mA shocks of two seconds duration delivered on a fixed-time 60-sec schedule Alcohol and water intakes were recorded for Squad One for one week following termination of the final shock phase (Phase VI) A pre-shock measure of fluid intake was recorded for Squad Two for one week prior to the beginning of the first shock phase (Phase I) During both of these non-shock phases, shock-box and safety cage groups were housed in the vivarium in standard Wahmann cages Water and ethanol intakes were recorded daily The order in which the animals were exposed to daily shock sessions was randomized and the time between shock sessions varied between 20–28 hours in order to control for temporal conditioning cues that might influence alcohol consumption

The SB animals were moved into the shock chambers to live at the beginning of Phase II Water was the only fluid available to both groups during phase II, and the alcohol solution was the only fluid available during the third phase Throughout Phases IV and V, subjects were provided with a choice of water and a 5% ethanol (v/v) solution These fluids were available to the rats in their respective living conditions and during the daily shock periods When subjects assigned to the safety-cage condition were placed in the shock boxes, the displaced SB animal was temporarily transferred to an empty cage in the vivarium The amount of each fluid consumed was recorded each morning at 1000 hours and immediately following each shock session during the four shock phases For Squad One, fluid intake was also recorded two hours after termination of the shock session, since consumption during this period was negligible, this aspect of the procedure was eliminated for Squad Two Fluid bottles were refilled immediately after daily morning recordings were taken and the location of these was alternated to control for position preferences All subjects were weighed daily, weights did not change during the experiment

RESULTS

Figure 1 illustrates the differences in alcohol and water consumption for the rats that were housed in the shock chambers (SB) and for those that lived in their home cages in the vivarium (SC) More water than alcohol was consumed by both groups in the shock-choice phases, except during phase V when SC animals increased consumption of the alcohol solution and decreased water intake Mann-Whitney U-tests indicated that the safety-cage animals drank signifi-

TABLE 3

MEDIAN VOLUME (ml) AND QUANTITY (g/kg) OF A SUCROSE + ETHANOL SOLUTION CONSUMED BY MALE AND FEMALE RATS LIVING IN THE SHOCK-STRESS CHAMBERS (SB—SHOCK-BOX) OR IN THEIR HOME CAGES (SC—SAFETY-CAGE) IN EXPERIMENT 3

	Amount of Sucrose + Ethanol Consumed							
	(ml)				(g/kg)†			
	SB		SC		SB		SC	
Phase	M	F	M	F	M*	F*	M*	F*
Pre-shock	12 43	9 76	10 24	12 33	1 09 (0 00–3 81)	1 29 (0 00–3 04)	0 92 (0 00–2 96)	1 78 (0 00– 9 08)
S+EtOH Only	42 93	37 67	27 07	49 60	3 75 (2 25–6 14)	4 99 (3 71–5 56)	2 43 (1 79–4 03)	7 15 (3 32–14 42)
Choice I	9 33	9 24	10 24	5 76	0 82 (0 00–2 85)	1 22 (0 00–4 50)	0 92 (0 00–3 05)	0 83 (0 00– 2 02)
Choice II	9 05	10 00	10 76	8 76	0 79 (0 00–1 99)	1 32 (0 00–3 97)	0 97 (0 00–2 69)	1 26 (0 00– 3 60)
Post-shock	14 29	8 19	12 43	7 57	1 25 (0 00–4 93)	1 08 (0 00–4 77)	1 11 (0 00–3 23)	1 09 (0 00– 2 45)

*Median ad-lib body weight (g) SB-males=456 1, SB-females=298 0, SC-males=440 0 SC-females=273 6 n=3 males and 3 females per group

†Range is in parentheses

TABLE 4

MEAN VOLUME (ml) AND QUANTITY (g/kg) OF A SUCROSE + ETHANOL SOLUTION CONSUMED BY MALE AND FEMALE RATS BEFORE, DURING AND AFTER REDUCTION TO 95% OF THEIR AD-LIB BODY WEIGHTS (EXPERIMENT 4)

	Males*			Females*		
		Amount of Sucrose + EtOH Consumed			Amount of Sucrose + EtOH Consumed	
Phase	Md Body Wt (g)	(ml)	(g/kg)†	Md Body Wt (g)	(ml)	(g/kg)†
Before	490 5	13 55	1 09 (0 00–5 07)	303 5	7 85	1 02 (0 00–5 72)
During	466 0	26 85	2 27 (0 00–5 67)	288 0	33 45	4 58 (0 00–7 53)
After	480 5	11 00	0 90 (0 00–5 42)	320 0	6 30	0 78 (0 00–5 18)

*n=6

†Range is in parentheses

cantly more alcohol than the shock-box rats did during both shock periods when a choice of water and the alcohol solution was available The amount of alcohol consumed during Phase I, the pre-shock phase, and Phase VI, the post-shock phase, did not differ between the SB and SC groups (For all experiments, medians were compared using the SPSS program for the Mann-Whitney U-Wilcoxon Rank Sum W Test Significance of the comparisons ($p<0$ 05) was determined by this program by computation of z scores and exact probabilities of obtaining these values Consideration of repeated measures always yielded n's>20)

Intake of the alcohol solution was significantly greater for the SC animals during each of the shock-choice phases than it was for these animals during the pre-shock baseline phase A between-squad comparison of alcohol intake during the pre-shock and post-shock phases (I vs VI) indicated that alcohol intake was still significantly elevated following termination of the shock-stress procedure and the previous fluid choice conditions These squads did not differ in ethanol intake during any of the stress periods The SB animals consumed a significantly greater amount of alcohol only during Phase V, the second shock-choice phase, than they had during Phase I The only time that total fluid intake significantly differed between the SB and SC groups was in Phase II, the water only shock phase, and in Phase IV, the first shock-choice phase More fluid was consumed by the SC group during Phase II, and by the SB rats during Phase IV It can be seen that this was due to the greater amount of

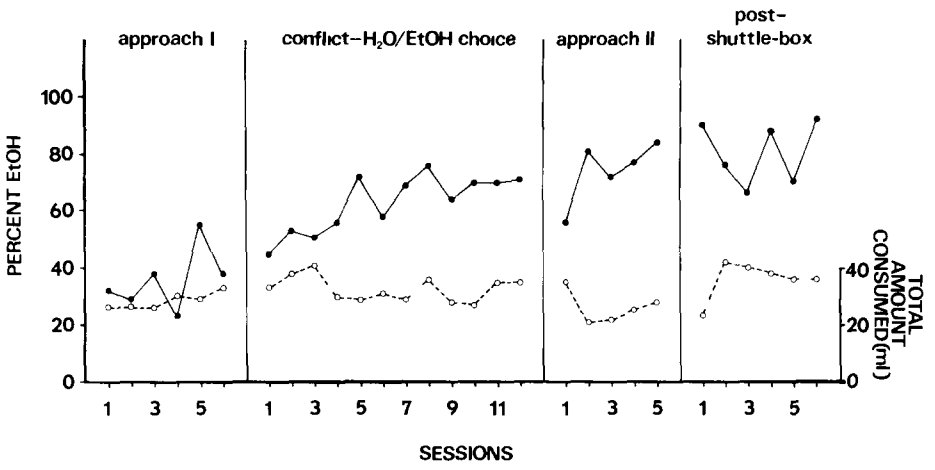

FIG 3 Percent alcohol consumed (—) and total fluid intake (○— —○) before, during, and after rats were subjected to shock punishment for crossover responses in the shuttlebox

water consumed by the respective groups during these periods

Figure 2 shows the percent of the alcohol solution consumed for individual animals in each group as a function of phase when both fluids were available to the animals Phases IV and V were the shock-choice phases and only one animal in the SB group consumed a significant amount of alcohol

Tables 1 through 4 show the volume (ml) of alcohol consumed by the respective groups, and the quantity in terms of g/kg [10] Differences in consumption by males and females are shown in Tables 2, 3, and 4 for the respective experiments This sex difference breakdown was not possible for the rats in Experiment 1 since only two females were included in the shock-box and safety-cage groups respectively

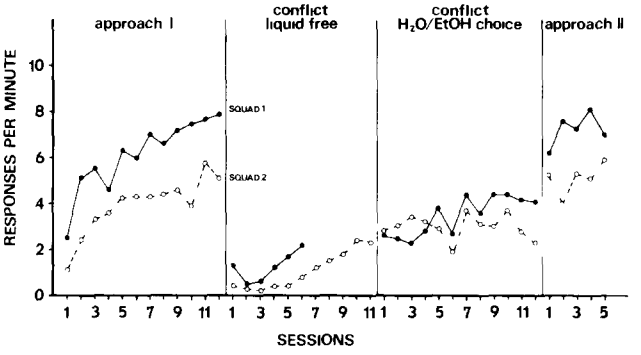

FIG 4 Median daily response rates before, during, and after crossover responses were punished with electric shock

EXPERIMENT 2

METHOD

Animals

The same rats were used in Experiment 2 as were used in Experiment 1 All were housed individually in standard rat cages located in the vivarium They were maintained at 95% of their free-feeding body weights and always had ad lib access to water in their home cages

Apparatus

A shuttlebox (20×48×19 cm) encased within a sound attenuating chamber was used The side panels of the box were constructed of stainless steel and the top, front, and back panels were made of clear Plexiglas A Plexiglass barrier 8 cm high divided the box into right and left halves Two Davis feeders (PD 104) mounted on each side of the chamber delivered 45 mg Noyes pellets into food trays located 3 5 cm above the floor in the center of the side walls A white stimulus light was located 10 cm above each feeder tray and signalled the beginning and end of each session A fan mounted on one wall of the chamber provided ventilation.

The floor of the shuttlebox consisted of stainless steel grids 0 4 cm diameter spaced 1 4 cm apart center to center These were connected to microswitches which were activated each time the animal jumped to the opposite side of the chamber These microswitches served to activate the appropriate feeder. The grids on the left side of the shuttlebox were also connected to a constant voltage, fixed impedence shock source which delivered current through an integrated circuit shock scrambler [4] Two inverted 100 ml graduated cylinders were mounted on the front panel on the right (safe) side of the shuttlebox, extended 3 cm into the box and hung 2 5 cm above the grid floor Feeder operation, shock delivery, session length and data recording were controlled by solid state modules and electromechanical counters located in an adjoining room

Procedure

Experiment 2 began approximately 3 weeks after the end of Experiment 1 The rats were placed in the shuttlebox for 40 min sessions, and were reinforced with food when they jumped over the barrier from one side of the shuttlebox to the other. The reinforcement schedule was continuous for the first six sessions, the probability of reinforcement was then changed to 85% Twelve sessions of approach training were given prior to initiation of the conflict procedure (Approach I) Subjects were provided ad lib access to a choice of water and a 5% ethanol solution in the shuttlebox and in their home cages during six of these sessions to obtain a baseline measure of consumption

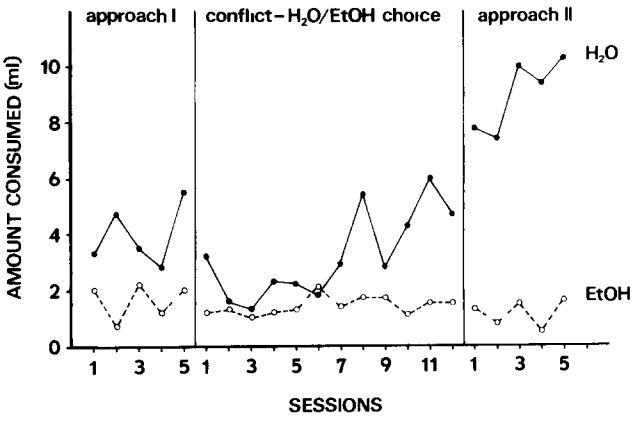

FIG 5 Median amounts (ml) of water and alcohol consumed in the shuttlebox during daily sessions

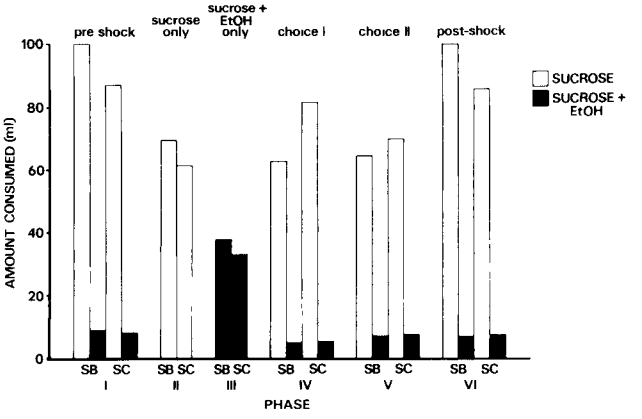

FIG 6 Median amounts (ml) of a sucrose and a sucrose-alcohol solution consumed by rats living in their home cages (SC) or in the shock chambers (SB) during the designated phases

Beginning on Session 13, the conflict procedure began Rats received a 0 3 mA shock of 0 5 sec duration every time they crossed the barrier from the right to the left side Crossovers from the left to the right side were never punished After 12 sessions, the animals were provided with access to an ad lib choice of water and 5% ethanol in their home cages and in the shuttlebox Following 12 sessions of this fluid choice, conflict condition, shock was terminated and five shock-free approach sessions were run (Approach II) with both fluids available For one week following termination of Experiment 2 when animals were returned to their home cages, they were provided ad lib access to food and to a choice of the alcohol solution and water These last two procedures were followed to determine if the amount of alcohol consumed would change after a period of conflict exposure had ended The amounts of fluids consumed in the home cages were recorded each morning at 1000 hours, and in the shuttlebox after each session

RESULTS

Figure 3 shows the percent of alcohol consumed and the total fluid intake during each stage During Approach I, the percent of alcohol consumed, still elevated above the initial baseline levels observed in Experiment 1, usually remained below 40% The semi-interquartile range ($IQ_r=(Q_3-Q_1)/2$) was equal to 21 92% This means that across animals and across days during this phase, the median percent intake of the ethanol solution (29 63%) varied by ±21 92% The rats increased alcohol intake to about 70% of their total fluid intake when they were subjected to the conflict procedure, when crossover responses to the left side of the shuttlebox were punished (IQr=27 38%) Alcohol intake decreased on the first day of Approach II, when shock punishment was discontinued, and then increased and remained elevated for the duration of the experiment when the animals continued to make shock-free crossover responses to obtain food reinforcement (IQr=19 23%), and following the shuttlebox procedure when they were returned to their home cages and free-feeding conditions (IQr=13 94%) Total fluid intake remained fairly constant throughout the experiment These results indicate that neither control over, nor termination of the aversive shock conditions necessarily results in the cessation of increased alcohol intake

Figure 4 shows how the crossover responses were suppressed when they were punished Crossover rates decreased for both squads of animals from 5 or 8 responses per minute to about one response per minute These rates started to show some recovery before the choice of fluids was made available to the animals and stabilized at around 3–4 responses per minute while the shock punishment procedure was still in effect When this punishment was eliminated, response rates increased to the pre-punishment levels

One further finding of interest revealed that liquid intake did increase in the shuttlebox but it was not of the alcohol solution Figure 5 shows that the amount of water consumed in the shuttlebox decreased when the conflict procedure was introduced, gradually increased to pre-conflict consumption levels, and then increased dramatically during Approach II when the conflict procedure was terminated This cannot be accounted for by increased number of food reinforcers received because water consumption was not as great during Approach I when just as many food pellets were being obtained

EXPERIMENT 3

METHOD

Animals

Twelve naive Sprague-Dawley rats (6 males, 6 females) obtained from Blue Spruce Farms, Altamont, NY, were run in two squads of six animals each, as was described in the first experiment At the start of this experiment, the first and second squads of animals were 188 and 223 days old respectively Subjects were housed individually under a 12-hour light/dark cycle They had ad lib access to food and a 3% sucrose (w/v) and/or an ethanol solution that was 5% of the 3% sucrose solution (v/v) The rats were assigned to either the safety-cage (SC) or shock-box (SB) living conditions

Apparatus and Procedure

The living conditions and inescapable shock procedure were the same as were described for Experiment 1 In the present experiment, data were obtained for all 12 rats in each of the six phases At the end of Experiment 3, the rats were

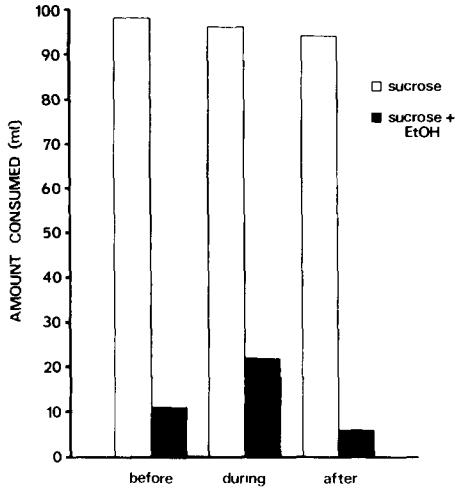

FIG 7 Median amounts (ml) of a sucrose and a sucrose-alcohol solution consumed by rats before, during, and after they were reduced to 95% of their ad lib body weights

maintained in their home cages in the vivarium and were allowed access to ad lib food and water for six weeks

RESULTS

Figure 6 shows the amounts of each solution that were consumed by the SB and SC groups during the six phases of the inescapable shock conditions It shows that most of the animals' fluid intake consisted of the plain sucrose solution when a choice was available to them (IQr– SB= 12 69 ml, SC=24 84 ml) There was a decrease in the amount of sucrose consumed by both groups during the shock phases (II–V) which was most pronounced for the shock-box rats These rats significantly decreased sucrose intake from 100 ml to 69 5 ml when shock was first introduced, even though the plain sucrose was the only solution available for them to drink (IQr=23 25 ml) These decreased intakes remained significantly lower throughout the shock phases of the experiment (p's<0 05), sucrose intake significantly increased to pre-shock levels when the shock phases were terminated (p<0 05, IQr=8 67 ml) Although the SC animals seemed to show a similar decrease in sucrose consumption in Phase II, it was not significant (p>0 05, IQr=27 87 ml) There was very little intake of the sucrose-alcohol solution by either group and it did not change during any phase of the experiment except during Phase III when it was the only solution available to them (IQr-SB=5 57 ml, SC=10 09 ml)

EXPERIMENT 4

METHOD

Animals and Procedure

At the end of the 6-week interval following Experiment 3, baseline weights were recorded from the rats for 10 days while they were being maintained on ad lib feeding and drinking The fluids available to the animals were changed from water to two 3% sucrose solutions, one of which was 5% alcohol The animals had access to these fluids from two graduated cylinders that hung on the front of their home

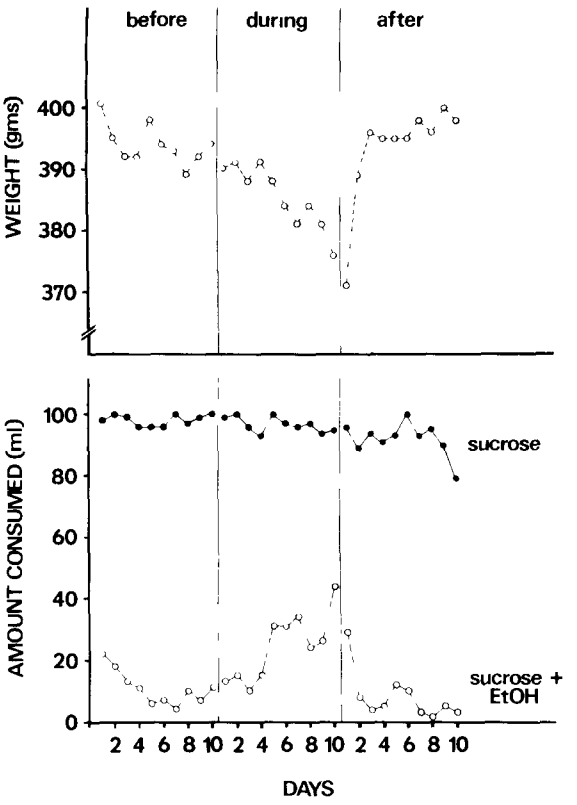

FIG 8 Daily weights and daily consumption of the sucrose and sucrose-alcohol solutions during each 10-day period before, during, and after deprivation

cages They were reduced to 95% of their ad lib body weights over the next 10-day period Rats were then returned to ad lib feeding and drinking conditions for a third 10-day period Weights of the rats and amounts of each fluid consumed were recorded daily at 1000 hours and bottles were refilled after each reading Their positions were alternated to control for position preference

RESULTS

Figure 7 shows the median amount of each fluid that was consumed by the rats before, during, and after they were reduced to 95% of their ad lib body weights Consumption of the plain sucrose solution was much higher than was the consumption of the sucrose-alcohol solution The median sucrose consumption was equal to 97 5 ml and the semi-IQ range (IQr) was equal to 3 73 ml The median amount of sucrose-plus-alcohol consumed was equal to 10 14 ml and the IQr was equal to 7 09 ml Sucrose consumption showed a very small but significant decrease during the deprivation phase (mdn=95 43 ml, IQr=3 96 ml) when consumption of the sucrose-alcohol significantly increased (mdn=21 5 ml, IQr=11 85 ml, p's<0 05) The daily intakes of both solutions significantly decreased below baseline levels when the rats were again allowed ad lib intake (p's<0 05) Across animals and across days during this phase, sucrose intake decreased to 92 39 ml (IQr=13 22 ml) No sucrose-alcohol was consumed 27 5% of the time, and only 5 57 ml was consumed 50% of the time Tables 2 through 4 show that both males and

females increase the volume and quantity of alcohol consumed under conflict and deprivation conditions, and this increase is greater for females than it is for males, as Meisch [10] has indicated is the usual finding

The daily consumption of each of these fluids is shown in Figure 8 Here it can be seen that the increasing consumption of the sucrose-alcohol solution during deprivation seems to parallel the decline in mean body weight that was occurring at the same time When the deprivation procedure was terminated, body weight increased by the second day and consumption of the sucrose-alcohol solution shows a corresponding decline These results indicate that food deprivation can cause rats to increase consumption of a caloric solution containing alcohol However, caloric deprivation cannot be the only reason for the increased ethanol intake because the animals decreased intake of the caloric sucrose solution at the same time

GENERAL DISCUSSION

The results of the first experiment replicated those of Volpicelli, Tiven, and Kimmel [22] amd support the conclusion that a discriminable post-shock safety period is necessary to observe an increase in alcohol consumption by rats Specifically, those animals that were returned to their home cages following exposure to noxious stimulation consumed more alcohol than those remaining in the shock chambers Virtually no alcohol was consumed by either group during shock exposure These findings cannot be explained by the Tension Reduction Hypothesis (TRH) which suggests that alcohol consumption following stress exposure is mediated by the depressant or tranquilizing effects of ethanol, it supposedly reduces tension induced by aversive stimulation or the actual noxiousness of it This hypothesis would thus predict that most alcohol would be consumed by rats living in the shock environment and that this intake would be most pronounced during the temporal interval immediately preceding or during aversive stimulation The present results do not support either of these predictions

They indicate that alcohol may not have the kind of stress-relieving properties that the TRH implies That is, the analgesic or tranquilizing effects of ethanol may not compensate for the effects of aversive stimulation that may directly interfere with drinking Von Wright, Pekanmaki and Malin [23] have suggested that an aversive environment elicits responses that are incompatible with drinking Therefore, alcohol intake will be more likely to occur following shock stimulation in an environment (or during a temporal interval) that the animals can discriminate as being safe and that does not elicit responses that are incompatible with the consummatory response They have observed that shock stimulation led to a lasting decrease in rats' level of activity while they were in an aversive environment which induced freezing and a variety of aggressive and escape behaviors Although no group differences in the amount of the sucrose-alcohol solution were observed in Experiment 3 when naive rats were subjected to the same stress and living conditions as the rats in Experiment 1, the fact that the shock-box animals in Experiment 3 showed a greater decrease in the amount of the plain sucrose solution consumed than did the safety-cage animals lends support to Von Wright *et al* 's hypothesis being in the aversive environment evidently elicited responses that even interfered with drinking a preferred sweet-tasting solution

These investigators have also suggested that the emotional arousal, anxiety, or tension that is induced by aversive stimulation remains high for some time after it ends The present finding in the first experiment, that little alcohol was consumed by rats in the first two hours after they were removed to their home cages following shock sessions indicates that the response suppression induced by the aversive environment can even interfere with drinking in a safe environment for awhile after the periodic shock stimulation ends

The results of Experiment 2 also support the hypothesis that stress-induced alcohol consumption is most likely to occur in a safe environment, since these animals did not consume any alcohol during conflict sessions but consistently increased and maintained alcohol intake when returned to their home cages Of interest is the fact that polydipsia was evidenced by an excessively high volume of water consumed in the shuttle-box even though alcohol came to serve as the fluid of choice in the home cage

Perhaps most important, these data suggest that controllability of the aversive stimulation is not a major factor influencing alcohol intake This is in contrast to the findings of Anisman and Waller [1] and Von Wright *et al* [23] showing reduced consumption of alcohol when rats could avoid shock occurrence by not responding Anisman and Waller demonstrated that rats placed into a conflict situation drank less alcohol than did those receiving inescapable electric shock, and they attributed these results to the ability of the rats in the conflict groups to control the occurrence of the aversive stimulation They stated that under these conditions, "the necessity of consuming alcohol for possible stress reduction is minimized " Von Wright *et al* 's results indicated that the increased alcohol intake following their conflict conditions was only transitory, while inescapable shock led to a fairly permanent alcohol preference following termination of the aversive conditions These results indicate that shock stimulation that can be controlled may be less aversive than that which cannot Although this assertion is intuitively plausible, whether or not a procedure is stress-inducing should be derived from a measure that is independent of the alcohol consumption which is purported to result from it This would include such physiological measures as levels of plasma corticosterone or degree of gastric ulceration and measures indicating that the physiological functioning of the organism becomes more vulnerable to insult following exposure to inescapable shock stimulation [9,21] The present results suggest that the ability to control the shock stimulation becomes an irrelevant factor influencing ethanol consumption, at least after animals have had shock-induced experience drinking alcohol Research is currently in progress to determine how much alcohol will be consumed by naive rats subjected to the same conflict conditions

All of these results suggest that a simple characterization of alcohol as being either positive or negative is not possible Rats maintained alcohol consumption following termination of the shock conditions in Experiments 1 and 2, indicating that the alcohol solution had acquired positive reinforcing properties Several investigators have demonstrated these by showing an ethanol perference over water following prolonged exposure to both solutions simultaneously [6,13], and Samson and colleagues have demonstrated these positive properties in an extensive series of experiments utilizing an operant conditioning paradigm [16, 17, 18]

Several other investigators have explicitly demonstrated the aversive properties of ethanol using a place conditioning

paradigm [20], and have shown that rats do not exhibit a flavor preference for a sweet solution when it has previously been associated with intubation of an ethanol solution [19] The latter results suggest that a sucrose solution containing ethanol will be aversive to the animals, they explain why rats receiving inescapable shock in Experiment 3 consumed very little of the sucrose-ethanol solution when they were given a choice between it and plain sucrose These findings also contradict the conclusion drawn by Mills *et al* [11] that taste plays a less important role in fluid selection with increasing exposure to stress Rats in their second experiment decreased intake of a saccharin solution in favor of a 5- or 10% ethanol solution when subjected to unavoidable shock stress Results of our Experiment 3 indicate that when a sucrose solution is utilized which contains calories, taste does play an important role, and a post-shock safety period becomes an irrelevant factor controlling alcohol intake

The importance of food-deprivation in determining choice of fluid consumed is demonstrated by the results of the fourth experiment consumption of the sucrose solution containing alcohol did increase when animals were reduced to 95% of their free-feeding weights, a very low deprivation level, and decreased when they were again placed on ad lib feeding conditions This finding is consistent with the conclusion drawn by Carroll and Meisch [3] in a review of studies investigating the relationship between food-deprivation and drug intake They concluded that a basic finding is that the rate of drug maintained behavior nearly doubles in food-deprived animals and that this holds true across various routes of administration, species, and types of drug

Based on several experiments comparing conditioned flavor preferences for neutral solutions paired with sucrose or alcohol, Sherman *et al* [19] had concluded that the positive properties that an alcohol solution can have are mainly due to its caloric content Since alcohol-consuming rats in the present experiments continued increased alcohol intake when all aversive shock conditions were terminated and they were being maintained on ad lib feeding, results indicate that it is not likely that the caloric content of the alcohol solution is the only factor contributing to the positive properties that ethanol can have In their review, Carroll and Meisch have also cited a number of studies indicating that the increased alcohol intake observed during food deprivation cannot be attributed solely to its caloric content A number of these studies found this deprivation-induced increase even when they used non-caloric drugs This conclusion is also supported by the finding that rats in our Experiment 4 showed a small but significant decrease in intake of a caloric sweet solution during the deprivation phase when they increased intake of the aversive sucrose-alcohol solution

The present series of experiments thus indicate that rats will increase consumption of a non-preferred ethanol solution following exposure to either inescapable or controllable shock stimulation This increase is most pronounced in a safe environment, in one that has not been associated with shock The finding that rats living in the aversive environment decreased consumption of a preferred sweet solution suggests that these aversive conditions may interfere with consummatory responses in general Finally, food deprivation does increase the probability that rats will consume a non-preferred alcohol solution over a plain sweet one, suggesting either that they can discriminate the higher caloric content of the sucrose-alcohol solution, or possibly that food deprivation is another kind of stress condition that can result in increased alcohol intake

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