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Effect of Cued and Uncued Inescapable Shock on Voluntary Alcohol Consumption in Rats

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KINNEY, L. AND H. SCHMIDT. *Effect of cued and uncued inescapable shock on voluntary alcohol consumption in rats.* PHARMAC. BIOCHEM. BEHAV. 11(6)601–604, 1979.—Rats were given cued and uncued inescapable shock; their voluntary alcohol intake was compared to a group given a yoked cue but no shock. Results suggested that, unlike uncued inescapable shock, cued inescapable shock caused an increase in voluntary alcohol intake, although the increase was insufficient to produce overt inebriation. It was suggested that the increase which occurred was due to a combination of adjunctive drinking and a gustatory and olfactory discrimination breakdown, both occurring in direct response to shock.

Voluntary alcohol consumption   Inescapable shock   Adjunctive behavior   Cued shock

CERTAIN studies investigating the animal model of alcoholism as a learned response to stress have concluded that psychological stress leads to an increased voluntary ingestion of alcohol [6, 14, 15]; whereas, physiological stress does not [5, 16, 20]. Psychological stress has generally been operationally defined by a situation requiring avoidance of a signaled shock; physiological stress has involved administration of uncued, inescapable shock [4]. The variable differentiating the two situations and responsible for the different effects on alcohol intake has been assumed to be some aspect of subjective experience characterizing the two types of stress [14]; the fact that psychological stress situations have used a cue to indicate shock and physiological stress situations have not has, for the most part, been overlooked or considered irrelevant [20].

When uncued inescapable shock is given, all environmental cues present become conditioned stimuli for a conditioned emotional response, such as crouching and freezing. Such behaviors interfere with consummatory behaviors when shock is imminent [8]. In contrast, during the days following inescapable shock, increased alcohol ingestion has been shown to occur and has been interpreted as evidence that alcohol's stress relieving properties are learned after the extinction of the conditioned emotional response [5,20]. The few seemingly contradictory studies which have demonstrated an increase in voluntary alcohol intake during inescapable shock have included only temporal regularities which could be learned as cues indicating when shock would occur; these same studies have not dealt with the fact that such a cue may be necessary for the increase to occur [1,13]. This experiment was designed to test whether inescapable but cued shock is sufficient to promote increased voluntary alcohol ingestion, thus questioning the basis on which the differentiation has previously been made between situations sufficient to lead to increased voluntary alcohol consumption (i.e., psychological vs. physiological stress).

METHOD

Subjects and Apparatus

Twenty-one, 120-day old albino rats were divided into three test groups, balanced for sex, littermate, and weight. Three rectangular test chambers (38.1×25.4×25.4 cm) were used, each with three 50 ml drinking tubes, a floor of stainless steel rods, and a 75-watt clamp-on bulb attached to the top.

Procedure

Time periods: The entire study lasted for seven, successive nine-day periods, called time periods. All animals spent one hour in the test chambers on each day of the time periods. Time periods 1 and 2 (TP's 1 and 2) served to establish baseline drinking behavior for the three groups; a food and water deprivation schedule was put into effect (food, 23 hr; water, 23.5 hr) and continued throughout the study. During TP's 3–5, the three groups were given three different experimental treatments (to be described below). Time periods 6 and 7 served as the extinction periods, during which all differential experimental treatments (with the exception of deprivation) were discontinued. Animals were weighed on the first and last day of each nine-day time period.

Experimental treatments (TP's 3–5): Each day, one of the four fifteen-minute periods, spent in the test chamber, was designated as the safety-period; the fifteen-minute period chosen to be the safety-period was varied daily according to a predetermined, block-randomized order. The remaining three fifteen-minute periods were designated as the shock periods.

Group 1 (the no-shock control group) was at no time given shock. During the safety-period the lights above the test chambers for this group were turned out, and during the shock-periods, these lights were left on. Group 2 (cued, shocked group) received the same light cues as Group 1 (that is off during safety-periods and on during shock-periods), but shock was administered to the subjects of Group 2 during the shock-periods (VI 2 min; 1 MA; 1 sec). Group 3 (uncued, shocked group) received no variation in light cue; that is, the overhead lights were kept on during both shock-periods and safety-periods. Shocks, paired to those administered to Group 2, were given to Group 3.

Presentation of solutions: Two types of solution were used: ethanol/sucrose and sucrose-only. All ethanol/sucrose solutions were made from 95% v/v grain alcohol with 50 g of white, granulated sugar added to increase palatability. Sucrose-only solutions were made from granulated sugar and water. On days 3, 6, and 9, of each nine-day time period (choice days), subjects of all groups were offered two solutions: one of the three ethanol/sucrose solutions (5% v/v, 10% v/v, or 15% v/v) and the calorically-matching sucrose-only solution. On the two days preceding the choice day for a given concentration, the solutions offered together on the choice day were offered alone, one on one day and one on the other; so, during any nine-day period, each subject was offered each of the three ethanol/sucrose solutions (5% v/v, 10% v/v, 15% v/v) and each calorically matching sucrose-only solution once as an only choice (6 out of 9 days) and once as calorically-matched pair (3 out of 9 days). The temporal order of presentation of concentrations and solutions was balanced within each group and matched across groups.

Tubes: Three tubes were at all times present in test chambers. Tubes not filled with solution (ethanol/sucrose or sucrose-only) were left empty. Relative positions of ethanol-sucrose and sucrose-only solutions within each chamber were changed every other day in a predetermined, random order (from a table of random numbers). Tubes were assigned daily to test chambers in a random manner so that spillage due to a characteristic of a particular tube would be randomly distributed among groups.

Measurement information: Only measurements of drinking behavior occurring on choice days were analyzed, since the proper controls were in effect only on those days. Fifteen minute recordings of liquid-levels from all drinking tubes were taken daily and recorded in four separate figures: milliliters drunk during the safety period of ethanol/sucrose and sucrose-only and total milliliters drunk during all shock periods for ethanol/sucrose and sucrose-only. Total liquid intake was converted to ml/kg; ethanol intake was converted to g/kg. Although weights were taken on the first and last day of each nine-day time period only, weights of subjects in Groups 2 and 3 showed what was virtually a linear decline during TP's 3–5; therefore, on the first and last days of each nine-day time period, subjects were the heaviest and lightest, respectively. The weight which minimized the probability of finding a difference among groups was used to calculate the measurements of intake used in the analysis. In calculating absolute intake of ethanol in response to shock (g/kg), both weights were used and both yielded the same result in reference to the occurrence of intoxication.

RESULTS AND DISCUSSION

The Effect of the Cue on Consummatory Behavior

Inescapable shock without a cue caused a suppression in general drinking behavior; inescapable shock with a cue allowed extinction of such a suppression during the safety periods. Figure 1 shows group means of total liquid intake, across all time periods, in ml/kg. The figure suggests no group differences during TP's 1–2, but a suppression of intake in both Groups 2 and 3 at the onset of shock (TP3). During TP's 4 and 5, Group 2 demonstrated a recovery of drinking behavior to a greater degree than did Group 3.

Statistical analyses support what the figure conveys. Two analyses of variance were done with time periods and concentrations as within group factors, one on TP's 1 and 2 and a second on TP's 3–7. No significant group differences were found during TP's 1 and 2. The analysis on TP's 3–7 demonstrated a significant Group × time period interaction, $F(1,9)=15.88$, $p<0.01$; a Greenhouse-Geisser conservative degrees of freedom was used to test the interaction due to rejection of the assumption of homogeneity of variance, $F_{max}=48.42$, $k(6)=15$, $p\leq 0.05$ [11]. A simple main effects analysis showed a significant variance among groups during TP's 3 and 5 (TP3: $F(2,89)=27.8$, $p\leq 0.01$; TP5: $F(2,89)=29.4$, $p\leq 0.01$); the degrees of freedom used are according to Satterthwaite as recommended in Winer [19]. Further probing showed that Group 1 drank signficantly more liquid than both shocked groups during TP3, $t(8)=4.40$, $p\leq 0.01$; during TP5, Group 1 was drinking significantly more than Group 3 only, $t(8)=3.14$, $p\leq 0.01$.

Additional evidence that the cue given to Group 2 allowed extinction of suppression of drinking was the tendency of Group 2 to drink the majority of liquid during the presence of the cue indicating no shock. Subjects of Group 2 drank a significantly greater percentage of their liquid during the safety periods than did Group 1, $t(12)=8.90$, $p\leq 0.01$ or Group 3, $t(12)=6.77$, $p\leq 0.01$. Group 2 drank a mean of 73.4% of all its liquid during the safety periods, while Group 3 drank 16.4%, and Group 1 drank 6.6% during the same safety periods. The difference between Groups 3 and 1 was not significant.

The Effect of the Cue on Ethanol Intake

The results indicated that inescapable shock with a cue causes a significant increase in voluntary alcohol intake. Figure 2 shows the median intakes of alcohol on choice days, averaged across concentration. Group medians were used due to the great variability existing among the alcohol intakes of individual subjects, $F_{max}=229.5$, $k(6)=15$, $p\leq 0.01$. In Fig.2, Group 2 shows an increase in intake during TP's 4 and 5; Group 3 shows a slight increase during TP3. An analysis of variance, using within-subject factors of concentration and time period (only TP's 3–5 were of experimental interest), showed a significant Group × time period interaction, $F(4,8)=6.00$, $p\leq 0.05$. No significant main effect or interaction involving concentration occurred. A simple main effect analysis showed significant variance due to groups at TP 4 only. A comparison of means, using a Newman-Keuls analysis, indicated that during TP 4, Group 2 drank significantly more

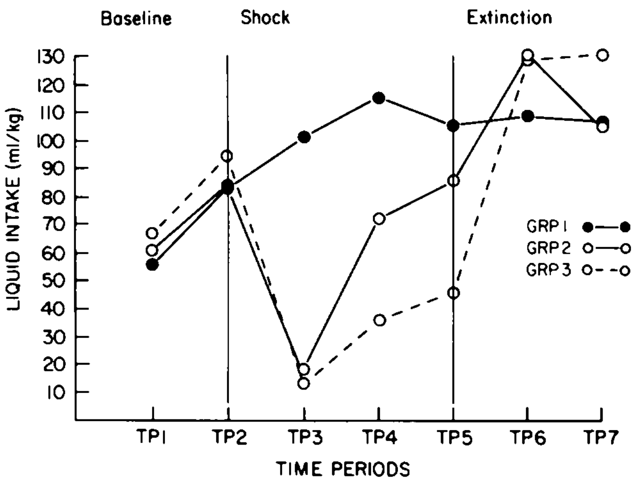

FIG. 1. Group means of total liquid intake (ml/kg) on choice days.

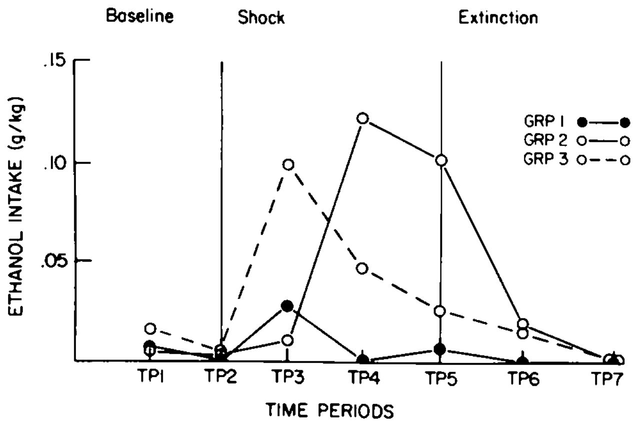

FIG. 2. Group medians of ethanol intake (g/kg) in choice days.

TABLE 1

PERCENTAGE OF ETHANOL/SUCROSE AND SUCROSE-ONLY SOLUTIONS DRUNK DURING SAFETY AND SHOCK PERIODS (GROUP 2)*

	Ethanol/Sucrose		Sucrose-Only	
Rat	Safety	Shock	Safety	Shock
1	25.0	75.0	89.0	11.0
2	8.0	92.0	67.0	33.0
3	24.0	76.0	88.0	12.0
4	20.0	80.0	58.0	42.0
5	15.0	85.0	61.0	39.0
6	0.0	100.0	90.0	10.0
7	33.0	67.0	80.0	20.0
Mean	17.9	82.1	76.1	23.8
SD	11.1	11.1	13.8	13.8

*Only on days when both solutions offered.

TABLE 2

PERCENTAGE OF TOTAL LIQUID DRUNK DURING SAFETY PERIODS AND DURING SHOCK PERIODS THAT WAS ETHANOL/SUCROSE*

Rat	Safety	Shock
1	1	30
2	2	10
3	0	19
4	1	16
5	0	20
6	0	17
7	0	11
Mean	.5	17.6
SD	.78	6.6

*Only on days when both solutions offered.

alcohol than did the no-shock control group. During no time period did Group 3 drink significantly more than the no-shock control group, a finding supporting the conclusions of former studies: that uncued, inescapable shock does not lead to a significant increase in ethanol intake when compared to a no-shock control group.

The absolute intakes of Group 2, on days when both sucrose and ethanol were offered, were not sufficient to suggest that subjects learned to drink to intoxication when given a choice of solutions, although on days when ethanol was offered as an only choice these same subjects did experience intoxication. The metabolic rate defines the minimum amount necessary for intoxication to be considered [7,12]. In a rat, the rate of ethanol metabolism is 7.2 g/kg/day [18] or 0.30 g/kg/hr. Behaviorally based criteria of intoxication were chosen, specifically those established by Arvola with the tilted plane test [2], which indicate .9 g/kg/hr as insufficient and 1.8 g/kg/hr as sufficient to lead to behavioral deterioration. The highest absolute intake of any subject of Group 2 on the days when both solutions were offered was 0.33 g/kg/hr, although when ethanol alone was offered, all but two subjects in Group 2 showed maximum intakes greater than 2.0 g/kg/hr.

An increase in alcohol intake was observed but was insufficient to produce overt effects. Spillage due to movement had to be considered as a possible explanation in light of the small increases in intake which occurred, but the following reasons make spillage an unlikely explanation. Maximal movement in response to shock was observed to occur during TP3; these behavioral observations suggest the occurrence of maximal fear during that time period and are supported by recorded data indicating that the maximal conditioned emotional response also occurred during TP3 (see Fig. 1). The increase in alcohol intake of Group 2 was, on the contrary, minimal during this time period. In addition, the fact that Groups 2 and 3 showed maximal alcohol intakes during different time periods contradicts an explanation in terms of spillage, for the chambers of both groups shared the same stainless steel grid and both groups received shock on the same schedule, suggesting that the amount of movement occurring in response to shock would vary comparably in the two groups.

The small amount of pattern data which had been collected was considered in further search of an explanation for the significant increase in alcohol intake occurring in Group 2. Looking only at choice days on which shock was delivered, it is of interest that Group 2 drank the majority of ethanol/sucrose solution during the daily shock periods (mean=82.1%) and the majority of sucrose-only solution during the daily safety periods (mean=76.1%) (see Table 1); statistically, Group 2 drank a significantly greater percentage of ethanol/sucrose than of sucrose-only during daily shock periods, $t(6)=7.60$, $p \leq 0.005$. These facts suggest that ethanol/sucrose solution was drunk specifically in response to shock. Behavioral observations indicated that some drinking occurred in bursts immediately following the delivery of shock. Drinking in response to shock in short bursts suggests that ethanol intake was a result of adjunctive drinking [9]. Another characteristic of ethanol consumption was that ethanol/sucrose solution comprised a greater percentage of the intake during the shock period (mean=17.6%) than during the safety period (mean=.5%), $t(6)=6.80$, $p \leq 0.005$, suggesting increased acceptability of ethanol/sucrose solution in response to shock (see Table 2). No such differences between consumption during the shock periods and safety periods occurred in Group 1, the no-shock control. The occurrence of gustatory and olfactory discrimination breakdowns is documented as a response to shock [3, 9, 17] and is here suggested as an explanation of the increased acceptability which occurred. In sum, adjunctive drinking and a diminished ability to discriminate ethanol/sucrose solution and sucrose-only solution, both having formerly been shown to occur in response to stress, are offered as possible explanations of the small but significant increase in voluntary ethanol intake which occurred in Group 2.

As in former studies, increased liquid intake occurred during the days following inescapable shock; but, contrary to former studies, data from this study suggested that the increase in liquid intake occurring following inescapable shock was due to caloric need rather than to a desire for pharmacological effects. The increase was in sucrose-only, the more palatable solution, rather than in ethanol/sucrose. The mean sucrose-only intake of Group 2 jumped from 83.5 ml/kg/hr during TP5 to 116.0 ml/kg/hr during the extinction periods; that of Group 3 went from 42.5 ml/kg/hr to 126.0 ml/kg/hr. The mean ethanol/sucrose intakes of the two groups showed decreases during the same period, Group 2 dropping from 2.88 to 0.28 ml/kg/hr, and Group 3 from 0.55 to 0.50 ml/kg/hr. Caloric need as an explanation was suggested by the fact that during shock (TP's 3–5) Groups 2 and 3 showed both a lower average weight and lower caloric intake than did Group 1, the no-shock control group; whereas, during the extinction periods, Groups 2 and 3 showed both a weight gain and an increased caloric intake.

The major finding of this study is that inescapable shock leads to a voluntary increase in alcohol intake if a cue as to when shock will occur is given. The fact that such an increase will not occur with inescapable shock without a cue, a finding of former studies, was upheld. Former studies differentiating psychological from physiological stress and differentiating the effects thereof on alcohol intake on the basis of some aspect of subjective experience have ignored the variable of the cue accompanying shock. The increase in alcohol intake occurring during shock was insufficient to conclude that animals learned to drink alcohol for the pharmacological effects; the post-shock increase in intake which occurred was in sucrose rather than in ethanol which declined in amount. According to these data, animals which do not learn to drink alcohol to relieve stress may at the same time show a significant increase in alcohol intake. Although the design was not intended to identify the exact source of such an increase, it is suggested that it may occur as a result of adjunctive drinking behavior and/or an olfactory and gustatory discrimination breakdown, both in response to shock. The important point is that some as yet unidentified variables can cause increased ethanol intake in response to shock; further study is needed to specify such variables. Until this is done, the meaning of increases in voluntary alcohol intake in response to cued shock (escapable or inescapable)—even those large enough to assume intoxication—will be unclear.

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