DRL schedule-induced alcohol ingestion*

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This study documents the efficacy of a differential reinforcement of low rates (DRL) barpress procedure in producing schedule-induced drinking of alcohol solutions in rat. Solution intakes were a monotonically decreasing function of alcohol concentration in the range of 2.5% to 10%. Conversely, the amount of absolute ethanol consumed increased as a direct function of alcohol concentration. Peak absolute alcohol ingestion with the 10% concentration was 1.5-1.8 g per rat. Within-session changes in barpress rates and interresponse time (IRT) distributions occurred coincident with intrasession declines in alcohol drinking.

Pellet delivery schedules that produce polydipsic water drinking have been used to induce rats to drink alcohol solutions. With some of these schedules, food pellets are delivered intermittently independent of a specified operant response. For example, Everett and King (1970) have demonstrated alcohol drinking with a variable-feeding (VF) schedule. Other investigators have used fixed-feeding (FF) procedures (Hawkins, Everett, Githens, & Schrot, 1970; Schrot, Hawkins, & Githens, 1971; King, McGill, Pierson, & Schaeffer, 1972). Alcohol drinking has also been produced when food pellets are delivered intermittently on operant schedules. For example, Lester (1961) has demonstrated alcohol drinking with a variable-interval (VI) schedule. Holman and Myers (1968) and Freed, Carpenter, and Hymowitz (1970) have demonstrated alcohol drinking with fixed-interval (FI) schedules.

Another operant schedule which has produced water drinking at polydipsic levels is the DRL schedule (Segal & Deadwyler, 1965). As yet, however, the effectiveness of the DRL schedule in producing alcohol drinking has not been reported. The purpose of the following experiment was to produce DRL schedule-induced water drinking and subsequently to determine the effect on fluid intake when water was replaced with various concentrations of alcohol.

METHOD

Subjects

Three male Wistar rats from the Walter Reed colony (Wm: WRC[WI]BR) were reduced from free-feeding weights of approximately 450 g to experimental weights of 300 g. Ss were housed individually in an animal holding chamber of constant illumination and an ambient temperature of $76^{\circ} \pm 2^{\circ}$ F. and were allowed continuous access to water in their home cages. The rats received a small food supplement of standard lab chow (2-6 g) following each experimental session for the purpose of maintaining the body weights at 300 g.

*In conducting the research described in this report, the investigators adhered to the "Guide for Laboratory Animal Facilities and Care," as promulgated by the Committee on the Guide for Laboratory Animal Facilities and Care of the Institute of Laboratory Animal Resources, National Academy of Sciences-National Research Council.

Apparatus

The experimental box measured 23 x 21 x 19 cm and contained a metal grid floor. Projecting from one wall were a response bar, a foodcup, and a drinking spout attached to a 100-ml graduated cylinder filled with either water or the appropriate alcohol solution. The foodcup was positioned between the bar and the drinking spout. Noyes food pellets (45 mg) were delivered via an automatic dispenser. The experimental box and pellet dispenser were enclosed within a larger plywood box containing a 15-W light bulb and an air blower. This isolation box was located in a sound-attenuating, temperature-controlled chamber containing masking noise. The DRL schedule was programmed by solid-state circuitry housed in a room outside the experimental chamber. Session records were obtained daily by means of a cumulative recorder.

Procedure

Throughout testing, body weights, home-cage water intakes, and experimental session fluid intakes were recorded daily. Experimental sessions for each S began at approximately the same time each day, 7 days per week. Alcohol solutions were prepared volumetrically (V/V) by mixing 95% ethanol with tap water.

Following 3 days of barpress training on a continuous reinforcement schedule and 7 days of a DRL 2-sec schedule, a graduated cylinder containing tap water was introduced into the experimental box. At this point, the schedule was changed to DRL 20-sec, making the delivery of each pellet dependent upon a barpress spaced at least 20 sec from the immediately preceding barpress. After 34 days, during which the DRL 20 barpress performance and session water intakes of each rat had stabilized, the water was replaced with alcohol solutions. Alcohol concentrations were presented in the following sequence for all Ss: 2.5%, 5%, 10%, 5%, 2.5%, 5%, 7.5%, 10%, 7.5%, and 10%. Each alcohol concentration was available for 15 consecutive days, except for the initial introduction of 2.5%, which was available for 20 days.

Sessions were automatically terminated either after 100 pellets had been delivered or after 2 h had elapsed, whichever occurred first. Split-session data were obtained for the last seven daily sessions of the final 7.5% presentation and for the last five daily sessions of the final 10% presentation. That is, separate fluid intakes and barpress data were recorded after the delivery of the first 50 reinforcements and again after the delivery of the second 50 reinforcements.

RESULTS

DRL schedule-induced water ingestion was at polydipsic levels (51-54 ml). Alcohol solution intakes

Fig. 1. Total-session fluid intake and grams of ethanol consumed as a function of alcohol concentration for Rats 218, 219, and 225.

were a monotonically decreasing function of the alcohol concentration. For example, the highest intake values obtained with the 2.5% alcohol concentration were 42-49 ml. The highest intakes obtained with the 10% alcohol concentration were only 19-24 ml. In contrast, the amount of absolute ethanol derived from each alcohol solution increased as a function of solution strength. The highest amounts of absolute ethanol ingested at the 2.5% concentration were only 0.8-0.9 g as compared with 1.5-1.9 g ingested at the 10% concentration. Figure 1 shows the session intakes and grams of ethanol consumed as a function of alcohol concentration for the individual rats. Each data point in Fig. 1 represents the median intake for the last 10 sessions at each concentration. The data points connected by the solid lines represent the intakes obtained during the final presentations of each concentration. These were differentiated to show that consumption of 7.5% and 10% alcohol increased from initial to terminal tests.

Figure 2 depicts the median solution intakes for the last five split sessions at 7.5% and 10% alcohol. This figure shows that the majority of total-session drinking occurred within the time during which the first 50 pellets were delivered. Within-S comparisons also show that greater volumes of solution were consumed during the first half of a session at 7.5% than during the first half of a session at 10%, reflecting the inverse

relationship between solution consumption and alcohol concentration that was evident in the total-session data.

Overall barpress performance was maintained at median rates of 3.2 ± 3 responses (rs) per minute, whether the Ss were drinking water or alcohol solutions. Similarly, overall IRT distributions remained typically distributed. Although the IRT distributions contained a large number of IRTs that were spaced less than 2 sec apart, the relative frequencies of IRTs rose to a peak between 18 and 24 sec, and then declined. For the most part, all Ss were obtaining 100 pellets within approximately 1 h. Ss did not obtain 100 pellets per session during the first few DRL 20 sessions with tap water. They typically emitted a large number of barpresses and many short IRTs, causing the 2-h time limit to terminate the session. As training progressed, session times became shorter, number of barpresses decreased, and fewer short IRTs were emitted. When 2.5% alcohol replaced tap water as the session fluid, and again during the initial introduction of 5% alcohol, barpress performance was disrupted. Performance in these instances was similar to the earlier DRL-20 acquisition with water. Normal DRL performance recovered after a few ethanol sessions, and resembled that of the later sessions with water.

Analysis of split-session barpress data showed that at both the 7.5% and the 10% concentrations, two Ss (218 and 225) responded at faster rates during the second half of a session than during the first half. The median increase in rate for S 218 was 0.4 rs/min at 7.5% and 0.3 rs/min at 10%. The median increase in rate for S 225 was 0.9 rs/min at 7.5% and 0.1 rs/min at 10%. The third rat (219) typically responded at lower rates during the second half of a session than during the first half. For this rat, the median decrease in rate was 1.0 rs/min at 7.5% and 0.8 rs/min at 10%. The decreasing rates for S 219 were primarily due to a substantial reduction in

Fig. 2. Split-session intake of 7.5% and 10% alcohol solutions for Rats 218, 219, and 225.

bursting behavior (IRTs < 2 sec) during the second half of a session.

IRT data showed within-session barpress changes that were more consistent across Ss than appeared in the response rate data. All three Ss consistently emitted more IRTs in the 2- to 20-sec range during the second half of a session than during the first half. For the three Ss combined, the median percentage increase in these short IRTs was 110 at 7.5% alcohol and 41 at 10% alcohol. Since the number of reinforcements remained constant at 50 in each half of a session, the frequencies of short IRTs relative to reinforcement number also increased in the second half of a session.

DISCUSSION

This study demonstrates that rats can be induced to consume and maintain substantial intakes of alcohol with a DRL schedule. The data also indicate that DRL schedule-induced alcohol drinking is strikingly similar to that produced by other procedures. For example, the inverse relationship between alcohol solution concentrations and volume consumed that was found in the present study has been previously demonstrated with an FI 90-sec schedule (Holman & Myers, 1968), a VF 60-sec schedule (Everett & King, 1970), and an FF 60-sec schedule (Schrot, Hawkins, & Githens, 1971).

Another similarity between the present ingestion data and published reports is that the intake of pure alcohol increases as a direct function of solution strength, at least within some range of alcohol concentrations. Holman and Myers (1968) tested FI schedule-induced drinking of solutions containing 1%-20% alcohol, and found that consumption of pure alcohol continued to increase as a direct function of alcohol concentration up to and including 11%. Everett and King (1970) tested VF schedule-induced drinking of a grape Kool-Aid preparation containing relatively low concentrations of alcohol (1%-5%). Ingestion of the least amount of pure alcohol occurred at 1%, and ingestion of the largest amount occurred at the highest concentration of 5%. Schrot et al (1971) measured ingestion across alcohol concentrations of 2.5%-10% on a FF schedule, and similarly determined that ingestion of pure alcohol increased as a direct function of alcohol concentration.

An additional finding, which appears to be general, is that intakes of high alcohol concentrations increase with repeated presentations of these concentrations. Schrot et al (1971) found that rats on a FF schedule drank more 10% alcohol the second time it was offered. The present DRL study spanned a much longer period of time than the Schrot et al study (189 vs 80 days) and contained at least two presentations of each alcohol concentration. However, we do not know if even the terminal intakes reported here were asymptotic.

A final consistent finding in our ingestion data is that rats typically do not continue to drink alcohol throughout the entire experimental session. In the present study, intake determinations at 7.5% and 10%

alcohol showed that a considerable reduction in alcohol drinking occurred within the second half of each session. Freed et al (1970) and Schrot et al (1971) have described similar changes with different spaced pellet procedures. However, these investigators relied on cumulative lick records to document the changes in drinking. The present work confirms the earlier reports and provides a direct measure of the suggested within-session declines in alcohol intake.

There is some evidence that the ingested alcohol was having a pharmacological effect on the Ss. This is suggested by the within-session declines in alcohol intake and also by the changes in barpress performance. Recently, Holloway and Vardiman (1971) reported similar changes in DRL performance produced by IP injection of 1.2 g/kg of alcohol. Thus, there would appear to be some common effects of ingested and injected alcohol.

It is possible, however, that the performance changes observed here were not due to the pharmacological effects of the alcohol, but were due to the declines in drinking per se. DRL disruption has been observed when a bottle of NaCl solution runs dry midway through the DRL session (Deadwyler & Segal, 1965). Similar DRL performance changes have also been reported when the opportunity to engage in well-developed collateral behaviors is experimentally blocked (e.g., Slonaker & Hothersall, 1972). An analogous situation may have occurred in the present experiment when the Ss, for whatever reason, stopped drinking the alcohol solutions. However, Deadwyler and Segal (1965) also reported that typical DRL performance returned after a few sessions, although they continued to allow the bottle to run dry midway through the sessions. No such recovery occurred in the present experiment, bringing us back to our earlier suggestion that the behavioral effects may have been pharmacologically induced.

The barpress changes are interesting, although their interpretation is quite tentative. What is most striking in overview is the marked similarity of ingestion of alcohol under the DRL schedule and under other spaced pellet procedures. The wide variety of procedures which yield high rates of both water intake and alcohol intake make it tempting to speculate that any procedure which produces schedule-induced polydipsia will also produce high rates of alcohol ingestion. There will probably be an increasing interest in these procedures in light of recent suggestions that they may be used to produce physical dependence on alcohol in rats (Hawkins et al, 1970; Falk et al, 1972).

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(Received for publication July 31, 1973;
accepted September 6, 1973.)