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Ethanol as a Positive Reinforcer via the Oral
Route for Rhesus Monkeys: Maintenance of
Fixed-Ratio Responding

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ABSTRACT

Two rhesus monkeys were required to emit lip-contact drinking responses on fixed-ratio (FR) schedules of liquid reinforcement. The values of the fixed-ratios were: FR 1, 2, 4, 8 and 16, and reinforcement was the delivery of 0.5 ml of either water or 8% (w/v) ethanol. At FR 1, both monkeys consumed intoxicating quantities of ethanol; however, monkey M-S's water-reinforced responding usually exceeded that maintained by 8% ethanol. Monkey M-P's water-reinforced responding was always substantially less than that maintained by 8% ethanol. For both monkeys, at FR 16, water-reinforced responding was decreased and was always less than ethanol-reinforced responding; also, amount (mg/kg of body weight) of ethanol obtained at FR 16 was similar to that obtained at FR 1. The data obtained at FR 16 clearly demonstrate the reinforcing efficacy of ethanol compared to that of water. The fixed-ratio responding maintained by 8% ethanol was similar to that maintained by more commonly studied reinforcers, such as food.

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Ethanol can serve as a positive reinforcer when self-administered via the oral route by rats (Meisch and Thompson, 1971, 1973) and by rhesus monkeys (Meisch, Henningfield and Thompson, 1975). Meisch and co-workers have reported data from two rhesus monkeys in which schedule-induced polydipsia was used to establish ethanol as a reinforcer. Schedule-induced polydipsia is a phenomenon originally described by Falk (1961) in which excessive liquid drinking is produced by a schedule of intermittent food presentation. In the Meisch *et al.* (1975) study, after schedule-induced ethanol drinking had occurred, the polydipsia was eliminated by discontinuing the intermittent schedule of food presentation. Subsequently, the monkeys consistently drank ethanol in volumes exceeding water control levels, and they drank intoxicating amounts of ethanol (3 g/kg/hr). The temporal pattern of ethanol-maintained responding remained distinct from that of water-maintained responding: Most ethanol responding occurred near the beginning of sessions, whereas water responding was more evenly distributed over the session. During the next few months of experimentation, the volume of water consumed by one monkey, M-S, drifted upwards within the range of ethanol consumption. Since water consumption by this monkey frequently exceeded volume of 8% ethanol consumed, it was necessary to determine if ethanol was functioning as a reinforcer. An alternative possibility was that ethanol intake was nonspecific and due simply to its liquid properties.

In the present study, the response requirement to obtain water or 8% (w/v) ethanol was increased to 16 responses per reinforcement. Reinforcement consisted of the delivery of approximately 0.5 ml of liquid. The rationale for increasing the FR size was that this procedure would have differential effects on responding maintained by reinforcers of unequal efficacy. That is, as the fixed-ratio size is increased, differences in responding maintained by reinforcers of unequal strength would be amplified such that substantially more responding would be maintained by the stronger reinforcer.

METHOD

Subjects

Two adult male rhesus monkeys (Macaca mulatta) served as subjects. The monkeys were the same as those used in an earlier study in which schedule-induced polydipsia was employed to establish ethanol as a positive reinforcer (Meisch et al., 1975). At 80% of his free-feeding weight, monkey M-P weighed 5.4 kg and monkey M-S weighed 6.2 kg. The monkeys were individually housed in stainless steel primate cubicals (Labco, #ME1305) in a constantly lighted room at 25.5°C.

Apparatus

The primate cubicals served as experimental chambers. All liquid was available via a Plexiglas drinking spout which required 1 cm of the spout to be inside of a monkey's mouth for lip contact to operate a drinkometer circuit. The lip contact response was always paired with the illumination of a clear lensed 4.7-W stimulus light, which was mounted 5.5 cm above the drinking spout. A liquid requirement consisted of the operation of a solenoid liquid valve, and each operation

resulted in the delivery of approximately 0.5 ml of liquid. Water availability was signaled by the steady illumination of a green-lensed stimulus light which was mounted 9.25 cm above the drinking spout. Ethanol availability was signaled by the flickering illumination (10 times per second) of the same stimulus light.

PROCEDURE

During daily 3-hr sessions either water or 8% (w/v) ethanol was available. The 8% solution was prepared at least 20 hr prior to use by adding 53.0 ml of 95% ethanol to a volumetric flask with sufficient tap water to make a total volume of 500 ml. Sessions were preceded and followed by 1 hr of stimulus blackout so that data could be recorded and solutions changed. Water was continuously available during the 19 hr intersession period via the drinking spout, and the daily ration of food was available following the 1 hr post-session stimulus blackout.

At a fixed-ratio value of 1 (FR 1), 5 consecutive sessions in which responding showed no trend were obtained with 8% (w/v) ethanol. Next, 10 consecutive sessions were obtained with water. Finally, 5 consecutive sessions were again obtained with 8% (w/v) ethanol, and then the ratio manipulations for ethanol were begun. Five sessions were run at each of an increasing series of ratio values: 1, 2, 4, 8, and 16. A response consisted of lip contact with the liquid spout such that the drinkometer circuit was activated and the correlated clear-lensed stimulus light was illuminated for the duration of lip contact. At FR 16, 5 stabilized sessions for 8% (w/v) ethanol, then 10 consecutive sessions for water, and finally 5 consecutive sessions for 8% (w/v) ethanol were obtained.

Figure 1. Responses and reinforcements per 3-hr session. Triangles: FR 1; circles: FR 16. Filled circles and triangles represent 8% (w/v) ethanol sessions, and unfilled circles and triangles represent water sessions. Note that at FR 16 both monkeys responded more when 8% ethanol was present than when water was present, whereas at FR 1, monkey M-S emitted more water than ethanol-reinforced responses.

RESULTS

Figure 1 shows that at FR 16, 8% (w/v) ethanol maintained substantially more responding by both monkeys than did water. At FR 1, monkey M-S's water-reinforced responding exceeded that maintained by 8% ethanol; the water-reinforced responding was quite variable (Fig. 1). In contrast, at FR 1, monkey M-P's ethanol-reinforced responding exceeded that maintained by water.

Figure 2. Cumulative records of monkey M-S were chosen as most representative on the basis of being closest to the mean session data. Responses are cumulated on the ordinate, and time is indicated on the abscissa. The hatch marks at FR 16 indicate liquid reinforcements. The principal effect of the FR 16 contingency was to decrease the number of water reinforcements obtained.

Cumulative records for monkey M-S (Fig. 2) show that patterns and rates of responding maintained by ethanol and water were similar under the FR 1 contingency. However, when 16 responses per reinforcement (FR 16) were required, ethanol-maintained responding was clearly distinguished from water-maintained responding: Ethanol responding occurred more frequently and was characterized by a high rate at the beginning of the session. For monkey M-P, cumulative records were similar except that responding seldom occurred when water was present. The temporal distribution of responses is similar to the fixed-ratio responding of rats reinforced by presentations of 8% ethanol (Meisch and Thompson, 1973), and it is distinct from the more irregularly-spaced

pattern observed when water is present. The cumulative records also reveal that the fixed-ratio responding, when it occurred, is similar in pattern to that maintained by food reinforcement in pigeons (Ferster and Skinner, 1957) or by 8% (w/v) ethanol reinforcement in rats (Meisch and Thompson, 1973).

For both monkeys, changing the ratio from FR 1 to FR 16 decreased the number of water reinforcements and increased the number of ethanol reinforcements (Fig. 3 and 4). At FR 16, both monkeys obtained significantly more ethanol than water reinforcements. Also, shown in Figures 3 and 4 are differences between water and ethanol in the temporal

Figure 3. Mean reinforcements cumulated over 3-hr sessions for monkey M-P. Solid symbols indicate 8% (w/v) ethanol and open symbols indicate water. Each point is a mean of ethanol 5 observations when ethanol was present or 10 observations when water was present. Brackets indicate the standard error of the mean.

Figure 4. Mean reinforcements cumulated over 3-hr sessions for monkey M-S. Solid symbols indicate 8% (w/v) ethanol and open symbols indicate water. Each point is a mean of either 5 observations when ethanol was present or 10 observations when water was present. Brackets indicate the standard error of the mean.

pattern of reinforcements obtained at FR 1 and FR 16.

Figures 3 and 4 show that the increase in the FR to 16 responses per reinforcement had opposite effects on water and 8% ethanol intake: The number of ethanol reinforcements increased, whereas the number of water reinforcements decreased. Also shown in Figures 2 and 3 are the differences between water and ethanol in temporal pattern of reinforcements that occurred at FR's 1 and 16.

Table 1 contains mean data obtained under each experimental condition. During the first hour of each session both monkeys frequently drank more than 0.85 g/kg/hr of ethanol.

DISCUSSION

Under a FR 16 schedule, 8% ethanol maintained responding at higher rates than did water. These data confirm that 8% ethanol was functioning as a positive reinforcer and also demonstrate that response-contingent presentation of 8% ethanol will maintain intermittently-reinforced responding by rhesus monkeys. When ethanol-reinforced fixed-ratio responding occurred, it was similar in pattern to that maintained by more commonly studied reinforcers, such as food. Differences in two dependent variables distinguished ethanol-reinforced responding from water-reinforced responding: First, the regular temporal pattern of responses that occurred at all FR values with 8% ethanol was in marked contrast to the irregularly-spaced responses obtained with water and, second, the response rates at FR 16 maintained by ethanol exceeded the rates maintained by water. Although monkey M-S drank more water than ethanol when each response was reinforced (FR 1), 8% ethanol was clearly shown to be a positive reinforcer by the introduction of the FR 16 response requirement.

These data extend the generality of findings obtained with rats (e.g., Anderson and Thompson, 1974; Meisch and Thompson, 1973); with intravenously catheterized rhesus monkeys (e.g., Winger and Woods, 1973); and with intragastrically catheterized rhesus monkeys (Yanagita and Takahashi, 1973): Under certain conditions, ethanol can serve as a positive reinforcer and can maintain intermittently reinforced responding.

Table 1. Values of the dependent variables at each experimental manipulation.

Available Solution	8%	WATER	Monkey M-P 8% (W/V) ETHANOL					WATER	8%
Fixed Ratio Size	1	1	1	2	4	8	16	16	16
Total no. ses.	14	10	5	5	5	5	5	10	8
Mean resp.	148±8.2*	34±10.2	117±8.6	297±30.0	717±36.6	2026±260.9	3431±129.8	167±64.4	3986±177.7
Mean reinf.	148±8.2	34±10.2	117±8.6	146±15.1	176±9.2	264±21.1	213±8.8	10±4	249±18.7
Mean intake (ml)	94±6.0	30±8.4	82±6.0	98±11.6	105±7.3	100±3.3	109±8.3	11±3.6	118±6.4
mg/kg/hr per 3hr	44.7	—	39.0	46.6	49.8	47.6	51.9	—	56.2
mg/kg/1st hr	118.2	—	103.0	94.7	72.4	91.6	89.9	—	
Mean Vol/reinf	.64	.88	.70	.67	.60	.38	.51	1.10	.47

Available Solution	8%	WATER	Monkey M-S 8% (W/V) ETHANOL					WATER	8%
Fixed Ratio Size	1	1	1	2	4	8	16	16	16
Total no. ses.	10	10	5	5	5	5	5	10	21
Mean resp.	251±7.9	375±55.5	185±3.7	284±28.0	534±58.7	1521±129.2	4094±184.9	1105±181.3	3283±225.1
Mean reinf.	251±7.9	375±55.5	185±3.7	142±14.1	133±12.8	190±16.4	256±11.6	69±11.3	205±14.0
Mean intake (ml)	150±5.5	229±30.9	114±3.6	86±9.6	70±8.2	105±7.2	146±19.7	47±7.9	118±7.3
mg/kg hr per 3hr	61.3	—	47.5	35.9	29.1	43.8	60.7	—	49.4
mg/kg/1st hr	117.7	—	86.0	61.1	54.7	77.6	88.8	—	
Mean Vol/reinf	.60	.61	.62	.61	.53	.55	.57	.68	.58

*Values are means ± the standard errors based on the last five sessions except for water sessions where 10 sessions were averaged.

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