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The Nature of the Scheduled Reinforcer and Adjunctive Drinking in Nondeprived Rhesus Monkeys

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GRANT, K. A. AND C. E. JOHANSON. *The nature of the scheduled reinforcer and adjunctive drinking in nondeprived rhesus monkeys*. PHARMACOL BIOCHEM BEHAV **29**(2) 295–301, 1988.—Adjunctive drinking was generated in three free-feeding rhesus monkeys by the contingent and intermittent delivery of flavored pellets. The amount of drinking generated was greater when pellet availability was restricted under fixed-interval schedules compared to a massed-reinforcer control condition. The volume of water consumed depended upon the fixed-interval of pellet delivery (FI 180 sec to FI 1800 sec). Peak amounts of water consumed ranged from 532 ml to 650 ml during the 2 hr sessions and the schedule which generated the most drinking was either FI 420 or FI 600 sec, across monkeys. Variables which did not appear to influence the amount of drinking generated within the session were the amount of water consumed outside the session, the rates of responding maintained by pellet delivery and the pattern of responding for pellet delivery. However, when either cocaine or diazepam was the scheduled reinforcer, these same free-feeding monkeys did not engage in adjunctive drinking. The ability of cocaine and diazepam to generate adjunctive drinking was determined first by gradually decreasing the frequency of pellet delivery while keeping drug delivery constant using a second-order schedule of pellet delivery [FR n (FI 300 sec: drug delivery) with n ranging from 1 to 6]. Second, a range of drug doses was tested under a FI 300 sec schedule (cocaine: 0.01–0.3 mg/kg/injection; diazepam: 0.01–0.56 mg/kg/injection). These results suggest that there may be some restriction on the generation of adjunctive drinking depending upon the nature of the scheduled reinforcer.

Adjunctive drinking Schedule-induced polydipsia Drug self-administration Cocaine Diazepam Monkeys

APPROACHES to evaluating the reinforcing properties of conventional reinforcers, such as food, have also advanced the understanding of how psychoactive drugs control behavior [11]. In general, the characteristics of behavior maintained by contingent drug presentation are similar to those maintained by food under similar environmental conditions [12,19]. In addition to maintaining operant behavior, another effect of food presentation is the ability to generate adjunctive behavior under certain conditions [6,8]. However, the ability of contingent drug presentation to generate adjunctive behaviors has not been assessed.

Although the demonstration of a class of behaviors characterized as adjunctive has resulted in considerable controversy concerning its purpose and place in behavioral classification schemes, the phenomenon itself is robust [8,21]. A number of adjunctive behaviors have been observed under various intermittent schedules, in several species, and using a wide range of scheduled reinforcers [7]. The predominant view is that adjunctive behaviors comprise a separate class, distinct from operant or classically conditioned behavior, generated by the prevailing schedule of reinforcement and determined by situational opportunities [8]. For example, under intermittent schedules, food reinforcement can generate excessive water consumption [6]. Falk [8] has argued that the reinforcer available under the schedule generating polydipsia need not be food. Instead, any commodity of sufficient importance to the animal and available under an intermittent schedule should result in the generation of adjunctive behavior. In support of this contention, several studies have shown that other reinforcers such as the opportunity to run in a wheel [18], or money [5] can induce polydipsia when available under interval schedules.

The purpose of the present study was to determine whether drugs delivered contingently generate adjunctive drinking under conditions that generate adjunctive drinking using food presentation as the reinforcer. Two of the defining characteristics of adjunctive behavior are excessiveness and a bitonic function of occurrence in relation to the schedule of reinforcer delivery [7]. In order to measure these characteristics, the amount of water consumed during a session was

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investigated under several schedules of food or drug delivery and compared to the amount of water consumed when the reinforcing stimulus (food or drug) was not intermittently presented.

METHOD

Animals

Three rhesus monkeys (*Macaca mulatta*), two female (4003 and 9079) and one male (4009), weighing between 5.6 and 7.0 kg, participated in this study. Monkey 4009 was experimentally naive, but the histories of the other 2 monkeys varied. Monkey 4003 had been exposed to a 2-month period of contingent diazepam delivery but responding was not maintained above operant levels. Monkey 9079 had an extensive history of self-administering sedatives and anxiolytics intravenously using a substitution procedure described by Johanson and Balster [10].

Each monkey had a single-lumen silicone venous catheter (i.d. 0.76 mm, o.d. 1.60 mm; Ronsil Rubber Division, Belle Mead, NJ) surgically inserted into a major vein (internal jugular, external jugular or femoral) under pentobarbital anesthesia (up to 30 mg/kg IV, as needed). The catheter was passed into the vein for a distance calculated to place the bevelled tip inside the vena cava. The other end of the catheter was routed subcutaneously to the animal's back where it exited the body. Following surgery, a monkey was prophylactically administered (IM) an antibiotic (Keflin®) for several days. If a catheter became dislodged, the animal was removed from the experiment for 1 to 2 weeks before another catheter was inserted into one of the remaining veins.

TABLE 1

THE ORDER OF PRESENTATION OF EXPERIMENTAL CONDITIONS*

I. Training using banana (Monkey 4009) or sucrose (Monkeys 4003 and 9079) pellets as the scheduled reinforcer under FI 180 sec schedule.

II. Determination of water consumption under several FI schedules of pellet delivery compared to consumption during massed-reinforcer control condition.

III. Determination of water consumption under FI 300 sec schedule of concurrent diazepam and pellet delivery.

IV. Determination of water consumption under FI 300 sec schedule of diazepam delivery and second-order schedule of pellet delivery [FR n (FI 300 sec: diazepam delivery) with n ranging from 1 to 6].

V. Determination of water consumption under FI 300 sec schedule of concurrent cocaine and pellet delivery.

VI. Determination of water consumption under FI 300 sec schedule of cocaine delivery and second-order schedule of pellet delivery [FR n (FI 300 sec: cocaine delivery) with n ranging from 1 to 6].

VII. Determination of water consumption under FI 300 sec schedule of drug delivery across a range of doses of diazepam and cocaine tested in ascending dose order.

*Monkey 4003 was only evaluated in conditions I through IV.

Apparatus

Each monkey was housed individually in a sound-attenuating wooden cubicle (internal dimensions: 70×80×70 cm) that also served as the experimental chamber. The monkey was restrained in the chamber by a stainless steel harness connected to a hollow spring arm (46 cm) attached to the back wall of the cubicle. The catheter was threaded through the protective spring arm and connected to a peristalic infusion pump (7540X, Cole-Parmer Instrument, Chicago, IL) located outside the chamber. Each chamber was equipped with a ventilation fan and a Plexiglas® window on the cubicle door. The window was open at all times except during the experimental session. A lever box mounted on the internal, righthand side of the cubicle door. The lever box contained 4 Dialco stimulus lights, 2 with red lens caps and 2 with white lens caps, located above the response lever (PRL-001, BRS/LVE, Beltsville, MD). Mounted in the center of the door, to the left of the lever box, was a dish where 1.0 gram food pellets (P. J. Noyes Co.) were delivered from a pellet dispenser attached to the outside of the chamber (Ralph Gerbrands Co., Arlington MA). On the ceiling of the cubicle was a Plexiglas® encased light box containing a white (40 W) and a red (12 W) houselight. Solid state circuitry recorded responses on the lever and controlled the operation of the stimulus lights, the feeder, and the infusion pump. The water bottle was attached to the outside right wall of the chamber, and an opening, 15 cm from the front wall and 30 cm from the floor, allowed the water bottle spout to protrude 4 cm into the chamber.

Procedure

In order to limit the possibility of inducing other behaviors (e.g., pica), the cubicle waste pan was cleaned and refilled with a small amount of fresh shavings prior to each session. When the session began, the white houselight and white lever lights were illuminated and remained on until a reinforcer was delivered. During the delivery of a reinforcer (food or drug), the white lever lights and houselight were extinguished and the red lever lights and houselight were illuminated for 10 sec. When scheduled, a pellet was delivered at the onset of the red light, while drug delivery occurred over the entire 10-sec period. Each session was 2 hr and conducted at the same time each day, seven days a week. Following each session, the monkey was fed (Purina Monkey Chow) and allowed ad lib access to drinking water. The amount of chow given the monkeys was always in excess of what the animal ate.

Since monkey 4009 was experimentally naive, he was trained to press the lever by differentially reinforcing successive approximations toward the lever with the delivery of 1 gram banana-flavored pellets. Monkeys 4003 and 9079 had previously been trained to press the lever for drug infusions under a fixed-ratio schedule and did not require additional training to respond for pellets. However, since rates of responding maintained by banana pellets were low in these 2 monkeys, relative to rates maintained in monkey 4009, sucrose-flavored pellets were used to maintain their responding. When responding maintained by pellet delivery became stable, the schedule requirement was changed to a fixed-interval 180 sec (FI 180 sec), such that the first response on the lever after 180 sec resulted in the delivery of a pellet. Prior to each session, a measured amount of water in a bottle containing a ball-bearing drinking spout was attached to the chamber.

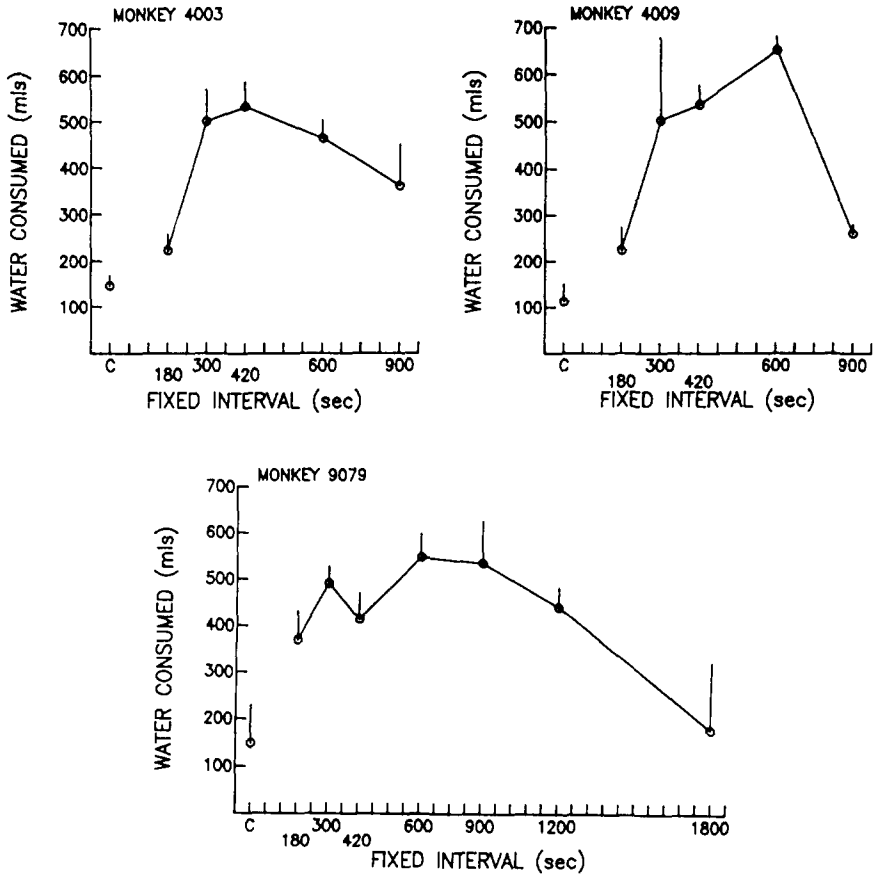

FIG. 1. The average amount of water consumed (±SD, n=3 sessions) as a function of fixed-interval length for each monkey. The "C" represent the massed-reinforcer control condition (see text). The order in which the schedules were presented were: Monkey 4003: FI 180, FI 300, Control, FI 420, FI 600, FI 900; Monkey 4009: Control, FI 300, FI 600, FI 420, FI 900, FI 180; Monkey 9079: Control, FI 300, FI 180, FI 600, FI 420, FI 900, FI 1200, FI 1800.

Following training, the monkeys were exposed to several experimental conditions as described in Table 1. Initially, they were tested under 6 to 8 different FI schedules of pellet delivery ranging from 180 sec for all three monkeys to 900 sec for monkeys 4003 and 4009 and 1800 sec for monkey 9079. Schedules were tested in a mixed order and remained in effect until both the response rate and the amount of water consumed during the session showed neither an increasing nor a decreasing trend over 3 consecutive sessions. A massed-reinforcer control condition, in which 40 pellets were placed in the food dish at the beginning of the session and a FI schedule was not in effect, was also tested for each monkey. This number of pellets corresponds to the maximum number that a monkey could receive under the shortest FI schedule (FI 180 sec).

Following the use of pellets as the scheduled reinforcer to generate schedule-induced polydipsia, the ability of drug administration to generate adjunctive drinking was investigated in the next 4 phases of the experiment (see Table 1). Each monkey was initially tested during sessions in which the delivery of both a pellet and an infusion of diazepam occurred under a FI 300 sec schedule. Following the determination of water consumed as a function of simultaneous food and diazepam presentation, the schedule of pellet delivery was placed under a second-order schedule with respect to drug delivery. That is, drug remained available under the FI 300 sec schedule but pellet delivery occurred under a ratio schedule of drug deliveries [FR n (FI 300: drug delivery)] with the value of n increasing from 1 to 6 in an ascending order. Therefore, when pellet delivery was available under a FR 2, the first response after 300 sec resulted in only drug administration. However, after an additional 300 sec had elapsed, the first response resulted in both pellet and drug delivery. Thus, when the schedule for pellet delivery was a second-order FR 2 (FI 300 sec), every second drug delivery was accompanied by a pellet delivery. When responding became stable, the FR was increased to 3 so that every third drug delivery also was accompanied by the delivery of a pellet. When the FR reached the value of 6, pellet delivery was completely discontinued while drug continued to be delivered under a FI 300 sec schedule. For monkeys 4009 and 9079, the amount of adjunctive drinking was also determined under the same second-order schedule using cocaine. Monkey 4003 was not tested with cocaine because of illness and was removed from the experiment.

Following the completion of the second-order schedule condition with both drugs, the effect of drug dose available under a FI 300 sec schedule on the amount of adjunctive

TABLE 2

RESPONSE RATE, INDEX OF CURVATURE (IOC) AND NONSESSION WATER CONSUMPTION (mean ± SD; n=3) AS A FUNCTION OF FIXED-INTERVAL (FI) LENGTH

FI (sec)	Response Rate (R/sec)	IOC	Water Consumed (ml) Session*	Nonsession
		Monkey 4003 Sucrose Pellet		
0			145 ± 23	718 ± 120
180	0.28 ± 0.02	0.20 ± 0.02	222 ± 35	825 ± 7
300	0.23 ± 0.03	0.17 ± 0.02	500 ± 70	758 ± 73
420	0.15 ± 0.02	0.20 ± 0.02	532 ± 55	842 ± 75
600	0.21 ± 0.01	0.16 ± 0.03	463 ± 40	873 ± 46
900	0.16 ± 0.01	0.07 ± 0.04	360 ± 90	890 ± 17
		Monkey 4009 Banana Pellet		
0			112 ± 38	628 ± 69
180	0.05 ± 0.03	0.07 ± 0.03	223 ± 50	580 ± 208
300	0.07 ± 0.02	0.27 ± 0.06	502 ± 177	582 ± 107
420	0.07 ± 0.01	0.25 ± 0.12	535 ± 41	732 ± 50
600	0.05 ± 0.01	0.26 ± 0.04	650 ± 30	633 ± 150
900	0.05 ± 0.01	0.18 ± 0.11	260 ± 20	1050†
		Monkey 9079 Sucrose Pellet		
0			148 ± 81	922 ± 138
180	0.05 ± 0.00	0.44 ± 0.07	370 ± 61	880 ± 134
300	0.06 ± 0.01	0.46 ± 0.02	491 ± 36	695 ± 315
420	0.03 ± 0.00	0.46 ± 0.08	413 ± 57	963 ± 55
600	0.06 ± 0.00	0.41 ± 0.05	548 ± 51	1142 ± 85
900	0.04 ± 0.00	0.42 ± 0.17	535 ± 91	1250 ± 218
1200	0.04 ± 0.00	0.34 ± 0.09	440 ± 43	1295 ± 188
1800	0.03 ± 0.02	0.73 ± 0.01	178 ± 144	1388 ± 320

*Data also depicted in Fig. 1.
†Indicates a single session determination.

drinking generated was determined. Monkeys 4009 and 9079 were tested with several different doses of diazepam (0.01–0.56 mg/kg/infusion) and cocaine (0.01–0.3 mg/kg/infusion), in an ascending order of dose presentation. Saline availability was also tested prior to the first diazepam dose in both monkeys.

Data Analysis

For each monkey the following measures were obtained: water consumed during the session, the number of pellets received, the rate of responding maintained by drug and/or pellet delivery, the index of curvature (IOC) for response distribution during the intervals, the amount of water consumed outside the session (i.e., 22-hr intake). The IOC was calculated by counting and sorting the number of responses made during each interval over the entire session into 4 equal and consecutive bins [9]. The mean (±SD) of the last 3 sessions of a condition were used to compare responding across conditions and monkeys.

RESULTS

The average amount of drinking that occurred under each FI schedule and during the control condition is shown for each monkey in Fig. 1. All three monkeys had a maximum average water intake of over 530 ml under at least one of the FI schedules, whereas average intake under control conditions was no greater than 160 ml. Although maximum water intake showed little individual difference, despite the difference in pellet composition (banana vs. sucrose), the FI schedule at which maximum water consumption was observed did vary across monkeys. Monkey 4003 drank the most water when pellet delivery occurred under a FI 420 sec, while monkeys 4009 and 9079 drank the most water under a FI 600 sec. When the FI was increased to 900 sec, the amount of water consumed decreased for monkeys 4003 and 4009. However, monkey 9079 consumed similar amounts of water over several schedules ranging from FI 180 to FI 1200 sec and only under a FI 1800 sec schedule did the amount of water consumed decrease. Despite this individual variability in schedule effects, water intake was a bitonic function of increasing interval length for each monkey.

Table 2 shows response rates and index of curvatures calculated for each monkey under each schedule condition. Rate of responding for pellets across several FI values was not related to the amount of drinking generated both within and across subjects. In all monkeys, response rate was relatively constant across FI values. Moreover, monkey 4003 had higher rates of responding for sucrose pellets than monkey 9079, whose rates were similar to those maintained by banana pellets in monkey 4009. Although monkey 4003 had higher response rates, the amount of water consumed under most schedules, was nearly identical to the amount consumed by monkey 4009. Similarly, the IOCs were not related to the amount of drinking generated either within or across subjects. For all monkeys, the IOC remained stable across schedules with exceptions occurring only at the lowest (monkey 4009) or highest (monkeys 4003 and 9079) intervals tested. Finally, each monkey's session intake was not altered systematically by their nonsession water consumption, although the amount of water the monkeys drank while not in session was greatest when the largest FI schedule was in effect. In summary, three variables which did not appear to influence the amount of drinking generated within the session were response rates maintained by pellet delivery, the pattern of responding for pellet delivery, and the amount of water consumed outside the session.

Table 3 shows the amount of drinking induced in the three monkeys when pellets and either cocaine or diazepam were delivered concurrently under a second-order schedule, or when drug alone was available. Generally, as the FR in the second-order schedule increased (essentially increasing the interval between pellet deliveries), within session drinking decreased. That is, the amount of drinking generated was related to the interval of pellet delivery (which increased from FI 300 sec to FI 1800 sec) rather than the interval of drug delivery (which remained at FI 300). The amount of water consumed fell to near zero when only drug, either cocaine or diazepam, was delivered under a FI 300 sec schedule and pellets were not available. Thus, it appears that drug delivery was neither necessary nor sufficient to generate adjunctive drinking in nondeprived rhesus monkeys.

Direct effects of drug delivery upon adjunctive drinking can be assessed by comparing the first condition of Table 3 (pellets and drug both available under FI 300 sec) with pellets alone delivered under FI 300 sec schedule (shown in Table 2). Diazepam delivered along with a pellet under a FI 300 sec schedule increased the amount of drinking 2 of 3 monkeys (monkeys 4009 and 9079). However, cocaine delivery superimposed on pellet delivery under a FI 300 sec schedule

TABLE 3

WATER CONSUMED (MEAN ± SD; n=3) DURING AND BETWEEN 2 HOUR SESSIONS UNDER A SECOND-ORDER SCHEDULE OF DRUG AND PELLET DELIVERY

Fixed-Interval Schedule		Water Consumed (ml)					
Pellets	Drug	Monkey 9079		Monkey 4009		Monkey 4003	
		SP +DZP 0.03		BP + DZP 0.1		SP + DZP 0.03	
		Session	Nonsession	Session	Nonsession	Session	Nonsession
300	300:	612 ± 49	1240 ± 194	870 ± 52	947 ± 39	520 ± 98	700†
600	300:	573 ± 3*	1375 ± 148	528 ± 144	1195 ± 7	485 ± 78*	580 ± 28
900	300:	577 ± 110	1140 ± 28	97 ± 71	1052 ± 33	355 ± 92	635 ± 106
1200	300:	430 ± 61	1188 ± 88			363 ± 91	677 ± 38
1500	300:	403 ± 61	1188 ± 88			280 ± 18	790†
1800	300:	247 ± 115	1287 ± 125			215 ± 49	780†
	300:	10 ± 0	1473 ± 130	20 ± 17	928 ± 113	10 ± 10	635 ± 92
		SP + COC 0.01		BP + COC 0.03			
		Session	Nonsession	Session	Nonsession		
300	300:	463 ± 34	1125 ± 318	532 ± 131	1030 ± 193		
600	300:	440 ± 72	1145 ± 92	620 ± 113*	890 ± 85		
900	300:	377 ± 74	1240 ± 219	405 ± 290	950 ± 167		
1200	300:	382 ± 22	1253 ± 283	305 ± 120*	1190†		
1500	300:	290 ± 82	1243 ± 203	117 ± 131*	1100†		
1800	300:	290 ± 26	1598 ± 175	30 ± 35	1175 ± 120		
	300:	65 ± 21	1135 ± 233	10 ± 0	1370 ± 141		

*Indicates 2 session means.
†Indicates a single determination.

had no effect in the two monkeys tested (also monkeys 4009 and 9079). Overall, the amount of drinking that occurred outside the session remained similar under the second-order schedule to the levels found when pellets alone were delivered. The average rate of responding and corresponding IOCs generated by the second order schedule did not change as a function of schedule value. Average rates of responding across all schedule conditions for the second-order of pellet/diazepam delivery were 0.07±0.02, 0.05±0.02 and 0.01±0.01 for monkeys 4003, 4009 and 9079, respectively (data not shown) and for the cocaine/pellet delivery were 0.06±0.01 and 0.04±0.01 for monkeys 4009 and 9079, respectively.

The amount of drinking generated by different doses of cocaine or diazepam delivery under a FI 300 sec schedule is shown in Table 4. Across several doses of cocaine and diazepam the amount of drinking generated under a FI 300 sec was not different from that seen when saline was available and less than when drinking was generated by pellet delivery. Cocaine delivery maintained higher rates of responding than either diazepam or saline. In addition, diazepam maintained low response rates across doses, while rates of responding for cocaine increased and then decreased as dose increased. Finally, response rates maintained by diazepam delivery were not different from those maintained by saline delivery in monkey 4009.

DISCUSSION

In the present experiment, excessive amounts of water consumption were generated when flavored food pellets were available under a fixed-interval schedule to nondeprived rhesus monkeys. This excessive drinking had two properties characteristic of an adjunctive behavior [7]. First, each monkey drank more water when the pellets were intermittently delivered under a fixed-interval schedule than when all the pellets were delivered at the beginning of the session. Second, the amount of drinking was a bitonic function of the schedule value for pellet delivery.

Scheduled-induced polydipsia has previously been reported in food-deprived primates [1–3, 13, 17]. Two of these studies [1,2] examined drinking under a number of fixed-interval schedule values, so the schedule length resulting in peak adjunctive drinking and the amount of water consumed can be compared with the results of the present study. Allen and Kenshalo [1] found that peak water consumption (463 and 840 ml/hr) in rhesus monkeys occurred under a FI 64 sec schedule when sessions were at least 1 hr in duration. In the present study, lower peak intakes of 266 to 325 ml/hr occurred under longer intervals of pellet delivery, FI 420 to 600 sec. Under similar conditions, 3 Java monkeys had peak water intakes (281 to 365 ml/hr) under a FI 128 sec schedule, although it should be noted that higher water intake rates occurred at shorter intervals, but the sessions were less than an hour [2]. Thus, the interval generating the most amount of drinking appears to be longer in the present study using nondeprived monkeys than in previous studies using food-deprived primates. In addition, the amount of water consumed appears to be greater in food-deprived rhesus monkeys. The monkeys in the present study drank less water under the interval generating peak consumption compared to

TABLE 4

WATER CONSUMED AND RESPONSE RATE (MEAN ± SD) AS A FUNCTION OF DRUG AND DOSE AVAILABLE UNDER FI 300 SEC

Monkey	Drug	Dose (mg/kg)	Water Consumed (ml)	Response Rate (R/sec)
4009	Saline		55 ± 10	0.010 ± 0.010
	Diazepam	0.01	30 ± 20	0.015 ± 0.010
		0.1	2 ± 1	0.012 ± 0.001
		0.3	5 ± 0	0.013 ± 0.002
	Cocaine	0.01	20 ± 5	0.040 ± 0.002
		0.1	0	0.068 ± 0.037
		0.3	0	0.045 ± 0.001
9079	Saline		5 ± 5	0.002 ± 0.001
	Diazepam	0.03	27 ± 3	0.019 ± 0.010
		0.1	35 ± 42	0.016 ± 0.002
		0.3	5 ± 5	0.009 ± 0.002
		0.56	8 ± 2	0.002 ± 0.001
	Cocaine	0.01	30 ± 24	0.054 ± 0.002
		0.03	0	0.084 ± 0.004
		0.1	0	0.048 ± 0.001
		0.3	2 ± 2	0.010 ± 0.002

the rhesus monkeys in the Allen and Kenshalo study [1]. In another study using food-deprived rhesus monkeys, Schuster and Woods [17] found intakes of 495 and 641 ml/hr under a VI 150 sec schedule. Since this was the only schedule investigated, a comparison with the present study cannot be made across intervals, however, the amount of drinking generated was greater with food-deprived monkeys [17] than peak levels of water consumption in the present study. Thus, food deprivation may affect both the interval of pellet delivery that generates the greatest adjunctive drinking and the peak levels of water intake under scheduled-induced conditions. However, as the present study demonstrates, food-deprivation is not a necessary condition for the generation of adjunctive drinking.

Although the amount of adjunctive drinking generated was systematcially related to schedule value, it was not dependent upon the rate of responding maintained by pellet delivery. Within the conditions of the present experiment (Table 2), the rates of responding remained largely unchanged across a number of schedule values for flavored food pellets, even though the amount of drinking was a bitonic function of interval length. A similar finding was noted in the Allen and Kenshalo study [1], which determined the amount of water consumed by food-deprived rhesus monkeys to be bitonically related to schedule, but not to response rates maintained by banana flavored pellets across a number of intervals. In addition, rates of responding maintained by food delivery under similar FI schedules with food-deprived primates were comparable to rates maintained in the present study by nondeprived monkeys even though total water consumption was different [1,3]. For example, in the present study flavored pellets maintained rates of responding that ranged between 0.06 to 0.21 res/sec under a FI 600 sec schedule. Food-deprived rhesus monkeys had response rates of 0.02 to 0.04 res/sec under a FI 512 sec schedule for banana pellets [1] and food-deprived chimpanzees had response rates of 0.03 to 0.39 res/sec under a FI 600 sec schedule for food biscuits [3]. Again, since different levels of adjunctive drinking were found across these studies, the amount of responding maintained by food delivery does not appear to determine the amount of adjunctive drinking generated, both within a deprivation state and across deprivation states.

Adjunctive drinking was not generated when either cocaine or diazepam was the scheduled reinforcer. The ability of these drugs to generate adjunctive drinking was determined under a number of conditions. First, adjunctive drinking was established in the presence of contingent drug and pellet delivery. Next, a second-order schedule of pellet delivery was used to gradually reduce the number of pellet deliveries in order to assess if drug delivery alone (i.e., when pellets were eliminated entirely) could generate adjunctive drinking. Finally, the influence of drug dose on drinking was investigated by making several different doses of cocaine or diazepam and saline available under a single FI schedule (FI 300 sec). Again, in the absence of pellet delivery, there was no adjunctive drinking generated by the intermittent delivery of cocaine or diazepam across several doses.

The failure to demonstrate adjunctive drinking induced by scheduled drug availability may have been due to the direct actions of cocaine or diazepam upon the generation of adjunctive drinking. In general, high doses of stimulants attenuate adjunctive drinking [16]. For example, cocaine had no effect on adjunctive drinking generated by food availability in food-deprived chimpanzees at doses of 0.1 and 3.0 mg/kg but decreased drinking following a dose of 10.0 mg/kg [3]. Likewise, in the present study, cocaine at doses of 0.01 and 0.03 mg/kg, delivered at regular intervals throughout the session either did not alter or slightly decreased the amount of drinking generated under the second-order schedule (FR 1:Pellet (FI 300:cocaine)) (Table 3) when compared to the amount of drinking generated by pellets under FI 300 (Table 2). Therefore, at the doses used in the present study, it does not appear that a direct effect of cocaine was precluding the generation of adjunctive drinking.

The effect of benzodiazepines upon adjunctive drinking generated by food presentation has been investigated primarily in rats (see [16]). Diazepam has been reported to have no effect on adjunctive drinking at doses ranging from 5.0 to 15.0 mg/kg [4]. At lower doses, 0.1 to 0.56 mg/kg, increases in adjunctive drinking were reported following diazepam administration [15]. In the present study, diazepam delivered under the second-order schedule had either no effect (monkey 4003) or increased the amount of water consumed (monkeys 4009 and 9079) under the second-order schedule (FR 1: Pellet (FI 300: cocaine)) (Table 3) when compared to the amount of drinking generated by pellet delivery under FI 300 sec (Table 2). Since diazepam is known to have a dipsogenic effect [20] this may have contributed to the increased drinking found with monkeys 4009 and 9079. However, the increase in water consumption did not continue when the interval of pellet delivery was lengthened under the second-order schedule, even though the exposure to diazepam remained the same. Therefore, the results of this and other studies support the conclusion that a direct effect of diazepam, at the doses investigated in this study, was unlikely to interfere with the generation of adjunctive drinking.

While it appears that diazepam was not a reinforcer in

monkey 4009 when available under the conditions of this study, cocaine availability maintained rates of responding above those maintained by saline in both monkeys. Still, adjunctive drinking was not generated when either cocaine (monkeys 4009 and 9079) or diazepam (monkey 9079) was the scheduled reinforcer. Therefore, it would appear that not any "important commodity" or reinforcer can generate adjunctive drinking under conditions in which the delivery of pellets generates adjunctive drinking (cf. [8]). In a review of the adjunctive behavior literature, Roper [14] concluded that there may exist a special relationship between food reinforcement and the production of scheduled-induced polydipsia. The data presented here add support for that conclusion.

In summary, it was possible to induce adjunctive water drinking in rhesus monkeys that were not food-deprived through the contingent, intermittent delivery of flavored pellets. The amount of drinking generated depended upon the interval of pellet availability, and was greater when pellet availability was restricted by a FI schedule compared to a massed-reinforcer control condition. These same free-feeding monkeys did not engage in adjunctive drinking when either cocaine or diazepam was the scheduled reinforcer. These results suggest that the generation of adjunctive drinking may depend upon the nature of the scheduled reinforcer.

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