was demonstrated experimentally as follows. Consumption rates of armyworms was artificially varied by feeding them control diet for 2, 4, or 8 hours per day. As indicated by fecal pellet number, the amount of food eaten over the instar was approximately equal for all three treatments ($F_{2,.5} = 0.51$, $P > .10$). The average number of fecal pellets produced daily was inversely correlated with pupal weight ($r = 0.613$, $P < .01$, $n = 18$). Since the number of fecal pellets is highly correlated with the amount of food eaten, this finding suggests that pupal weight is inversely correlated with feeding rate.

19. Specimens were deposited in Cornell University Collection, Lot 1023, sublot 41b. Microlepidoptera were prepared by R. Brown and S. Passoa and determined by J. G. Franclemont.
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21. Supported by NSF predoctoral fellowship grant (M.B.) and NSF research grant DEB 76-20114 (to P. P. Feeny). I thank C. F. Wilkinson and M. Root for the loan of armyworms; J. Christy for assistance with statistics; R. Root, L. Brattsten, and W. Blau for comments on an earlier version of this manuscript; M. Rausher for unpublished date, technical advice, and unremitting enthusiasm; and my adviser, P. P. Feeny, for general encouragement.

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## Choice Behavior in Rhesus Monkeys: Cocaine Versus Food

Abstract. *Rhesus monkeys were allowed to choose between intravenous injections of cocaine and food reinforcement for lever pressing. A choice trial was available every 15 minutes continuously for 8 days. The animals chose cocaine almost exclusively, which resulted in high cocaine intake, decreased food intake, weight loss, and marked behavioral toxicity. The study provides evidence of the reinforcing efficacy of cocaine.*

Various techniques have been proposed to determine the relative strength of a variety of reinforcers. One method involves presenting the subject with a choice between two different reinforcement conditions. Typically the choice of one reinforcer postpones the opportunity to obtain the second reinforcer. The number of times one reinforcer is chosen compared to the total number of opportunities to choose can be viewed as an index of preference. Techniques have been developed that allow animal subjects to indicate a preference between two or more qualitatively different reinforcers such as food, drugs, or electrical brain stimulation (*1*, *2*).

Illicit use of cocaine and other psychomotor stimulant drugs has been increasing in the past several years. Cocaine has been termed the ultimate euphorigenic whose preference by the drug connoisseur is undisputed (*3*). Numerous studies have shown that animals will readily learn to press a lever in order to obtain an intravenous injection of cocaine (*4*). In monkeys given unlimited access to intravenous cocaine, irregular periods of high intake result in marked behavioral toxicity similar to that seen in human users of intravenous stimulants (*5*, *6*). Experimental analogs of human psychomotor stimulant abuse may be obtainable using animal subjects and may offer new insights into this problem.

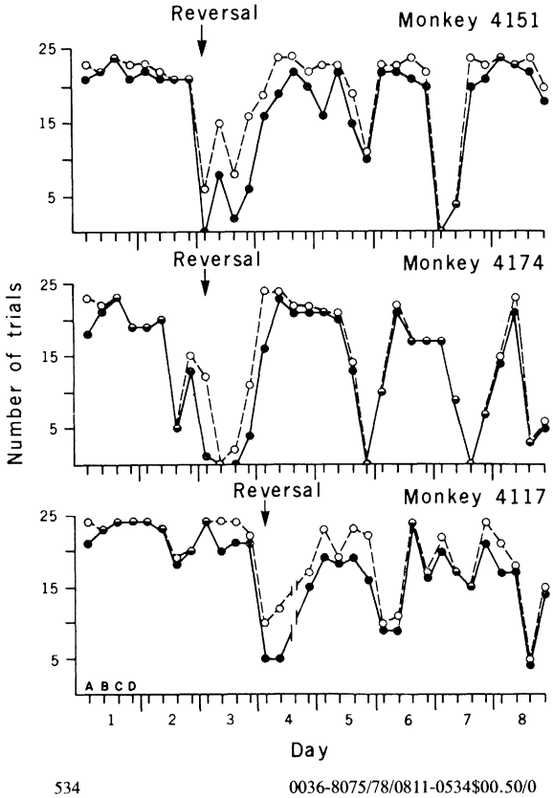


Fig. 1. Number of drug choices and total trials completed by each of three rhesus monkeys during 8 days of testing. The data for each day are divided into 6-hour blocks, where *A* indicates 12:00 p.m. to 6:00 p.m., and so forth. Arrows indicate the point at which stimulus light color and reinforcement condition pairings were reversed. The break in the graph for monkey 4117 indicates loss of data due to equipment failure.

The purpose of this study was to examine the relative reinforcing strength of cocaine in a competitive situation in which a qualitatively different reinforcer was also available. Rhesus monkeys were allowed to choose either an intravenous injection of cocaine or a small amount of food. The anorexigenic properties of cocaine have been documented (*7*) and may be a bias in favor of drug choices. However, monkeys self-administering cocaine under conditions of limited access eat relatively normally. The experimental design allowed access to both reinforcers 24 hours a day, but limited the number of choice trials within that period. Since no other food source was available to the animals, food was considered to be a competitive reinforcer.

Three adult male rhesus monkeys with prior experimental and drug histories were used as subjects. Under phencyclidine-pentobarbital anesthesia, each animal was surgically prepared with a permanently indwelling venous catheter and outfitted with a stainless steel restraining harness (*5*). Throughout the study, the animals were individually housed. The drug was injected by a peristaltic pump located behind the cubicle. Cocaine hydrochloride was dissolved in saline so that a concentration of 0.3 mg (as the salt) per kilogram of body weight would be delivered in 1 ml of fluid in 8 seconds. A pellet dispenser (BRS/LVE PDC) mounted on the outside of the cage delivered five 1-g food pellets (Noyes) into a trough on the inside of the cage. Two response panels, each with three stimulus lamps and a single primate lever (BRS/LVE PRL-001), were also mounted on the inside of the cage, one on each side of the food trough. All contingencies were controlled by solid-state behavioral programming equipment. Data were collected in the form of digital counts and cumulative recordings of lever-pressing behavior. Sessions were run continuously for 8 days. At 12:00 p.m. each day, data were recorded, pump and feeder reservoirs were refilled, and the animal's catheter was checked for patency.

The choice procedure was similar to one previously reported (*2*) except that


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the animal was not forced to initiate and complete each trial. Every 15 minutes a tone sounded and three white lights were illuminated above the left response lever. Simultaneously, either a red or a green light was illuminated above the right lever. At this time, responses on the right lever had no programmed consequence. Four consecutive responses on the left lever resulted in a change in the color of the lights over the right lever (from red to green or green to red). Each additional four-response sequence changed the color again. Any time after a minimum of three color changes had occurred, the first response on the right lever turned off the tone and white lights. Further responses on the left lever no longer changed the lights over the right lever. Right-lever responses prior to the three required switches reset the initial conditions. Completion of 31 additional right-lever responses produced either the cocaine injection or the five food pellets followed by a 15-minute time out (all lights off). If the 31 additional responses were not completed within 5 minutes, all lights were extinguished and the animal was required to wait 15 minutes for the next trial. At the beginning of the study the red light signaled cocaine reinforcement and the green light signaled food reinforcement. These pairings were reversed on day 3 or 4.

The animals were well trained in the task (*8*) and food-deprived 23 hours before the first trial on day 1. Throughout this study the only food available to the subjects was what they earned. No attempt was made to obtain a daily weight for the animals over the 8-day study because of their hyperexcitability. Cocaine doses for the entire study were calculated on pre-experimental weights. Weights obtained for the animals before and after the experiment showed an approximate 6 to 10 percent loss in body weight (*9*) over the 8 days. In spite of the complexity of the choice procedure and the high drug intake (Table 1), the three monkeys reliably performed the procedural requirements throughout the 8 days (Fig. 1). In animals given a choice between food and cocaine, the drug was almost exclusively chosen. Periods of low drug intake did not coincide with increased food intake. The animals either chose the drug or they did not complete the schedule requirements. Even following periods of no choice behavior the animals did not attempt to obtain food. This exclusive preference for cocaine persisted for 8 days. Concern for the health of the animals prohibited extending the testing period.

Table 1. The total daily (24-hour) intake of cocaine for three monkeys. The values are in milligrams per kilogram.

| Day | Monkey | | |
|---|---|---|---|
| | 4151 | 4174 | 4117 |
| 1 | 26.4 | 24.3 | 27.6 |
| 2 | 25.5 | 16.8 | 25.5 |
| 3 | 4.8* | 1.5* | 25.8 |
| 4 | 23.1 | 24.3 | 7.5* |
| 5 | 18.9 | 16.2 | 21.6 |
| 6 | 25.5 | 19.5 | 16.8 |
| 7 | 13.5 | 9.9 | 21.9 |
| 8 | 26.1 | 12.9 | 15.6 |

*Stimulus light–reinforcer pairing reversed.

During the first 48 hours (72 hours for monkey 4117), all three animals completed nearly the maximum number of trials possible. Sleeping, if there was any, occurred in the 15-minute intertrial intervals, since the subjects initiated almost all choices when the tone was presented. In an attempt to force the animals to make food choices, the light colors were reversed at the end of 48 hours (72 hours for monkey 4117). The first trials were completed in the presence of the red stimulus light (formerly paired with cocaine), which resulted in the delivery of food. During the next 6 to 12 hours the animals were observed sleeping. After this period, all three monkeys began increasing the number of choices for cocaine by increasing choices for the green stimulus light—that is, by relearning the schedule contingencies in order to obtain cocaine. From this point on, the majority of completed trials resulted in cocaine reinforcement. A greater amount of variability in the number of completed trials was seen during the last 4 days of the study. This was mainly because the animals slept for short periods of time and initiated fewer trials. These data were similar to the irregular pattern of drug intake in monkeys given unlimited access to cocaine (*5*).

Although no systematic behavioral observations were made, the animals were frequently watched during time-out periods. All three animals demonstrated various signs of behavioral toxicity during the 8 days of high cocaine intake. Behaviors similar to those reported for long-term amphetamine administration (*10*) were evident after 24 hours. These included excessive grooming, scratching, and facial grimacing as well as a continuous stereotyped movement of the head. A moderately severe athetosis involving the thumbs and a dysjunctive posture with arms and legs splayed were present during the last 4 days. All of these exaggerated behaviors disappeared after the study ended. At no time were any convulsions observed.

The results demonstrate that rhesus monkeys, in a nonforced situation, will consistently choose intravenous cocaine over food, even after several days of reduced food intake. The dose of cocaine was not particularly high. It produces only minimal physiological effects in this species when given for a short time (*11*) and is within the range of intravenous doses used by humans (*12*). Self-administration of this dose every 15 minutes, however, results in very high cocaine intake (often 23 to 27 mg/kg in 24 hours) and it is this high intake that results in the anorexia and behavioral toxicity we observed. This study has demonstrated under laboratory conditions the efficacy of intravenous cocaine reinforcement in rhesus monkeys. Evidence for the potent positive reinforcing properties of cocaine should be considered in the etiology of recreational cocaine use by humans.

THOMAS G. AIGNER*
ROBERT L. BALSTER†
*Department of Pharmacology,*
*Medical College of Virginia,*
*Virginia Commonwealth University,*
*Richmond 23298*

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8. Training took place in 8-hour sessions each day (32 trials) with 0.1 mg/kg of cocaine versus 5 g of food as the baseline choices. These baseline conditions resulted in 40 to 70 percent drug choices. Before this experiment, however, unearned food was given to the subject at the end of the session.
9. Monkey 4117 went from 10.8 to 10.2 kg, monkey 4174 from 8.8 to 8.0 kg, and monkey 4151 from 9.5 to 8.6 kg.
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* Present address: Psychiatry Department, University of Chicago, Pritzger School of Medicine, Chicago, Ill. 60637.
† Reprint requests should be sent to R.L.B.

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