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Effects of d-Amphetamine and Ethanol on Responding of Squirrel Monkeys Maintained Under Fixed-Ratio Schedules of Food Presentation and Stimulus-Shock Termination

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KATZ, J. L. AND J. E. BARRETT. *Effects of d-amphetamine and ethanol on responding of squirrel monkeys maintained under fixed-ratio schedules of food presentation and stimulus-shock termination.* PHARMAC. BIOCHEM. BEHAV. 8(1) 35–39, 1978. – Effects of d-amphetamine and ethanol were assessed on comparable behaviors maintained under fixed-ratio schedules of either food presentation or termination of electric shock and an accompanying visual stimulus. Ethanol affected the behaviors similarly in all important aspects; d-amphetamine increased rates of responding maintained by stimulus-shock termination at doses that did not affect rates of food-maintained responding. The increases in responding maintained by stimulus-shock termination were not solely due to decreases in the pause prior to the initiation of responding.

d-Amphetamine Ethanol Fixed-ratio schedules Food-presentation Stimulus-shock termination Escape

THE BEHAVIORAL effects of the amphetamines often depend largely upon the normal rate of occurrence of the particular behavior. Typically behaviors occurring infrequently are increased, while more frequent behaviors are increased less or decreased [4, 5, 6, 11]. These rate-dependent effects of amphetamines have been found to be independent of the particular events maintaining behavior. Kelleher and Morse [10] maintained responding of squirrel monkeys under multiple fixed-interval fixed-ratio schedules with either food presentation or termination of a visual stimulus and associated schedule of electric shock presentation. d-Amphetamine increased the relatively lower overall response rates under the fixed-interval schedules and only decreased higher rates under the fixed-ratio schedules, regardless of the event maintaining responding.

Comparable effects of d-amphetamine on responding maintained by disparate events under fixed-interval schedules have also been obtained in a number of recent studies [2, 3, 13]. Under fixed-ratio schedules, however, comparable d-amphetamine effects are not consistently obtained. Barrett and Katz [3] found increases with d-amphetamine in responding under fixed-ratio schedules of stimulus-shock termination at doses that did not affect, or decreased responding maintained under fixed-ratio schedules of food presentation.

Other drugs appear to have differential effects on responding maintained by dissimilar events under fixed-interval schedules but not under fixed-ratio schedules. For example, Barrett and Katz [3] found that ethanol, along with certain other drugs, increased responding under fixed-interval schedules of food presentation but not stimulus-shock termination. Responding under fixed-ratio schedules maintained by the two events was not differentially affected by ethanol [3,9]. In the present study, d-amphetamine and ethanol effects were further assessed on responding under fixed-ratio schedules of food presentation or stimulus-shock termination. Monkeys were exposed to each consequent event alternately throughout an experimental session so that a simultaneous assessment could be made with single organisms exposed to both consequent events. Under these conditions d-amphetamine increased responding under the stimulus-shock termination schedule at doses that did not affect responding maintained by food presentation. Ethanol produced decreases in responding maintained by both events.

METHOD

Animals

Two mature male squirrel monkeys (*Saimiri sciureus*) were used. They were housed individually and given unrestricted access to water. Their body weights were not decreased by food deprivation but were maintained at a

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constant level by postsession feeding. Each had considerable experience under FR schedules of both food presentation and stimulus-shock termination [9].

Apparatus

During experimental sessions the subjects were seated in a lucite restraint chair [8] enclosed in a sound-attenuating, ventilated chamber that was equipped with white masking noise. Above the animal (24 cm above waist level), behind the clear front panel were three pairs of colored lamps which served as discriminative stimuli. Centered 9 cm above waist level was a recessed opening through which 0.3 ml liquid food could be delivered [7]. Directly in front of the monkey (7 cm to the right of center, 8 cm above waist level) was a response key (BRS/LVE Rat lever No. 121-05) presses on which, exceeding 20 g (0.196 N), produced an audible click of a relay mounted behind the front panel and defined a response. Below the monkey was a small stock which held the tail motionless for shock (650 V, 60 Hz, 6 mA, 200 msec) delivery. Electrodes were placed on a small shaved portion of the tail which was massaged with electrode paste (EKG sol) to insure low resistance contact. Data were recorded and experimental conditions arranged with electromechanical switching equipment and a Gerbrands cumulative recorder.

Procedure

Animals were exposed to a multiple schedule of reinforcement with food presentation and stimulus-shock termination components. Each session started with a 60 sec blackout, during which responses had no scheduled consequences (timeout), followed by illumination of a pair of green stimulus lamps. If thirty responses were made within thirty sec, food was made available for four sec and was followed by a timeout. If thirty responses were not emitted within thirty sec, the timeout occurred without food delivery (thirty sec limited hold). Following the timeout a pair of red lamps were illuminated for a maximum of thirty sec. If thirty responses were emitted within the thirty-sec period, timeout immediately followed the thirtieth response and shock was not delivered. If thirty sec elapsed prior to the emission of thirty responses a single shock was delivered and was followed by the timeout. Components of the multiple schedule alternated after each timeout. Sessions consisted of a total of fifty components and were conducted six days per week.

When performances stabilized, drugs were administered, typically on Tuesdays and Fridays, provided that the immediately preceding day's performance was comparable to the stable performance established prior to drug administration. Absolute ethanol diluted in tap water to a 16% W/V concentration was administered by stomach gavage (infant feeding tube, Tomac 8 Fr) in a volume calculated for the appropriate dose in grams per kilogram body weight. d-Amphetamine sulfate was disolved in 0.9% sodium chloride solution so that the appropriate dose in mg/kg could be given in a solution of 1.0 ml per kilogram body weight. Doses of each drug were typically administered at least twice in a nonsystematic order with the entire

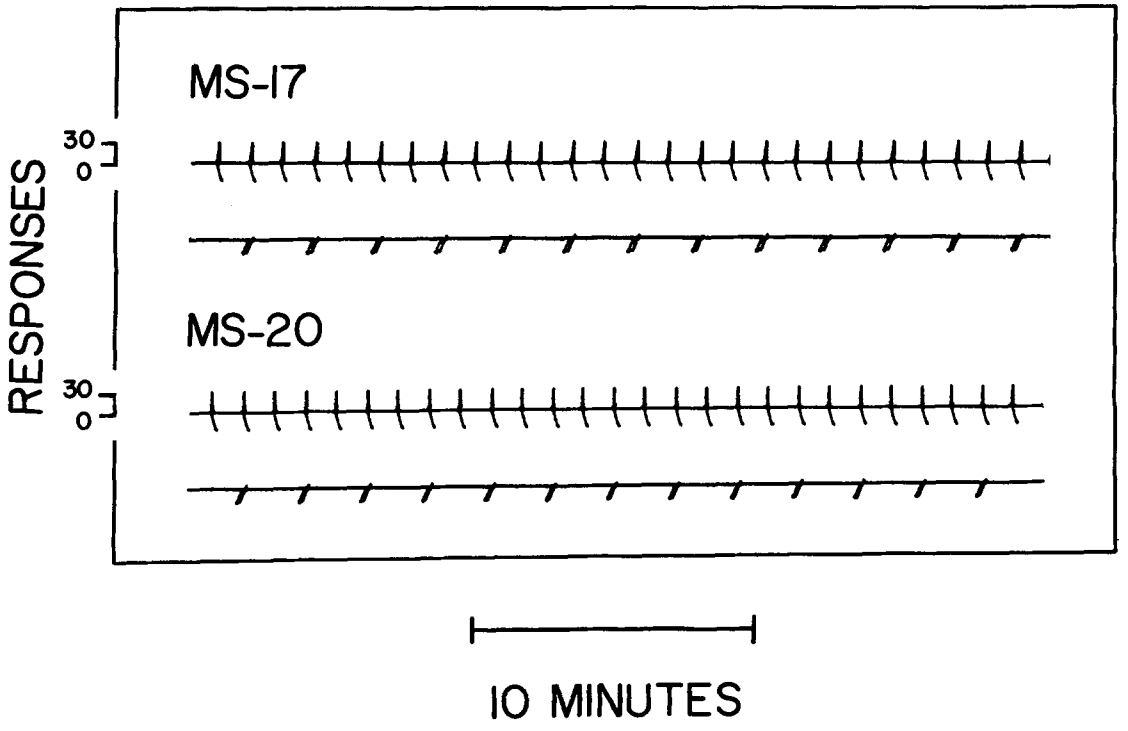

FIG. 1. Cumulative response records of control performances under the thirty-response fixed-ratio schedules. Ordinates: cumulative responses; Abscissae: time. Slashes indicate component onset. The pen reset to baseline at the completion of the thirty-response requirement. The recorder ran during components and the timeouts that followed components. Responses were not recorded during timeouts. The event line is displaced downward during stimulus-shock termination components.

ethanol series completed prior to d-amphetamine administrations.

RESULTS

Control Performances

High sustained rates of responding in excess of four responses per sec were maintained in both components of the multiple schedule (Table 1, Fig. 1). Each sequence of thirty responses followed a brief pause of approximately 1.0 to 1.5 sec. The thirty-response requirement was typically completed well in advance of the thirty-sec limited hold and shocks were rarely delivered. Comparable patterns of responding were maintained in both components of the multiple schedule (Fig. 1) with rates slightly lower under the stimulus-shock termination schedule than under the food-presentation schedule (Table 1).

TABLE 1

CONTROL RATES OF RESPONDING IN RESPONSES PER SECOND (± 1 SD IN PARENTHESES) IN THE TWO COMPONENTS OF THE MULTIPLE SCHEDULE FOR EACH DRUG SERIES

Drug Series	Component	MS-17	MS-20
Ethanol	food	4.863 (± 0.255)	7.537 (± 0.359)
	termination	4.602 (± 0.458)	7.337 (± 0.534)
d-Amphetamine	food	5.015 (± 0.284)	7.155 (± 0.132)
	termination	4.639 (± 0.145)	6.623 (± 0.292)

d-Amphetamine Effects

d-Amphetamine produced increases in responding under the termination schedule across a range of doses that had no effect on responding maintained by food presentation (Fig. 2). The increases in overall response rate were often accompanied by decreases in pause times (Fig. 3). However, the increases in response rate did occur without decreases in pause time (e.g., MS-17 at 0.56 and 1.0 mg/kg; MS-20 at 1.0 and 1.7 mg/kg); decreases in pause time in the food presentation component (MS-20 at 0.3 and 0.56 mg/kg) did not necessarily coincide with increases in response rate. At the doses given, response rates were never decreased at any time to the extent that shocks were received.

Ethanol Effects

Ethanol produced comparable dose-related decreases in response rates in both components of the multiple schedule (Fig. 2). Decreases in response rates were typically accompanied by increases in pause times (Fig. 3) that were comparable in the two components of the multiple schedule. The rate decreases, however, were not solely a result of increases in pause time. Doses greater than 0.5 g/kg generally decreased response rates to the extent that shocks were delivered with increasing frequency as a function of dose.

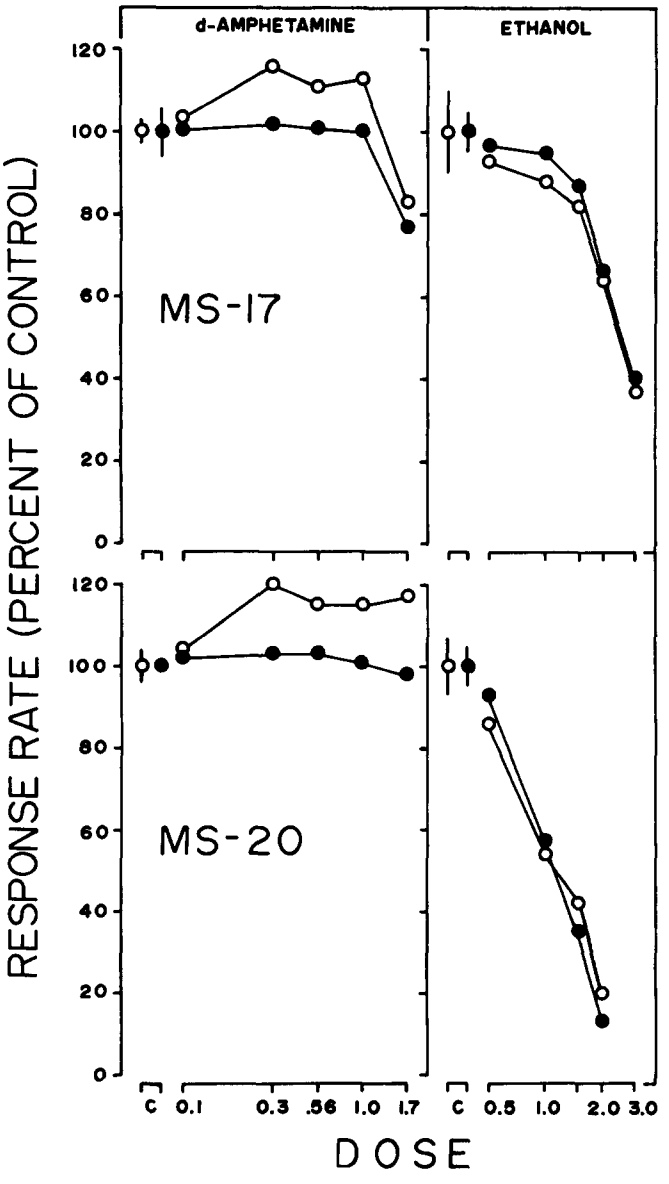

FIG. 2. Dose-effect functions for response rate under both *d*-amphetamine (in mg/kg body weight) and ethanol (in g/kg body weight). Open and filled symbols represent rates under the stimulus-shock termination and the food-presentation schedules respectively. Points above C are the control values with ± 1 SD represented by the vertical bars. Where no bars are present the symbol encompasses them. Doses are represented on a logarithmic scale.

DISCUSSION

Under the present schedules, similar rates and patterns of responding maintained by disparate events were affected comparably by ethanol and differently by d-amphetamine. The comparable effects of ethanol are consistent with earlier reports that, under FR schedules, the effects of ethanol do not depend upon the event that maintains responding [3,9]. Under interval schedules of food presentation, ethanol generally increases response rates [1, 3, 12]; however, under interval schedules of stimulus-shock

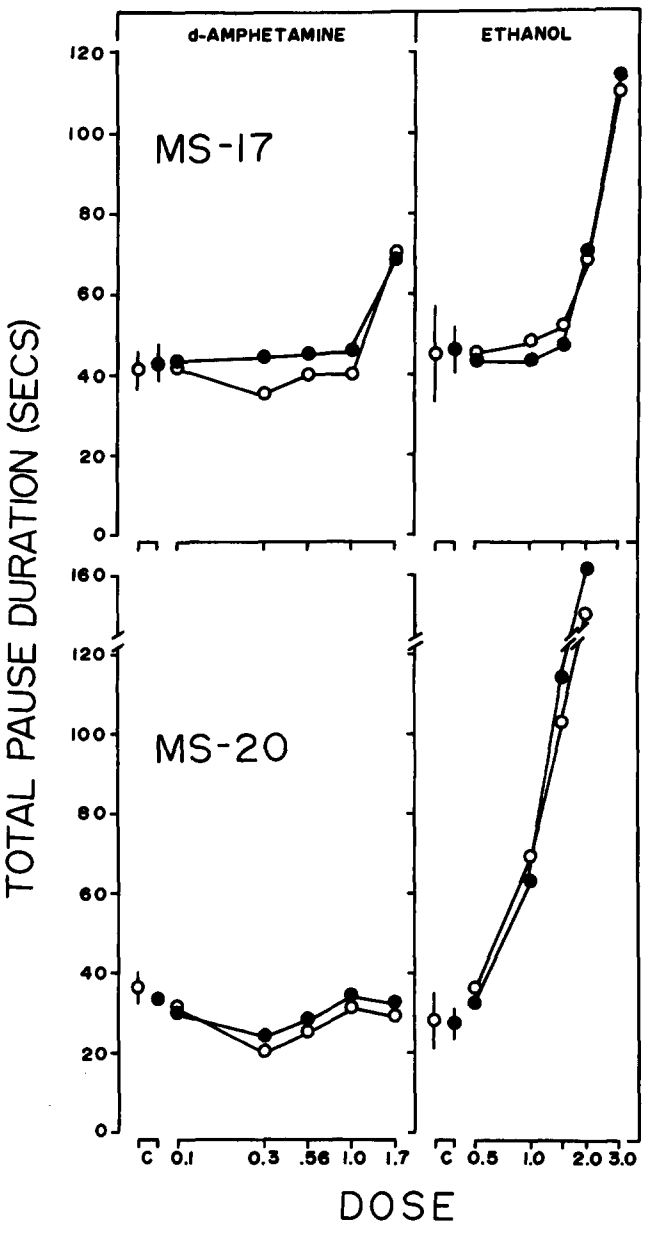

FIG. 3. Dose-effect functions for pause duration cumulated over the entire session under both *d*-amphetamine (in mg/kg body weight) and ethanol (in g/kg body weight). Open and filled symbols represent rates under the stimulus-shock termination and the food-presentation schedules respectively. Points above C are the control values with ± 1 SD represented by the vertical bars. Where no bars are present the symbol encompasses them. Doses are represented on a logarithmic scale.

termination or shock presentation ethanol generally decreases responding [1,3]. Thus the effects of ethanol on schedule-controlled behavior can depend upon the event maintaining responding under some conditions and not others.

The effects of amphetamine have repeatedly been found to depend upon the control rate of responding [4, 5, 6, 11]. Typically amphetamine increases low response rates while higher rates are increased less or decreased [6,11]. The slightly different control response rates in the present study could have contributed in part to the obtained differential effects on responding maintained by the disparate events. All control rates of responding were, however, much greater than those typically decreased by amphetamine [6], and the seemingly moderate increases were on the order of one response per second and well outside the range of control values.

The present differential effects of d-amphetamine on responding under FR schedules are consistent with the findings of Barrett and Katz [3] but differ from those reported by Kelleher and Morse [10]. At the present time it is unclear what differences between the studies account for the conflicting results. Since in the present study, shocks were never delivered after any dose of d-amphetamine, it is unlikely that the slightly different schedules of shock presentation in the three studies or changes in shock frequency after drug administration account for the different findings. Regardless, under the present conditions as well as others [3], d-amphetamine produces reliable differential effects, while under some conditions it produces comparable effects on behaviors maintained by dissimilar events [2, 3, 10, 13].

The experiment by Kelleher and Morse [10] showed conditions under which the effects of d-amphetamine and chlorpromazine depended more upon the schedule-maintained rates and patterns of responding than upon the particular events maintaining responding. Their report was instrumental in directing the interpretation of drug effects away from presumed motivational states and towards the actual environmental control of behavior. The recent findings of drug effects that depend upon the event maintaining responding should not abrogate their emphasis [14,15]. That events maintaining responding influence drug effects under some conditions and not others is inconsistent with a unitary motivational mechanism of drug action. Rather, the behavioral effects of drugs depend critically upon a variety of environmental factors which contribute to the development and maintenance of behavior.

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