Pharmacology Biochemistry & Behavior, Vol. 4, pp. 169–173.

Effects of Alcohol on Punished and Unpunished Responding of Squirrel Monkeys[1]

JOHN R. GLOWA AND JAMES E. BARRETT

Department of Psychology, University of Maryland, College Park, MD 20742

(Received 10 March 1975)

GLOWA, J. R. AND J. E. BARRETT. *Effects of alcohol on punished and unpunished responding of squirrel monkeys.* PHARMAC. BIOCHEM. BEHAV. 4(2) 169–173, 1976. -- Lever pressing of two squirrel monkeys was maintained initially under a multiple 5 min fixed-interval 5 min fixed-interval schedule of food presentation where, in each of 2 separate stimulus conditions, the first response after 5 min elapsed produced food. Subsequently, during one of the fixed-interval components responding was punished by the presentation of a 5 mA electric shock following each 30th response; rates of responding were markedly suppressed during this component. Unpunished response rates occurring during the alternate fixed-interval component remained unchanged for one monkey and decreased for the other. Alcohol (1.0–3.0 g/kg) increased overall punished rates of responding and decreased unpunished response rates; at higher doses (3.5–4.0 g/kg) all responding was decreased. Where lower local rates of both punished and unpunished responding were comparable, as measured in successive quarters of the fixed-interval, these rates were increased equivalently with alcohol. Comparable higher local rates of punished and unpunished responding were both decreased to about the same extent. The effects of alcohol were determined by the control rate at which behavior occurred, irrespective of whether responding was punished or unpunished.

Alcohol Punishment Rate-dependent drug effects Squirrel monkeys

IN analyzing the effects of drugs on punished behavior, the typical procedure has been to establish a baseline of food-reinforced responding and to then superimpose presentations of some stimulus, usually electric shock, on this baseline. Under most circumstances, when responding also produces shock, the rate or frequency of that behavior subsequently decreases, with this decrease defining the outcome of punishment [1]. Drugs such as the benzodiazepines and barbiturates have been shown to increase behaviors suppressed by punishment [3, 7, 8, 11, 15, 16, 18, 19, 20]. Many of those drugs that increase punished responding, however, also increase low rates of responding under conditions where punishment is not in effect [12,20]. Thus, increases in punished responding may not derive from any selective effect of a drug on behaviors suppressed by punishment, but may be due instead to the general tendency of certain drugs to increase low rates of responding regardless of how these rates are controlled.

In view of the fact that the control rate of responding can determine the behavioral effects of many drugs, experiments analyzing the effects of drugs on punished responding must necessarily compare the drug's effect on comparable rates of both punished and unpunished behavior [4,12]. If the drug is affecting low response rates (regardless of how those rates are engendered), comparable changes in equivalent rates of punished and unpunished responding should be obtained. Wuttke and Kelleher [20] compared the effects of various benzodiazepines on the responding of pigeons which, for separate groups, was either punished or unpunished and found that comparable rates of punished or unpunished responding were increased to about the same extent. The present experiment was based on that study. Responding by squirrel monkeys was established initially under a multiple fixed-interval 5 min fixed-interval 5 min schedule (mult FI 5 min FI min) where a response in each of two distinctive stimulus conditions delivered food after 5 min had elapsed. Responding under this schedule was characterized by a near zero level of responding early in each interval which gradually increased as time elapsed; i.e., rates of responding throughout each interval cycle were positively accelerated [6]. When responding stabilized under these conditions, a schedule of shock presentation was introduced during one component of the multiple schedule which decreased response rates. As was the case in the Wuttke and Kelleher [20] experiment, punished rates of responding were still generally positively accelerated throughout the interval, thus allowing for a direct comparison of comparable local rates of both punished and unpunished responding. Under these conditions, alcohol produced overall increases in punished responding while only decreasing overall unpunished response rates. These rate-increasing effects of alcohol were

[1] Research supported by U. S. Army Medical Research and Development Command, Contract DADA 17–73–C–3126 and by Grant AA 02104 from the National Institute on Alcohol Abuse and Alcoholism. We thank Evarilla Cover for help in the preparation of the manuscript and Beth Weinberg for aid with the figures. Send reprint requests to J. E. Barrett, Department of Psychology, University of Maryland, College Park, Md., 20742.

not specific to punished behavior, however, but depended on the control rate of responding. Generally, alcohol produced equivalent increases in the relatively low but comparable rates of both punished and unpunished responding, whereas higher corresponding rates of punished and unpunished responding were usually decreased.

METHOD

Animals

Two adult male squirrel monkeys (*Saimiri sciureus)* were maintained at 80% of their free-feeding body weights and were handled following the general procedures outlined by Kelleher *et al.* [10]. Water was available in their individual home cages. Both monkeys had prior exposure to fixed-interval schedules of food presentation.

Apparatus

Experiments were conducted with each monkey seated in a Plexiglas restraining chair [9,11] placed inside a sound-attenuating, ventilated enclosure containing white masking noise. A stock held the monkey's tail motionless and shock was delivered through 2 brass electrodes that rested on the shaved portion of the tail. The 200 msec 5 mA shock was 650 V AC, 60 Hz, delivered through series resistance. Prior to each session EKG sol was applied to ensure a low resistance electrical contact with the tail. A response lever (No. 121–05, BRS/LVE, Beltsville, Md.) was mounted on the clear panel in the front of the chair and was activated by a force of approximately 20 g (0.196 N) which also produced the click of a relay mounted below the lever and was recorded as a response. Directly above the lever were 3 pairs of differently colored 7 W Christmas lamps would could be separately illuminated. Positioned directly in front of the monkey, 3 in. above the restraining waist plate was a circular receptacle into which liquid SKF squirrel monkey diet (Nutritional Biochemical Corp.), could be delivered via a 0.3 cc dipper (R. Gerbrands Co., Model No. B-L.H.). The dipper area was illuminated by two 6.5 W clear bulbs and dipper presentation lasted for 4 sec. Events were controlled from and data collected in a separate room.

Procedure

Both monkeys had been trained previously to eat from the liquid dipper. At the beginning of this experiment responding was maintained under a multiple FI 5 min FI 5 min schedule of food presentation. Under this schedule the first response after 5 min had elapsed produced access to the liquid food. During one FI cycle a pair of yellow lamps were illuminated and during the second cycle white lamps were illuminated. These different stimuli alternated regularly throughout a session of 20 cycles (approximately 100 min). Separating each FI component was a 1 min period during which all lights were extinguished and responding had no scheduled consequences (time-out). After approximately 30 sessions under this schedule, a 30 response fixed-ratio schedule (FR 30) of shock presentation was added during the component of the multiple schedule when the white lights were illuminated (Component 2). Under this schedule, each 30th response produced a shock and the first response after 5 min delivered food; the ratio reset at the beginning of the component during which responses produced shock. Monkey MS-4 was also studied under single-component schedule conditions, i.e., when the schedule of punishment was in effect and subsequently, when responding was not punished.

Drugs

Absolute ethanol was mixed with tap water and administered in g/kg body weight from prepared solutions of either 25% or 16% (v/v). Solutions were administered PO, intragastrically, using infant feeding tubes (Tomac, 5 fr) 30 min prior to the session. Doses were given in an irregular order on either Tuesday or Friday, given that control performance on Thursday was stable. Doses of equicaloric glucose solutions and water in equivalent volumes were administered occasionally on either a control day or on a day when alcohol would normally have been given. All doses of alcohol were administered at least twice, except for 3.5 and 4.0 mg/kg which were given only once. At least 20 sessions were conducted under each schedule condition prior to the initial administration of alcohol. Monkey MS-4 also received alcohol during the single component schedule conditions.

Analysis of Results

Average control rates of responding were obtained from at least 8 control sessions. Average rates of responding were recorded separately during successive quarters (75 sec) of each FI cycle to examine alcohol's effects on local rates of responding throughout the FI. Drug effects are expressed as percent changes in overall and local rates of responding from control response rate.

RESULTS

Control Performance

Under the multiple schedule without punishment, rates of responding were positively accelerated during each component and resembled those found previously under comparable schedules of food presentation [6, 11, 13]. At the beginning of each FI cycle responding was low or did not occur, but generally increased to a high terminal rate as the interval elapsed. Figure 1A shows cumulative response records of responding for MS-4 under the multiple schedule without shock. Figure 1B shows that the addition of the FR 30 schedule of shock presentation to one component of the multiple schedule (Component 2) markedly decreased responding during that component (punishment). Most intervals were terminated without a shock being presented. Although overall rates of punished responding were low the pattern of responding throughout each FI cycle was still positively accelerated. In the alternate component of the multiple schedule, unpunished responding showed a slightly longer initial pause and a more rapid transition to a higher terminal rate of responding (Fig. 1B). Table 1 summarizes for both monkeys the overall rates of responding under the experimental conditions before and after shock was introduced. With MS-4, unpunished rates of responding (Component 1) increased slightly above those obtained prior to the introduction of shock. For MS-11 there was a general reduction in responding during both components after the shock was introduced.

TABLE 1

RESPONSE RATE (RESPONSES PER SEC) DURING EACH COMPONENT OF THE MULTIPLE FIXED-INTERVAL 5 MIN SCHEDULE BEFORE SHOCK WAS INTRODUCED AND AFTER RESPONDING HAD STABILIZED (CONTROL CONDITIONS)*

Animal	Prepunishment		Punishment	
	Component 1	Component 2	Component 1	Component 2
MS-4	0.321 (± 0.028)	0.390 (± 0.034)	0.375 (± 0.031)	0.083 (± 0.014)
			0.463 (± 0.023)†	0.053 (± 0.010)†
MS-11	0.987 (± 0.118)	0.973 (± 0.281)	0.092 (± 0.053)	0.051 (± 0.022)

*Prepunishment data based on mean of the last 5 sessions prior to the introduction of the fixed-ratio 30 shock presentation schedule in Component 2. Punishment data taken from 8 control days during the administration of alcohol. Figures in parentheses denote ±1 SD.

†Represent control data (based on 5 sessions) ±1 SD when each schedule was separately in effect.

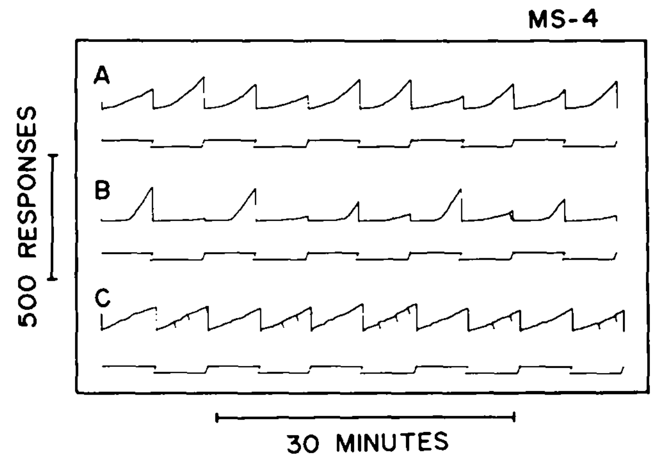

FIG. 1. Cumulative response records of MS-4 under each of the experimental conditions. Ordinate: cumulative responses; abscissa: time. Panel A: multiple 5 min fixed-interval schedule under which a response after 5 min in each of two different stimulus conditions produced food. Panel B: multiple 5 min fixed-interval schedules plus a 30 response fixed-ratio schedule of shock presentation (lower event pen was offset during the interval in which responses also produced shock). Panel C: effects of 3.0 g/kg alcohol on responding under the condition shown in Panel B. The response pen reset to baseline following food presentation; diagonal displacements of the response pen denote shock delivery.

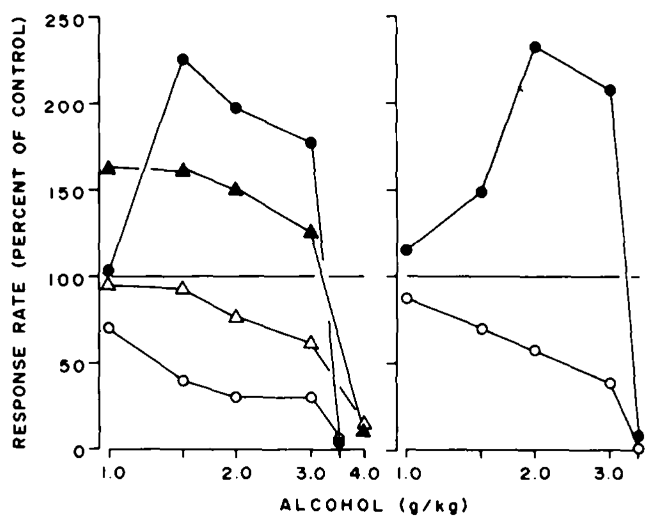

FIG. 2. Effects of alcohol on punished and unpunished responding of both monkeys under the multiple schedule (left panel) and under the single component schedules for MS-4 (right panel). Filled symbols represent punished responding, open symbols, unpunished responding. Circles show effects with MS-4, triangles with MS-11.

Drug Performance

The control rates of responding during each of the components shown in Table 1 were used in determining the effects of alcohol on punished and unpunished responding presented in Fig. 2. Changes in overall response rates with alcohol are shown as percentage of the control rates of responding. Doses of alcohol from 1.0–3.0 mg/kg produced marked increases in punished responding while only decreasing responding that was not punished. These changes in response rates with alcohol (3.0 g/kg) are shown also in the cumulative response records for MS-4 in Fig. 1C. In addition to the increased frequency of shock presentation, alcohol produced changes in both punished and unpunished response patterns within each cycle of the FI. Generally, after alcohol, responding began earlier in the interval and occurred at a steady rate throughout.

The effects of alcohol on average local response rates occurring during successive quarters of the FI are shown in greater detail in Fig. 3 for MS-4. In this figure, percent changes in the control rate of responding with alcohol are plotted as a function of the control response rate during successive 75 sec portions of the FI. Generally, across all doses, alcohol produced rate-dependent effects; low response rates occurring early in the interval were increased and higher rates toward the end of the interval were decreased. These effects were similar whether responding

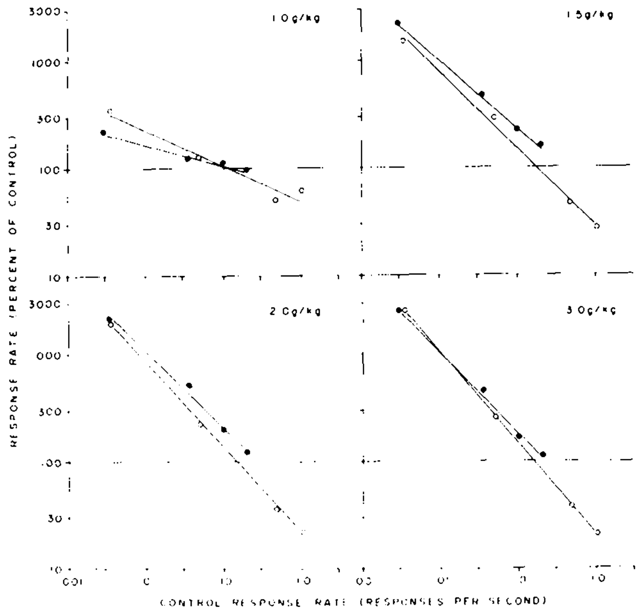

FIG. 3. Effects of alcohol on average local punished and unpunished response rates during successive 75 sec of the multiple fixed-interval schedule for MS-4. Open circles represent unpunished responding; filled circles, punished responding. Ordinate and abscissa are logarithmic. Regression lines were fitted by least squares.

was punished or unpunished. For the most part, all points fall along a single regression line indicating that alcohol did not differentially affect punished or unpunished responding. The rate-dependent effects of alcohol on punished and unpunished responding with MS-4 are identical to those obtained with MS-11 under the multiple schedule. When MS-4 was studied under the single-component schedule conditions, unpunished response rates were higher and rates of punished responding slightly lower than those obtained under the multiple schedule (see Table 1). Panels A and C of Fig. 4 show patterns of unpunished and punished responding respectively when responding was separately maintained under the single schedule condition. Unpunished response rates were still positively accelerated (Panel A) although the pattern of punished responding was often negatively accelerated (Panel C). Despite these differences in response rates and patterns of responding, the effects of alcohol under the single component schedule conditions were comparable to those obtained under the multiple schedule. The right panel of Fig. 2 shows the effects of alcohol with MS-4 when the two multiple schedule components were studied in isolation. Alcohol produced large increases in punished responding at doses of 1.0–3.0 g/kg, but only decreased unpunished responding at these doses. The cumulative records in Fig. 4 show changes in responding with 3.0 g/kg alcohol for both unpunished (Panel B) and punished responding (Panel D).

Figure 5 shows the rate-dependent effects of alcohol on responding of MS-4 under the single component schedules. Except at the lowest dose (1.0 g/kg), where lower rates of unpunished responding were not increased, alcohol increased average local rates of both punished and unpunished responding to about the same extent. As under the multiple schedule, increasing doses of alcohol generally

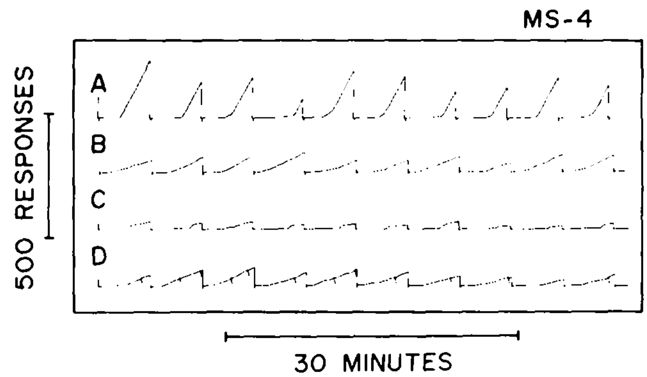

FIG. 4. Cumulative response records obtained under the single component schedules where responding was unpunished (Panel A) and punished (Panel C). Effects of 3.0 g/kg alcohol on unpunished responding are shown in Panel B; the effects of the same dose on punished responding are shown in Panel D. Recording as in Fig. 1.

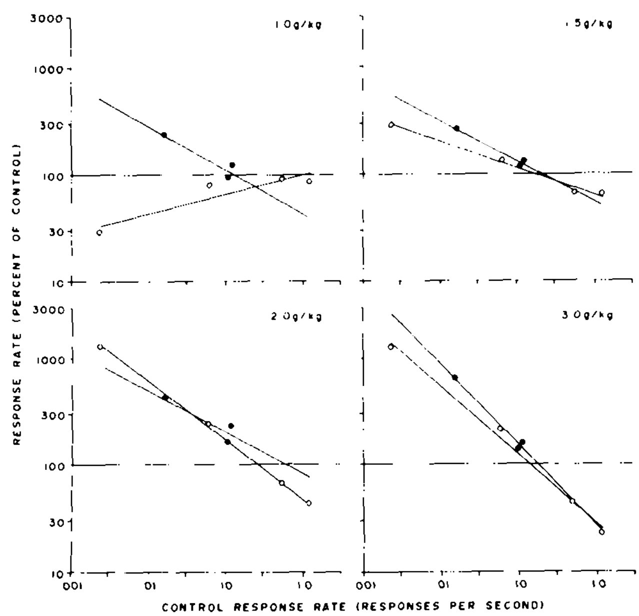

FIG. 5. Rate-dependent effects of alcohol on average response rates during successive 75 sec periods of the single component schedules (MS-4). Filled circles represent punished responding; open circles, unpunished responding. Coordinates are logarithmic. Control punished response rates during the first 75 sec period of the fixed-interval schedule were zero.

increased the slopes of the regression lines indicating that lower control response rates were increased more at the higher doses, while higher rates of responding were decreased even further with the larger doses.

DISCUSSION

When lever pressing during one component of a multiple FI food presentation schedule also produced shock, responding during that component was decreased. Unpunished responding occurring under a different stimulus condition, but controlled by an identical schedule of food delivery, was slightly increased for one monkey (contrast) and decreased markedly for the second animal (induction). Increases in unpunished responding have been reported previously [2,15] as have the more general suppressive effects of punishment on behaviors occurring under different stimulus conditions [1]. Although rates of unpunished responding usually return to pre-punishment levels [1], this effect was not obtained with one animal (MS-11) in the present experiment over at least a 5 month period; unpunished response rates were still suppressed relative to those rates occurring before shock was introduced. Despite these differences, for both monkeys rates of unpunished responding were consistently higher than those of punished responding.

Alcohol produced overall increases in punished responding at doses that only decreased overall unpunished response rates. These effects were obtained under both single component and multiple schedule conditions. Although there were subtle differences in the pattern and rate of responding maintained under the multiple or single schedule conditions, these differences did not appear to influence the effects of alcohol. Changes in punished and unpunished responding with alcohol under both conditions (i.e., under either the single component or multiple schedule conditions) depended on the control rate with which those behaviors occurred. When equivalent rates of punished and unpunished lever pressing were compared, alcohol affected these rates similarly; relatively low local rates of responding were increased and higher response rates were decreased. It would appear that the control rate of responding and not the schedule of punishment per se was a more important factor in producing these effects. As such, these results are comparable to those found with the benzodiazepines [20] although others have found the benzodiazepines to increase low rates of punished responding to a greater extent than were equivalent rates of unpunished responding [3,15]. These different effects have been shown to be related to the schedule and intensity of shock presentation, the duration of shock as well as the baseline schedules maintaining responding [14, 15, 16]; these factors would probably also modify the rate-dependent effects of alcohol as well.

Previous studies on the effects of alcohol on punished responding have yielded inconsistent results [17] and, at the present time, relatively little information is available on the comparison of alcohol's effects on behavior with other drugs, Variables known to be important determinants of the effects other drugs will have on behavior, such as the control response rate, have not typically been the focus of experimentation in alcohol research. Often the effects of alcohol on behavior are ascribed to its affects on motivational factors believed to underlie the particular behavior being investigated. Similar conclusions could have been drawn from the present study if only the effects of alcohol on overall response rates were reported: behavior suppressed by punishment was increased, whereas unpunished behavior decreased. An analysis of alcohol's effects on comparable local response rates, however, revealed that the rate-increasing effects of alcohol were not specific to punished responding but also occurred with comparable low rates of unpunished responding. The results of this study appear to indicate that the effects of alcohol are rate-dependent and that this principle adequately describes alcohol's effects on both punished and unpunished behavior under the present experimental situation.

REFERENCES

1. Azrin, N. H. and W. C. Holz. Punishment. In: *Operant behavior: Areas of Research and Application.* edited by W. K. Honig. New York: Appleton-Century-Crofts, 1966, pp. 380–447.
2. Brethower, D. M. and G. S. Reynolds. A facilitative effect of punishment on unpunished behavior. *J. exp. Analysis Behav.* **5:** 191–199, 1962.
3. Cook, L. and A. C. Catania. Effects of drugs on avoidance and escape behavior. *Fedn Proc.* **23:** 818–835, 1964.
4. Dews, P. B. A behavioral effect of amobarbital. *Arch. exp. Path. Pharmak.* **248:** 296–307, 1964.
5. Ellison, T. and W. C. Riddle. Commercial liquid diet for animals in behavioral studies. *J. exp. Analysis Behav.* **4:** 370, 1961.
6. Ferster, C. B. and B. F. Skinner. *Schedules of Reinforcement.* New York: Appleton-Century-Crofts, 1957.
7. Geller, I. Relative potencies of benzodiazepines as measured by their effects on conflict behavior. *Archs int. Pharmacodyn. Thér.* **149:** 243–247, 1964.
8. Geller, I., J. T. Kulak and J. Seifter. The effects of chlordiazepoxide and chlorpromazine on a punishment discrimination. *Psychopharmacologia* **3:** 374–385, 1962.
9. Hake, D. F. and N. H. Azrin. An apparatus for delivering pain shocks to monkeys. *J. exp. Analysis Behav.* **6:** 297–298, 1963.
10. Kelleher, R. T., C. A. Gill, W. C. Riddle and L. Cook. On the use of the squirrel monkey in behavioral and pharmacological experiments. *J. exp. Analysis Behav.* **6:** 249–252, 1963.
11. Kelleher, R. T. and W. H. Morse. Escape behavior and punished behavior. *Fedn Proc.* **23:** 808–817, 1964.
12. Kelleher, R. T. and W. H. Morse. Determinants of the specificty of the behavioral effects of drugs. *Ergebn. Physiol.* **60:** 1–56, 1968.
13. McKearney, J. W. Effects of *d*-amphetamine, morphine and chlorpromazine on responding under fixed-interval schedules of food presentation or electric shock presentation. *J. Pharmac. exp. Ther.* **190:** 141–153, 1974.
14. McKearney, J. W. and J. E. Barrett. Punished behavior: Increases in responding after *d*-amphetamine. *Psychopharmacologia* **41:** 23–26, 1975.
15. McMillan, D. E. Drugs and punished responding I: Rate-dependent effects under multiple schedules. *J. exp. Analysis Behav.* **19:** 133–145, 1973a.
16. McMillan, D. E. Drugs and punished responding III: Punishment intensity as a determinant of drug effect. *Psychopharmacologia* **30:** 61–74, 1973b.
17. Mello, N. K. Some aspects of the behavioral pharmacology of alcohol. In: *Psychopharmacology: A Review of Progress 1957–1967,* edited by D. H. Efron. U.S. Govt. Printing Office, Washington, D. C., 1968, pp. 787–809.
18. Miczek, K. A. Effects of scopolamine, amphetamine and chlordiazepoxide on punishment. *Psychopharmacologia* **28:** 373–389, 1973.
19. Morse, W. H. Effect of amobarbital and chlorpromazine on punished behavior in the pigeon. *Psychopharmacologia* **6:** 286–294, 1964.
20. Wuttke, W. and R. T. Kelleher. Effects of some benzodiazepines on punished and unpunished behavior in the pigeon. *J. Pharmac. exp. Ther.* **172:** 397–405, 1970.