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PUNISHMENT-SPECIFIC EFFECTS OF PENTOBARBITAL: DEPENDENCY ON THE TYPE OF PUNISHER[1]

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Pigeons were trained to peck a key under a multiple random-interval 1-minute, random-interval 6-minute schedule of food presentation. Subsequently, over three phases, additions were made during the random-interval 1-minute component as follows: pecks during the component occasionally were punished by timeout presentation (Phase 1), timeouts were presented independently of responding during the component (Phase 2), pecks during the component occasionally were punished by electric-shock presentation (Phase 3). In Phases 1 and 3, response-dependent timeout and shock suppressed responding and established equivalent rates in both components of the multiple schedule. Intermediate doses of pentobarbital increased responding suppressed by electric-shock punishment but had little or no effect on responding suppressed by timeout punishment. Response-independent presentation of timeouts did not result in suppression of responding (thus showing that response-dependent timeout acted as a punisher), and pentobarbital did not reliably increase unpunished responding. Pentobarbital's selective "punishment-attenuating" properties depend on the nature of the punisher.

Key words: positive punishment, negative punishment, random-interval schedules, multiple schedules, electric shock, timeout, barbiturates, key peck, pigeons

Several drugs used clinically as minor tranquilizers (*e.g.*, meprobamate, agents from the benzodiazepine and barbiturate classes) can increase rates of responding that have been suppressed by punishment operations (see review by McMillan, 1975). These drugs often also increase low rates of unpunished responding (Kelleher and Morse, 1968), and, since response rates under punishment conditions are usually quite low, it is possible that some, or all of the increases simply reflect the tendency of these drugs to increase low rates of responding. Cook and Catania (1964) attempted to determine if meprobamate has a punishment-specific effect separable from its effects on low rates. Squirrel monkeys pressed levers under concurrent variable-interval (VI) schedules, using a changeover-key procedure (*cf.* Findley, 1958), with a VI 6-min schedule of food presentation in one component and a conjoint VI 2-min schedule of food presentation VI 2-min schedule of electric-shock presentation (punishment) in the other. After response rates under the two schedules were equalized by varying the intensity of the shock, a range of doses of meprobamate was tested. Meprobamate increased rates under both schedules, but the increases under the conjoint schedule were larger, suggesting a punishment-specific effect. The use of a concurrent-schedule procedure, however, allowed changes in overall rate to be confounded with changes in time spent responding under either of the concurrent schedules (*cf.* Rachlin, 1973), and effects on local rates of responding were not reported.

Wuttke and Kelleher (1970) and McMillan (1973) also have tried to separate the punishment-attenuating effects of benzodiazepines and barbiturates from the low-rate increasing effects of these drugs. In Wuttke and Kelleher's experiment, the responses of some subjects, reinforced according to a fixed-interval (FI) 5-min schedule of food presentation, were punished with electric shock according to a fixed-ratio (FR) 30 schedule. In McMillan's experiment, every response in one component of a

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multiple FI 5-min FI 5-min schedule was followed by shock. Both studies identified portions of the fixed intervals where, on the average, local unpunished and punished rates were approximately equal, *e.g.*, a low rate early in the unpunished intervals was matched with an equivalent rate during a later portion of the punished intervals. Wuttke and Kelleher reported that chlordiazepoxide, diazepam, or nitrazepam (all benzodiazepines) had the common effect of increasing low response rates, regardless of whether the rates were due to punishment. McMillan, by contrast, reported that diazepam and pentobarbital increased low rates of punished responding more than "equivalent" low rates of unpunished responding.

A potential problem when local rates are expressed as averages (*e.g.*, based on several repetitions of a fixed interval, as was the case in the above studies) is that the average may not be representative of all samples of rates. For example, if the underlying distribution of rates is bimodal, as Branch and Gollub (1974) have shown is the case under fixed-interval schedules, then a local rate that is low, on the average, may be a combination of instances when there is no responding with instances when there is substantial responding. One purpose of the present experiment was to provide a comparison of pentobarbital's effects on equal rates of punished and unpunished responding under conditions in which local rates were homogeneous.

Our experiments also examined the generality of pentobarbital's ability to increase rates of punished responding by using two different types of punishers, timeout and electric shock. Although occasionally other stimuli have been used, most experiments examining the interactions of drugs and punished responding have used electric shock. Generally, it has been reported that punishing stimuli other than electric shock interact with drugs in a manner similar to that observed when electric-shock punishment is used (McMillan, 1975). In our experiments, however, a clear difference was obtained.

METHOD

Subjects

Four male White Carneaux pigeons were used. All had served previously in an undergraduate psychology laboratory. The pigeons were housed individually with continuous access to water and health grit. Their access to food was restricted to maintain them at 80% of their free-feeding weights.

Apparatus

In the first phase, two pigeon conditioning units were used. One was a commercially prepared unit (Lehigh Valley Electronics, Model 1519c), and the other a custom-built unit similar in design and dimensions to that described by Ferster and Skinner (1957). Only the commercial unit was employed in Phases 2 and 3. For Phase 3, this unit was modified by attaching a mercury commutator to the ceiling, through which electric shock could be delivered.

A static force of 0.15 N applied to the key was defined as a response and produced a 60-msec operation of either a tone generator (2800 Hz) in the commercial chamber or a relay in the custom-made chamber. Sessions were monitored and controlled by a PDP8/f computer operating under the SKED software system. The computer and a cumulative response recorder were located in an adjacent room. White masking noise was continuously present.

Procedure

Phase 1: response-dependent timeout presentation. The pigeons were trained to peck the key under a multiple random-interval 1-min random-interval 6-min (RI 1-min RI 6-min) schedule of food presentation. Specifically, when the key was illuminated by a red light, a probability generator was sampled once every second and arranged the availability of food presentation with a probability of 0.017. When the key was illuminated green, the probability generator also was sampled once every second, but the probability was set to 0.003. A random-ratio (RR) schedule of timeout (houselight and keylight extinguished, and pecks ineffective) presentation was also in effect when the key was lighted red. Timeouts were 20 sec in duration and presented with a probability of 0.33 following key pecks by Pigeons B1, B2 and B4, and with a probability of 0.20 for Pigeon B3. Components were 3 min long, exclusive of time during timeouts, and each component appeared four times in a session.

A peck that resulted in grain presentation could not also produce a timeout. Food presentation consisted of 2.5 sec access to mixed grain, during which all lights in the chamber, except one in the grain hopper, were turned off. Twenty-one sessions under this procedure were conducted before drugs were administered. Sessions immediately preceding those in which injections were made were designated as control sessions. The doses administered to each pigeon, and the number of administrations of each dose can be seen in Table 1.

Pentobarbital sodium (supplied by Abbott Laboratories) was dissolved in distilled water and injected intramuscularly in a volume of 1.0 ml per kilogram body mass. Injections were made immediately prior to selected sessions, and at least four days intervened between drug administrations. Dosages were administered in an irregular order, and are specified in terms of the salt.

Phase 2: response-independent timeout presentation. Pigeons B1 and B2 served in Phase 2, which served as a control for the reduction in overall frequency of food presentation that accompanied response-dependent timeouts. Procedural details were the same as in Phase 1, except for the manner in which timeouts were scheduled. During Phase 2, timeouts were presented according to a random-*time* schedule when the RI 1-min schedule was in effect. A probability generator ($p = 0.33$), sampled once every 1.28 sec (Pigeon B1) or every 1.03 sec (Pigeon B2), determined when timeouts occurred. The intervals between samples were obtained by taking the reciprocal of the mean response rate for each pigeon in control sessions of Phase 1, thus ensuring comparable overall frequencies and temporal distributions of timeouts between Phases 1 and 2. After 44 sessions of exposure to these conditions, the effects of a range of doses of pentobarbital were determined. The number of administrations and dosages in Phase 2 are shown in Table 1.

Phase 3: response-dependent shock presentation. Pigeons B1 and B2 served. They were fitted with electrodes (0.061-cm diameter stainless-steel orthodontic arch wire) around their pubis bones after the method described by Azrin (1959). During the RI 1-min component of the multiple schedule, 100-msec electric shocks were delivered according to an RR3 schedule. A key peck that resulted in food presentation could not also result in shock presentation. Shocks, delivered from a variable transformer through a 10,000-ohm series resistor, were varied in intensity occasionally over the course of Phase 3 in order to keep response rates in the RI 1-min component comparable to rates in Phase 1. Adjustments in intensity, of course, were never made during drug sessions or sessions immediately preceding drug sessions. Intensities ranged from 25 V to 37.5 V for Pigeon B1 and from 50 V to 85 V for Pigeon B2. Administration of pentobarbital began after 33 or 76 sessions of exposure to these conditions for Pigeons B1 and B2, respectively. The dosages examined and the number of determinations in Phase 3 are shown in Table 1.

Table 1

Number of Injections of Each Dosage

	Phase 1				*Phase 2*		*Phase 3*	
	Subject				*Subject*		*Subject*	
Dosage	*B1*	*B2*	*B3*	*B4*	*B1*	*B2*	*B1*	*B2*
0.0	2	2	2	2	2	1	2	1
3.0	3	3	3	3	2	2	4	2
5.6	3	3	2	3	2	2	4	2
10.0	4	2	4	3	2	2	4	2
17.0	2	–	3	–	1	–	1	–

The presentation of timeouts in Phase 1 resulted in sessions that were about 65 min longer than sessions in Phase 3, so the effects of 5.6 mg/kg were examined when the drug was administered 65 min before sessions, rather than immediately before. For Pigeon B1, the effects of 10.0 mg/kg were also determined with the long presession injection time to control session-length differences between Phases 1 and 3. By injecting the drug 65 min before sessions, the role played by the time-course of action of pentobarbital was examined.

RESULTS

Figure 1 shows cumulative response records from representative sessions during the first two phases. The records are from control sessions in which response rates in the two components most closely approximated the overall mean control rates for each pigeon

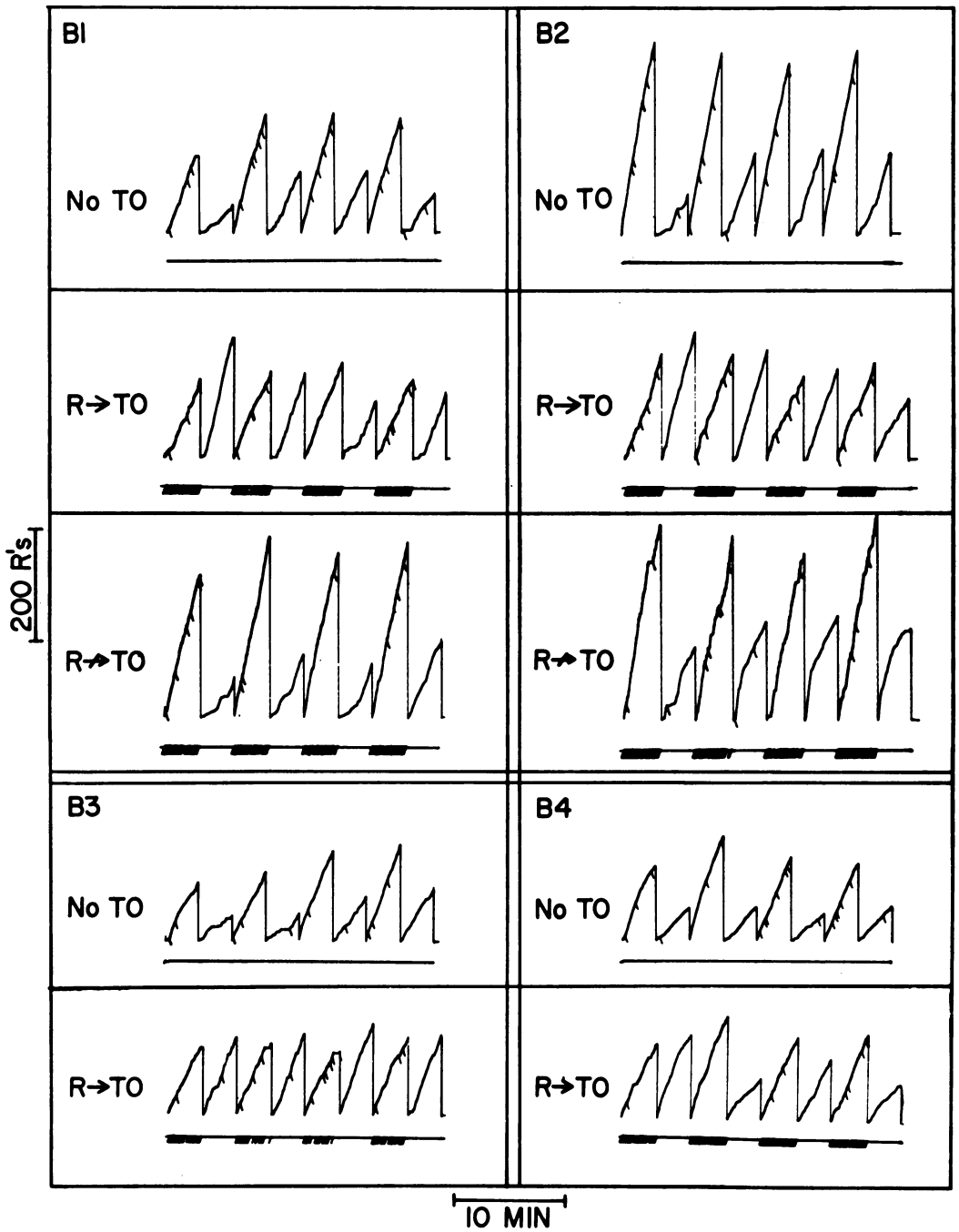

Fig. 1. Cumulative records of key pecking by Pigeons B1, B2, B3, and B4 during Phases 1 and 2. Y-axes: Cumulative key pecks. Short diagonal marks on the records indicate food presentations, and marks on the event line indicate timeouts. The recorder did not run during timeouts or food presentations. The pen reset to the baseline at the end of each component of the multiple schedule. The top record for each subject shows responding under a multiple RI 1-min RI 6-min schedule. Each session began with the RI 1-min schedule. The middle records for Pigeons B1 and B2, and the lower records for Pigeons B3 and B4, show responding under the multiple schedule when response-dependent timeouts (punishment) occurred during the RI 1-min component of the multiple schedule. The bottom records for Pigeons B1 and B2 show responding when timeouts were presented independently of responding during the RI 1-min component.

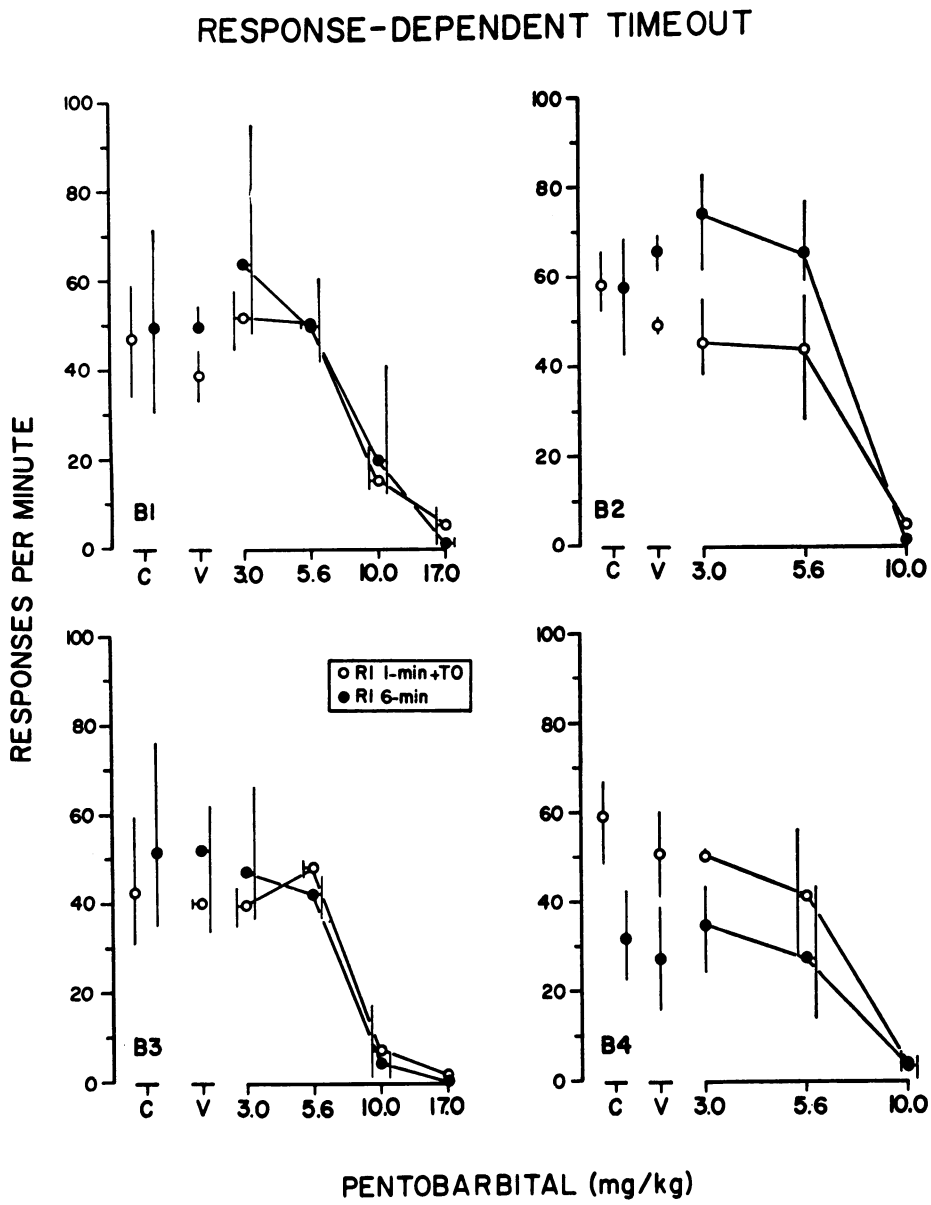

Fig. 2. Mean responses per minute under each component of the multiple RI 1-min RI 6-min schedule as a function of dosage of pentobarbital for Pigeons B1, B2, B3, and B4. Response-dependent timeouts (punishment) were scheduled during the RI 1-min component. Open symbols show rates during the RI 1-min component, and filled symbols show rates during the RI 6-min component. The points above "C" are means from all control sessions, and the brackets indicate ranges. The brackets have been displaced to the side in those cases where they overlap. Other points are means from two or more administrations. Points above "V" show the effects of injection of the drug vehicle (distilled water).

in a phase. The upper record for each pigeon shows responding under the multiple RI 1-min RI 6-min schedule. Steady, moderate response rates were engendered in both components. The RI 1-min schedule controlled a higher response rate than the RI 6-min schedule for all four pigeons. The middle records for Pigeons B1 and B2 and the lower records for Pigeons B3 and B4 show responding under conditions of response-dependent timeout presentation (punishment) during the RI 1-min component. Timeout presentation resulted in suppression of responding during this component for Pigeons B1, B2,

and B3. The degree of suppression ranged from 35% to 50%. An additional effect of adding timeouts to the RI 1-min component was a modest increase in rate of responding during the RI 6-min component.

Figure 2 shows the effects of several doses of pentobarbital on responding when timeouts were presented dependent on responding. Pentobarbital generally decreased response rate in both components of the multiple schedule. At low doses, however, Pigeons B1 and B2 showed occasional increases in the rate of pecking during the RI 6-min (no punishment) component. Overall, pentobarbital was administered 42 times, and on not a single occasion were response rates during the RI 1-min component increased above the range of control values.

The bottom cumulative records for Pigeons B1 and B2 in Figure 1 show responding from Phase 2 in which timeouts were presented independently of responding during the RI 1-min component. Response-independent timeout presentation did not suppress responding during the RI 1-min component, and response rates for Pigeon B1 were actually higher than under no-timeout conditions.

Figure 3 displays the effects of pentobarbital on responding in both components of the multiple schedule under the conditions of Phase 2 (response-independent timeout during RI 1-min). Pentobarbital only decreased rates during the RI 1-min component, and at low doses produced small, unreliable increases in rate during the RI 6-min component.

Cumulative response records of responding during Phase 3 (response-dependent shock during the RI 1-min component) are shown in Figure 4. The top records show responding under the multiple RI 1-min RI 6-min schedule after the pigeons had been fitted with electrodes. Although each pigeon wore a harness attached to the mercury swivel, re-

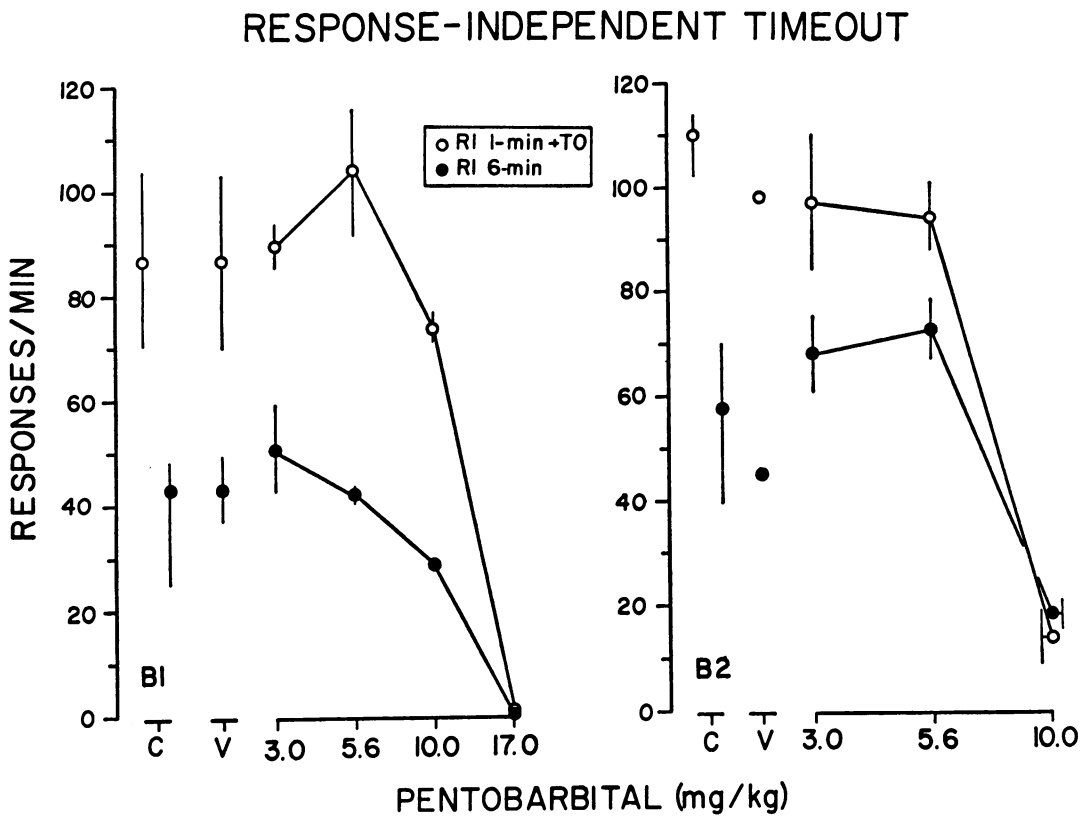

Fig. 3. Pentobarbital effects on mean responses per minute during each component of the multiple RI 1-min RI 6-min schedule when timeouts were presented independently of responding. Details are the same as for Figure 2.

sponse rates comparable to those without such encumbrances were obtained (compare Figure 1). Again, steady, moderate rates of pecking occurred during both RI 1-min and RI 6-min components, with a higher rate prevailing during RI 1-min. The middle record for each pigeon shows responding when response-dependent electric shocks were arranged during the RI 1-min component. Pigeon B1 responded about as it had when response-dependent timeouts were scheduled in Phase 1. For Pigeon B2, however, rates during the RI 6-min (no punishment) component were more variable and were generally less elevated than during Phase 1. For both pigeons, response rates under the electric-shock punishment conditions of Phase 3 were comparable to those under the timeout punishment conditions of Phase 1.

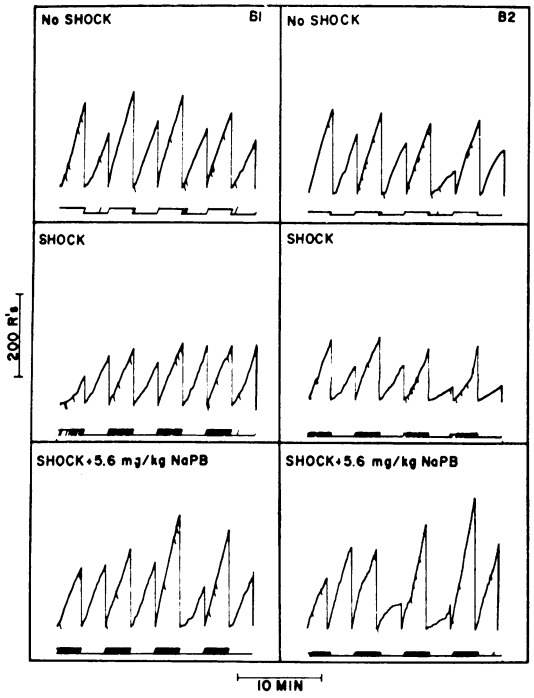

Fig. 4. Cumulative response records from Pigeons B1 and B2. Y-axes: cumulative key pecks. Short diagonal marks on the record indicate food presentations. The event pen was deflected downward during the RI 6-min component of the multiple schedule, except during food presentations. The event pen was also deflected briefly each time a shock was delivered during the RI 1-min component. The top records show responding during sessions when no shocks were scheduled. The middle records show responding when response-dependent shocks (punishment) occurred during the RI 1-min component, and the bottom records are from sessions in which the punishment procedure was in effect and that were preceded by administration of 5.6 mg/kg pentobarbital.

The effects of a range of doses on response rates are depicted in Figure 5. For Pigeon B1, dosages of 3.0 and 5.6 mg/kg reliably increased rates during the RI 1-min component; other doses resulted in decreases in rate. For Pigeon B2, the 5.6 mg/kg dosage produced a large increase in rate during the component in which responses were punished. The 5.6 mg/kg dosage was administered a total of six times (four times to Pigeon B1 and twice to Pigeon B2), and on each occasion response rate during the RI 1-min (punishment) component was elevated to levels higher than in any control session. Response rates during the RI 6-min (no punishment) component were not affected by lower doses and were decreased by larger doses. The bottom cumulative records in Figure 4 show responding during a session that was preceded by an injection of 5.6 mg/kg of pentobarbital. Response rates during the punishment component were substantially elevated, although the effect is not visible until the second presentation of the RI 1-min component of the multiple schedule.

Also shown in Figure 5 are points resulting from administration of pentobarbital 65 min before a session began. Sessions were much longer when responding was punished by timeout presentation than when responding was punished by electric-shock presentation. By injecting the drug 65 min before a session, the time between injections and the end of a session was approximately equal to that observed under control conditions in Phase 1. Increasing the time between injection of the drug and the beginning of the session did not prevent pentobarbital from increasing the rate of punished responding. In fact, administration of 10 mg/kg of pentobarbital 65 min before a session resulted in the largest increase in punished responding observed in Pigeon B1.

DISCUSSION

The most striking aspect of these data is the clear difference between pentobarbital's effects on responding suppressed by response-dependent timeout presentation *versus* effects on responding suppressed by response-dependent electric-shock presentation. Responding that was suppressed by timeout presen-

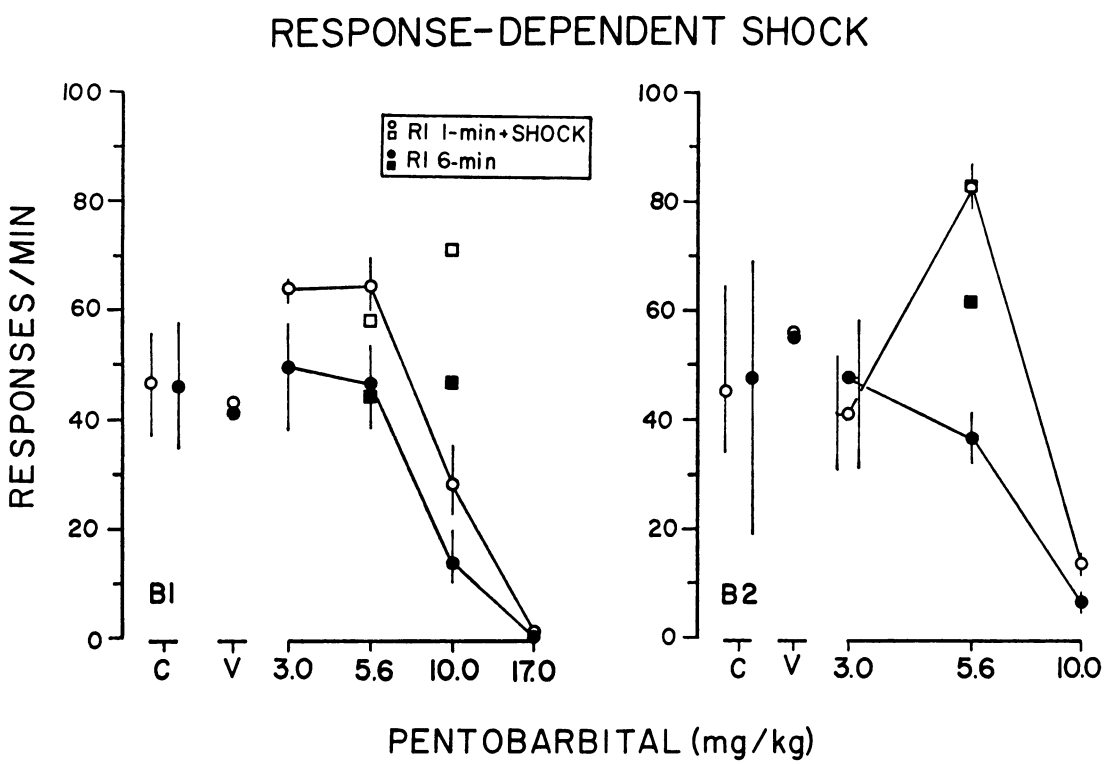

Fig. 5. Pentobarbital effects on responding during each component of the multiple RI 1-min RI 6-min schedule when response-dependent shocks were scheduled during the RI 1-min component. Details are similar to those for Figure 2. Unconnected symbols (squares) are from single sessions that were preceded by injections that occurred 65 min before the session, rather than immediately prior.

tation was not increased by pentobarbital, but equivalent rates of responding under electric-shock punishment were reliably increased at some doses. The comparison of rates from Phases 1 and 3, however, is complicated somewhat by a feature of timeout presentation. That is, under the conditions of Phase 1, much of the session was spent in timeout, and the average rates from this phase are from many rather brief periods of responding. Consequently, latencies between the end of a timeout and a key peck entered significantly into the calculation of rate from this phase. Latencies after shocks also entered into average rate calculations in Phase 3, but it is not unreasonable to assume that during a timeout a pigeon might get farther away from the key than it would following a shock. If such were the case, the pigeon would often not be in position to execute the key-peck response at the end of a timeout, and consequently one of the fundamental aspects of a free-operant situation would be absent (*cf.* Ferster, 1953), rendering the use of response rate suspect. Response-independent presentation of timeouts in Phase 2, however, showed that the suppressive effects of response-dependent timeout presentation in Phase 1 were not due simply to long latencies after timeouts. The role played by posttimeout latencies and postshock latencies remains to be investigated.

A comparison of control performances in Phases 1 and 2 shows that timeout acted as a punisher in the first phase. The temporal distribution of timeouts was the same in both phases, yet responding was suppressed when the timeouts were response dependent and was not suppressed when they were response independent. Thus, the suppression in Phase 1 was not due simply to the reduction in overall frequency of food presentation that necessarily occurred when timeouts were introduced, and consequently the difference in pentobarbital's effects on timeout-punished *versus* shock-punished responding was not due to failure of timeout to function as a true punisher.

McMillan (1967) also compared the effects of pentobarbital on responding suppressed by timeout punishment with responding suppressed by electric-shock punishment. He found that pentobarbital increased rates of responding suppressed either by timeout presentation or shock presentation, although responding suppressed by shock presentation was increased to a greater extent. The failure of pentobarbital to increase rates suppressed by timeout punishment in the present experiments may have been due to the relatively high response rates (about 45 per minute) that prevailed under punishment conditions. In McMillan's experiments by comparison, punished rates were between two and five responses per minute. A thorough parametric examination may reveal that pentobarbital can increase rates suppressed by timeout punishment, but that, as compared to electric-shock punishment, greater degrees of suppression are required.

The initial goal of our experiments was to separate the rate-increasing effects of pentobarbital from its specific punishment-attenuating properties. Such separation was achieved when electric shock was used as a punisher. As shown in Figure 5, equivalent average control rates were affected differentially, since pentobarbital increased punished rates at doses that did not alter unpunished rates. These data extend the generality of the finding that pentobarbital will preferentially increase responding suppressed by response-dependent electric clock (*cf.* Cook and Catania, 1964; McMillan, 1973).

The present results have important implications for conceptualizations of punishment and also serve to demonstrate how drugs can be used as tools in the analysis of behavior. Had behavioral measures and manipulations alone been used, the conclusion might have been that response-dependent electric shock or timeout functioned equivalently, since presentation of either resulted in comparable suppression of response rate. Under conditions of pharmacological intervention, however, differences appeared. Thus, the present results suggest that positive punishment (*e.g.*, shock presentation) and negative punishment (*e.g.*, timeout presentation) may be distinct processes, even though both suppress behavior. These results are consistent with other data that show that equivalent performances maintained by different consequent events may be differentially sensitive to the effects of drugs (Barrett, 1976; McKearney, 1974).

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