Pharmacology Biochemistry & Behavior, Vol. 39, pp. 817–820. © Pergamon Press plc, 1991. Printed in the U.S.A. 0091-3057/91 $3.00 + .00

BRIEF COMMUNICATION

The Effects of Phenobarbital on Responding Under Delayed-Matching-to-Sample Procedures With Differential and Nondifferential Outcomes

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ALLING, K., M. NICKEL AND A. POLING. *The effects of phenobarbital on responding under delayed-matching-to-sample procedures with differential and nondifferential outcomes.* PHARMACOL BIOCHEM BEHAV **39**(3) 817–820, 1991.—Pigeons were exposed to delayed-matching-to-sample procedures in which food or a flash of the feeder light followed correct responses. When these consequences were correlated with a particular stimulus (e.g., food followed matching responses to red and a flash of the feeder light followed matching responses to green), accuracy was significantly higher (i.e., stimulus control was greater) than when discriminative stimuli and consequences were not correlated. Acute administrations of phenobarbital (10–40 mg/kg) produced similar effects regardless of whether or not differential outcomes were arranged for correct responses to a particular stimulus. At doses of 30 and 40 mg/kg, phenobarbital significantly decreased accuracy under both variations of the delayed-matching-to-sample procedure. Given these results, it appears that degree of stimulus control in the absence of drug did not modulate drug effects in the present study.

Phenobarbital Delayed-matching-to-sample Pigeons Stimulus control Differential outcomes effect

ACCORDING to Urcuioli (21), "One of the most consistent and powerful effects on the learning and retention of conditional discriminations is the enhancement of performance by differential outcomes" (p. 410). This phenomenon can be readily demonstrated under delayed-matching-to-sample (DMTS) procedures. For example, Peterson, Wheeler and Armstrong (12) exposed pigeons to a DMTS procedure in which the sample stimulus was a red or a green key light, the comparison stimuli were a horizontal and a vertical line, and the outcomes were food or water. The correct comparison stimulus was chosen more often when food always followed correct responses in one type of trial (e.g., red) and water followed correct responses in the other type of trial (e.g., green) than when 50% of all correct responses were followed by food and the remainder were followed by water. Improved stimulus control when different outcomes are used, generally termed the differential outcomes effect (DOE), has been demonstrated with a variety of outcomes, including different delays to reinforcement (2), different probabilities of reinforcement (4), and food plus a tone versus the tone alone (11).

Although there are exceptions [e.g., (8,17)], a given drug at a particular dose usually produces less disruption when behavior is strongly controlled by a discriminative stimulus than under conditions where stimulus control is weaker (8, 9, 18). Because accuracy is higher under the DMTS procedure with differential outcomes than under the same procedure with nondifferential outcomes, drug effects might differ in magnitude under the two variations. Specifically, one would predict greater effects with nondifferential outcomes. Whether this occurs was examined in the present study, which explored the effects of phenobarbital in pigeons exposed to DMTS procedures with differential and nondifferential outcomes.

Phenobarbital is used clinically as an anticonvulsant. Its mechanism of action in the central nervous system appears to be a combination of postsynaptic suppression and enhanced inhibition. Inhibition is at least partially mediated by GABA systems, where the drug enhances binding (5,10). The behavioral effects of phenobarbital in nonhumans have been explored in some detail (16), and in prior studies phenobarbital produced generally dose-dependent decreases in accuracy (percent correct responses) under DMTS procedures with nondifferential outcomes (7,15). The effects of the drug under DMTS procedures with differential outcomes have not been reported.

METHOD

Subjects

Eight white Carneau pigeons, maintained at 80% of their free-feeding weights, served as subjects. Subjects were individually housed with unlimited access to water and grit in a room

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with a 16-h/8-h light-dark cycle. Four subjects were experimentally naive at the start of the experiment. The other four subjects had previously served in a DOE experiment examining the effects of *d*-amphetamine.

Apparatus

Experimental sessions were conducted in four chambers (Lehigh Valley Electronics, Lehigh Valley, PA) measuring 36 cm high, 36 cm wide, and 30 cm long. A 6 cm by 6 cm aperture, centered on the front wall permitted access to a grain feeder. When raised, the feeder was illuminated with a 7-W bulb. Three response keys, mounted in a horizontal row on the front wall, could be illuminated in red or green. The right key was 9.5 cm from the right wall and the three keys were spaced 8.9 cm apart. Each key could be operated by a force of 0.2 N. Ambient illumination was provided by a 7-W light (houselight) centrally located on the ceiling of the chamber. Masking noise was supplied by a white noise generator through a speaker mounted on the lower right corner of the front wall. A PDP8/A minicomputer (Digital Equipment Corporation, Maynard, MA), equipped with SUPERSKED software (State Systems, Kalamazoo, MI), arranged experimental conditions and collected data.

Procedure

All birds were initially trained to keypeck using procedures described elsewhere (1). After keypeck training, they were exposed to DMTS procedures. Uncorrelated and correlated DMTS procedures were employed in the experiment proper. Four subjects (Group 1) initially were exposed to the correlated procedure; four others (Group 2) initally were exposed to the uncorrelated procedure. Under the uncorrelated DMTS procedure, trials were separated by 7-s intertrial intervals (ITIs). Each trial began with a 0.25-s darkening of all lights, after which the houselight was illuminated and the center key light was lighted in either red or green (i.e., the sample stimulus was presented). After 5 key pecks, the center key light was darkened and a delay of 0.01 s (hereafter referred to as 0 s) or 8 s ensued. Each delay value was randomly selected, with the exception that each occurred equally often. After the delay ended, both side keys were illuminated, one in red and one in green (i.e., the comparison stimuli were presented). A peck to the side key that matched the color previously on the center key, designated a correct response, produced either 4-s access to grain or a 0.5-s flash of the feeder light. The outcome on a given trial was randomly determined, save that the two outcomes occurred equally often. A peck to the other side key, termed an incorrect response, produced a 2-s blackout followed by the ITI. The same trial was then repeated until a correct response occurred. Trials were aborted if the response requirement on either the center key or the side key was not completed within 30 s. These trials were not considered incorrect. Red and green sample stimuli, and the key locations on which red and green comparison stimuli occurred, were arranged at random with the exception that red and green illuminations were presented equally often as the sample stimulus in each session. Sessions ended after 70 trials or 50 min elapsed, whichever occurred first.

The correlated procedure was identical to the uncorrelated DMTS procedure, with one exception: under the correlated procedure, the outcome for a given correct response depended on whether the trial involved a red or green sample stimulus. For two subjects, food was presented after correct responses on red trials and a flash of the feeder light was presented after correct responses on green trials; for two other subjects, food was delivered on correct green trials, and a flash of the feeder light on correct red trials.

Subjects were exposed to the assigned procedure for (a) at least 10 sessions and (b) until there was no visually evident trend in percent correct responses for each delay across 5 consecutive sessions. When both criteria were met, all birds were given acute phenobarbital injections under a BBCD design wherein B represents baseline (no injection), C vehicle control sessions (a 70% propylene glycol, 20% distilled water, and 10% ethyl alcohol solution), and D drug sessions. Two series of phenobarbital injections were given; each series comprised four doses (10, 20, 30, and 40 mg/kg). Within each series, the four doses were given in random order for each bird. All injections were administered intramuscularly (IM) at a 1 ml/kg volume 30 minutes before the session. The phenobarbital (Sigma, St. Louis, MO) was dissolved in a 70% propylene glycol, 20% distilled water and 10% ethyl alcohol solution.

After subjects completed two series of phenobarbital injections under the conditions described above, conditions were reversed so that Group 1 was exposed to the uncorrelated DMTS procedure and Group 2 was exposed to the correlated DMTS procedures. These procedures were arranged as described above and drug administrations were repeated. After performance stabilized, the effects of phenobarbital were again examined. This was done in the same fashion as the first drug evaluation (i.e., each bird received each of four doses twice in random order under a BBCD design).

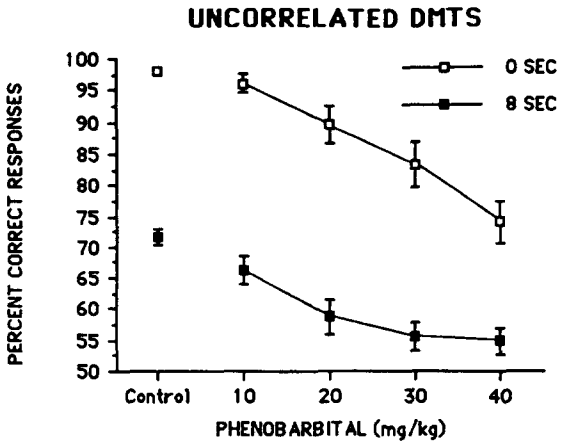
RESULTS

Mean percent correct responses at each delay during control and phenobarbital sessions are portrayed in Fig. 1. Visual inspection of these data suggests that, under the correlated DMTS procedure, phenobarbital decreased accuracy in dose-dependent fashion. Statistical analysis (one-way repeated measures analysis of variance) of data for the correlated procedure revealed significant overall drug effects at both the 0-s delay, $F(4,28)=22.8$, $p<0.01$, and 8-s delay, $F(4,28)=44.4$, $p<0.01$. Planned comparisons using the Tukey method (5) showed that accuracy was significantly below the control level at phenobarbital does of 30 mg/kg and 40 mg/kg for both the 0-s delay ($q=6.2$, $p<0.01$; $q=6.9$, $p<0.01$) and 8-s delay ($q=8.0$, $p<0.01$; $q=10.8$, $p<0.01$).

Visual inspection suggests that phenobarbital also decreased accuracy in dose-dependent fashion under the uncorrelated DMTS procedure. Statistical analysis of data for the uncorrelated procedure revealed significant overall drug effects at both the 0-s delay, $F(4,28)=15.4$, $p<0.01$, and 8-s delay, $F(4,28)=11.2$, $p<0.01$. Tukey tests revealed that accuracy was significantly below the control level at phenobarbital doses of 20, 30, and 40 mg/kg for the 0-s delay ($q=4.2$, $p<0.05$; $q=5.2$, $p<0.01$; $q=5.4$, $p<0.01$) and 30 and 40 mg/kg for the 8-s delay ($q=4.2.$, $p<0.05$; $q=6.8$, $p<0.01$).

Rate data are portrayed in Fig. 2. Under the correlated procedure, the mean rate of responding to the sample stimulus in the absence of drug was higher during trials followed by food than in trials followed by a flash of the hopper light. No such rate difference was evident under the uncorrelated procedure.

For data collected under the correlated procedure, repeated measures analysis of variance revealed a significant drug effect on mean response rate during both trials followed by food, $F(4,28)=3.9$, $p<0.05$ and trials followed by a flash of the hopper light $F(4,28)=3.7$, $p<0.05$. However, planned comparisons by the Tukey method revealed that response rates at all phe-



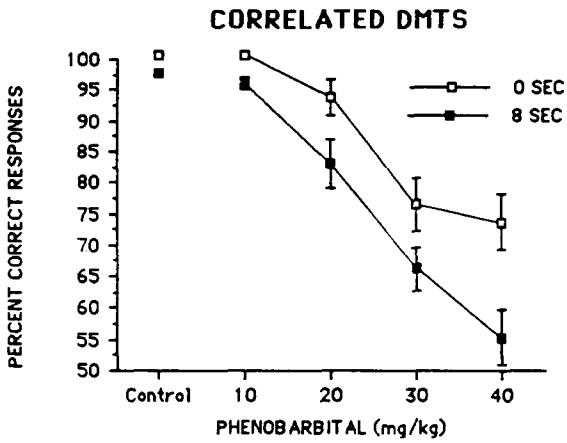
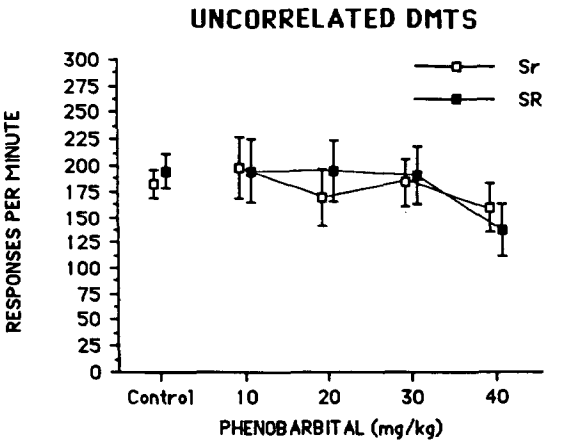


FIG. 1. The percentage of correct responses to the comparison stimuli at 0-s and 8-s delays in control and phenobarbital sessions under correlated and uncorrelated DMTS procedures. Control data points represent the mean of all sessions immediately prior to drug administration for all eight birds; phenobarbital data points are the mean of two series of administrations for those birds. Vertical lines are standard errors.



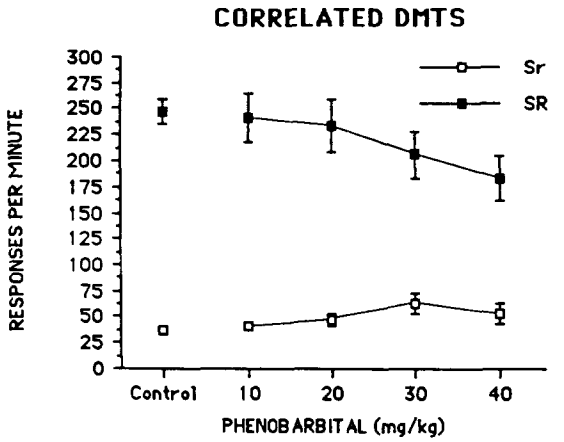


FIG. 2. Responses per minute in the presence of the sample stimulus correlated with food (SR) and with a flash of the feeder light (Sr) during control and phenobarbital sessions under correlated and uncorrelated DMTS procedures. Control data points represent the mean of all sessions immediately prior to drug administration for all birds; phenobarbital data points are the mean of two series of administrations for all birds. Vertical lines are standard errors.

nobarbital doses did not differ significantly from the control level.

For data collected under the uncorrelated procedure, repeated measures analysis of variance revealed a significant drug effect on mean response rate only for trials followed by food, $F(4,28) = 4.0$, $p<0.05$. As under the correlated procedure, planned comparisons by the Tukey method revealed that response rates at all phenobarbital doses did not differ significantly from the control level.

DISCUSSION

In the present study, the percentage of correct responses at both 0-s and 8-s delays was higher under the correlated procedure than under the uncorrelated procedure. Moreover, accuracy was less disrupted by delay under the correlated procedure than under the uncorrelated procedure. These findings are in general agreement with those of other studies of the DOE [e.g., (3, 4, 11, 12, 19)].

As a rule, behavior that is strongly controlled by a discriminative stimulus is less affected by drugs than similar behavior that is stimulus-controlled to a lesser degree (8, 9, 18). This phenomenon has been previously demonstrated with phenobarbital (14). In that study, pigeons were exposed to a fixed-consecutive-number (FCN) schedule of food delivery with and without an added external discriminative stimulus. Under these schedules, a reinforced run consisted of responding between eight and 12 times on one response key and then responding once on another response key. For one group of pigeons an external discriminative stimulus (change in key color) signalled completion of the response requirement on the work key, whereas no stimulus change was programmed for the other group. In the absence of drug, response accuracy (percentage of reinforced runs) was consistently higher under the FCN schedule with the added discriminative stimulus. Phenobarbital (5–60 mg/kg) decreased accuracy and rate of responding under both variations of the FCN schedule. The magnitude of these accuracy- and rate-decreasing

effects was larger under the FCN schedule without the external discriminative schedule. These data suggest that degree of stimulus control established prior to testing was an important determinant of the behavioral effects of phenobarbital.

Given these specific findings, and the general finding that degree of stimulus control modulates drug action (8, 9, 18), we hypothesized that phenobarbital would disrupt accuracy to a lesser degree under the correlated version of the DMTS procedure than under the uncorrelated version. This did not occur. Although accuracy was higher under the correlated version of the DMTS, indicating greater stimulus control, drug effects were comparable under the correlated and uncorrelated procedures. At sufficiently high doses, phenobarbital decreased accuracy and rate of responding under both procedures. These findings are similar to those of prior investigations employing uncorrelated DMTS procedures (7,15).

Although there is no generally accepted explanation of the DOE, it is possible that differences in rate of responding to sample stimuli correlated with food and a flash of the hopper light contributed to the phenomenon in the present study [cf. (1)]. Under the correlated DMTS procedure, the former stimulus controlled a much higher rate of keypecking. In view of reports that arranging sample-specific response patterns by programming different operant contingencies for different sample stimuli facilitates accuracy under DMTS procedures [e.g., (19, 20, 22)], it is certainly plausible that the difference in response rates associated with food-paired and light-paired sample stimuli contributed to the improved accuracy observed under the correlated DMTS procedure in the present study. Given this possibility, it is interesting to compare the effects of phenobarbital on response rates and accuracy under the correlated DMTS procedure. When this is done, it is obvious that the drug significantly reduced accuracy at doses (30 and 40 mg/kg) that did not significantly affect rate of responding. Although this finding does not clarify the role that rate differences may play in contributing to the DOE in the absence of drug, it does indicate that rate disruption is not necessary for a drug to disrupt accuracy under a correlated DMTS procedure. Further pharmacological manipulations (e.g., with a drug that produced rate convergence) could ascertain whether rate disruptions are sufficient to impair accuracy.

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