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Effects of Sodium Pentobarbital on Matching Behavior in the Pigeon[1]

ROBERT N. LANSON,[2] DAVID A. ECKERMAN AND ROBERT BERRYMAN

Queens College of CUNY; the University of North Carolina, Chapel Hill, NC and The American University of Cairo, Egypt

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LANSON, R. N., D. A. ECKERMAN AND R. BERRYMAN. *Effects of sodium pentobarbital on matching behavior in the pigeon.* PHARMAC. BIOCHEM. BEHAV. 11(2) 159–164, 1979.—Nine pigeons in a matching-to-sample task with 5 alternative stimuli were exposed to 4 dose levels of sodium pentobarbital. Each drug session alternated with a control session, and 6 determinations were made at each dose level. Dose-response curves were obtained, and drug effects are described for position-specific and stimulus-specific behaviors. These results suggest that the drug effect is to weaken control by the sample stimulus and shift control to properties of the comparison stimuli.

Matching-to-sample Conditional discrimination Sodium pentobarbital Stimulus control Drug effects Barbiturates

PENTOBARBITAL and other barbiturates have been found to reduce accuracy for several species in a variety of discrimination tasks. Frequently, the errors produced represent failures to respond (omission errors) [1, 2, 15, 16, 17]. Such changes in accuracy may simply represent the sedative properties of the drugs.

In other studies, however, an increased tendency to respond to the inappropriate stimulus (commission errors) is observed. This effect has been reported in some go/no-go tasks, where only one stimulus is present at a given time [11, 12, 13, 14, 15, 16, 19] and in simultaneous discriminations, where the animal is required to respond to one of several stimuli present [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 18]. Some of these discriminations require a simple stimulus choice, while some require a response based on more complex stimulus characteristics. These errors are not a result of motor impairment, but are seemingly the result of true loss of stimulus control, described by some as reduced cognitive ability ([10], p. 284), a true central effect ([16], p. 316) or a retarded mechanism of "processing and interpretation of sensory input" ([3], p. 253).

In many simultaneous discriminations, this effect is simply reported as decreased accuracy without analyzing what kind of change in performance is involved. One might observe random error patterns or specific increases in other, alternate but inappropriate performances. Matching-to-sample offers a good way to examine such errors. In this procedure, the subject is shown a 3 stimulus display. The sample (or standard, denoted ST) stimulus is presented in the center display; and a response to the ST turns on the comparison (denoted CO) stimuli on the side keys. A reinforcer is provided for a response made to the CO stimulus which is physically identical to the ST stimulus.

Correct matching-to-sample performance is based on control by both the ST and CO stimuli. Decreased accuracy could result from loss of control by one or more ST-stimuli, from increased preference for one or more CO-stimuli, from increased preference for a specific CO-stimulus position, or from combinations of these influences. Where particular alternate sources of control are clear, it seems appropriate to describe the drug effect as a shift rather than as merely a loss of control.

There is some evidence that barbiturates do produce a shift rather than a mere loss of stimulus control. Blough [6], using a modified free-operant procedure and 2 alternative ST stimuli, found position-specific behaviors to increase with decreases in accuracy. Branch [7], using a procedure where the number of responses required on the center key (an ST of 25 or 35 responses) determined which of the side keys (CO's of left and right key) was correct, found position-specific behaviors to increase with decreases in accuracy. Rosenberg and Woods [18], in replicating Branch's study, also found an increase in position-specific behavior, although these did not change systematically across dose levels. Berryman, Cumming and co-workers [4, 5, 8, 9] also found position preferences to be increased, using procedures closely related to the

[1]Dedicated to the memory of Dr. W. W. Cumming. His untimely death, on January 8, 1970, prevented his participation in the preparation of this report; his colleagues and co-workers thus assume full responsibility for any flaws that may detract from its merit, and hope that it will, nevertheless, show something of the excellence that characterized his work. The study was supported by Grants MH-03673 and MH-10384 from the National Institute of Mental Health, Public Health Service, to Dr. W. W. Cumming. Preparation of the manuscript was partially supported by training Grant MH-14269 from the National Institute of Mental Health, Public Health Service.

[2]Reprints are available from: Dr. R. N. Lanson, Psychology Department, Queens College, 120 Remsen Hall, Flushing, NY 11367.

matching procedure employed here. In the present study, 5 ST stimuli were used and thus shifts in control may be related to several specific stimulus characteristics.

METHOD

Animals

Nine adult white Carneau pigeons, supplied by Palmetto Pigeon Plant, were maintained at 80% of their individual free-feeding weights. Training sessions were given only if their weights were within ± 15 g of the 80% value. All subjects had over 200 sessions of matching-to-sample training and had maintained accuracies of 70% correct or greater for at least 3 months (or about 50 sessions)before the present experiment.

Apparatus

A Lehigh Valley Electronics 3 key pigeon chamber (Model 132-02) was used. Each 2.5 cm circular response key could be transilluminated with one of 5 hues produced using gelatin filters—nominally: blue, green, red, yellow, and white. General illumination was provided by a houselight mounted above the center key. A grain magazine, located below the center key, provided food reinforcement for correct behavior. The food consisted of a mixture of Kaffir corn, vetch, and peanut hearts.

Procedure

Each experimental session consisted of 120 trials. A trial began with the presentation of one of the ST hues on the center key. A response to this center key produced illumination of the CO stimuli on the side keys, with the center key remaining on. The reinforcement contingency required a response to the CO which was physically equivalent to the ST. A response to either side key turned off all 3 key lights. A response to the key of matching color was followed by 3-sec access to grain; a response to the other key was followed by a 3-sec blackout during which time all illumination in the chamber was extinguished. Following reinforcement or blackout, a 15-sec intertrial interval, with the houselight on, ensued, after which a new trial was begun with the onset of the center key.

The present study used 5 ST colors and 5 CO colors. Each ST color was presented 24 times throughout the session, 3 times with each of the other colors as the incorrect CO on the left and 3 times on the right key. The distribution of stimuli was randomly permuted so that all colors appeared equally often on both CO keys. In this way systematic position habits or color preferences resulting from differential reinforcement were kept to a minimum.

Sessions were scheduled 6 days a week. On a drug day, a bird was injected in the pectoral muscle with either 5.0, 7.5, 10.0, or 12.5 mg/kg of sodium pentobarbital. Volume of solution was given according to body weight, and dose was varied by concentration change. The bird was then placed in the experimental chamber with the houselight on, and the experiment was begun after 10 min. On those rare occasions when the bird did not begin responding after 30 min, the animal was removed from the chamber, the data were not considered in the analysis, and the drug dose was then repeated in a subsequent session.

Each drug session was followed by a non-injection control session so that drug days were at least 48 hr apart. Dose levels were randomly permuted for successive drug sessions. In all, 6 drug sessions were given at each dose level.

RESULTS

Accuracy of the matching performance was reduced below control ranges by pentobarbital in all animals (see Fig. 1). At higher doses, accuracy was decreased to nearly chance levels (50%). For Bird 352 (middle row on left in Fig. 1), the large drop in accuracy at 5 mg/kg obscured the apparent slope of the function. Therefore, three further drug sessions were subsequently given with 2.5 mg/kg. The three control sessions given for this drug level were injection controls, using a comparable volume of water. No difference was found between the two types of control sessions.

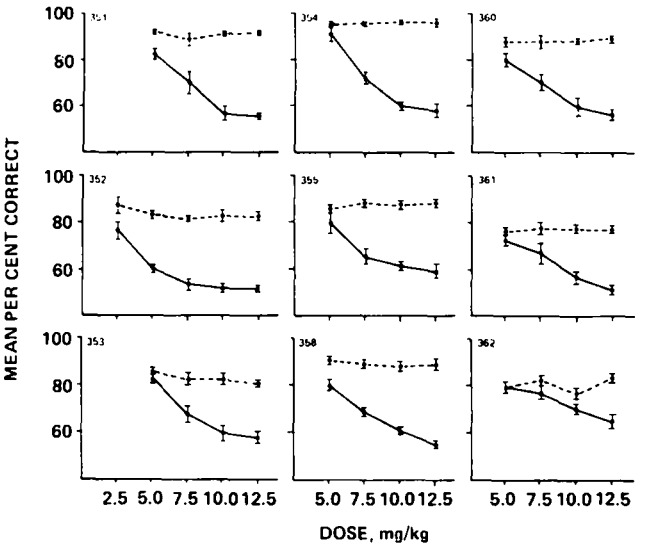

FIG. 1. Mean percent correct matching as a function of dose level for each bird. Performance on control sessions is indicated by the dashed line. Variability bands show ± 1 standard error of the mean.

The observed accuracy decrements were accompanied by a shift of control from the matching-to-sample contingency to other dimensions of the situation. One such shift took the form of position specific behaviors. The percent deviation from equal responding on the left and right CO keys can be taken as a measure of position preference. For all animals, control sessions show little evidence of position preference (see Fig. 2). Of the 9 birds, however, 6 showed increased position preference with the drug, although the shapes of these dose-preference functions differ across animals—with some birds (e.g., No. 358) showing a steady increase in preference with dose, while others show more complex functions.

A second shift in mode of responding was stimulus (in this case, color) preference. The data may be analyzed for individual color preferences by disregarding the standard hue and considering only the comparison hues chosen. When particular hues were either (a) chosen very consistently regardless of the ST hue or position (R or L) or (b) avoided very consistently regardless of the ST hue or position, the performance involved color preferences. A measure of this

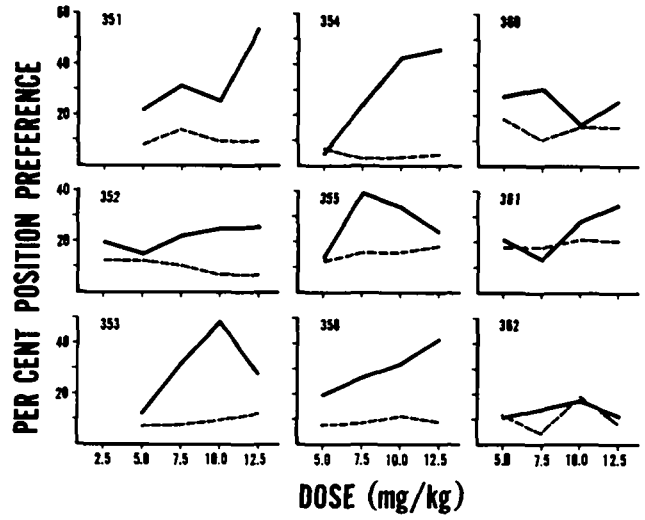

FIG. 2. Percent position preference as a function of dose level for each bird. Performance during control sessions is shown by the dashed line.

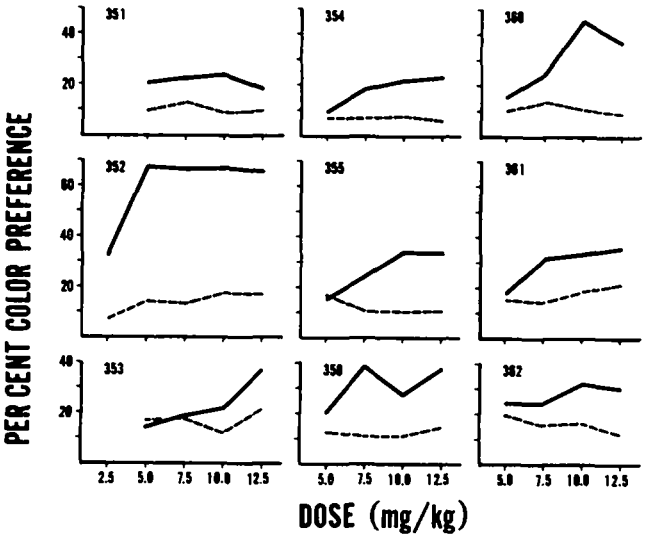

FIG. 3. Percent color preference as a function of dose level for each bird. Performance during control sessions is shown by the dashed line.

preference is provided by calculating the percent deviation from equal choice of the five CO hues. A 100% preference would involve a hierarchy in which stimulus A was always chosen, stimulus B was always chosen except over A, stimulus C was always chosen except over A or B, and so on.

Color preferences were increased for all birds when given pentobarbital (Fig. 3). For 8 of the birds the increase was dose-dependent. The extreme case is represented by bird No. 352, which consistently avoided responding to the red CO at the four highest dose levels and also showed a high preference for the green hue. This avoidance and preference were not characteristic of either the injection or non-injection control data on this bird. For no bird was the ordering of hue preferences at the highest dosages a simple exaggeration of the individual color preferences seen in control sessions.

The two preference measures just presented can be compared for each subject. Because one measure is determined by position with colors equated on both sides and the other measure is determined by stimulus color equated for position, these measures are largely independent, though a complete position preference would yield 0% color preference and vice versa. A strategy involving both color and position specific behaviors would give intermediate values on each preference measure. Comparison of the color and position preference data shows that every subject, in varying degrees, adopted at least one of these two alternative modes of responding. For each bird at least one preference increased systematically with dose, suggesting that at least one of two alternate sources of control was accentuated by the pentobarbital.

Figure 4 shows the recovery of accuracy, starting 10 min after drug injection, plotted as a function of successive blocks of 20 trials for each dose level. The data for all birds other than No. 352 were sufficiently similar in form to allow averaging. These average data are shown in the left panel; the recovery function on the right is for Bird No. 352. For the averaged birds, the 5.0 mg/kg dose depressed accuracy early in the session with almost complete recovery of the control performance in the final 20 trials. The recovery functions for higher doses are quite parallel to that for 5.0 mg/kg over the course of the session. An analysis of the recovery data from individual animals suggests some instances, however, of a slower rate of recovery with increased dose.

Bird No. 352 shows a lack of ordering of the recovery functions for the four highest dose levels, with only slight indication of recovery at the end of the session. The 2.5 mg/kg curve shows considerably less decrement than the higher dose functions and a recovery of accuracy by the last block of trials.

If the matching situation is viewed as a conditional discrimination with the number of discriminations dependent on the number of ST stimuli, one can analyze and compare matching accuracies for each ST color. Mean accuracy for each ST as a function of dose level is given in Table 1 for each bird. Accuracy was reduced for each ST color with increased dose. For most birds, the amount of accuracy reduction was unrelated to initial accuracy, and decrements were similar for all ST hues. The effect of the drug is thus not simply to magnify differences in accuracy between STs observed in control sessions.

To this point, the results have considered the single response to the side key that terminated the stimuli and was followed by reinforcement or blackout. Responses to keys during the intertrial interval or to the center key after the bird had produced the CO hues on the side keys had no effect. It was observed early in the experiment that these birds made extra responses and that the frequency of these extra responses was related to dose level. The total number of extra responses to the side keys and the number of extra center key responses were then recorded and averaged as a function of drug dose. Because this measure was not taken from the outset of the experiment, however, even though all available sessions were included in the average, the number of determinations going into each drug point varied between 3 and 6. The mean number of responses is plotted in Fig. 5 for

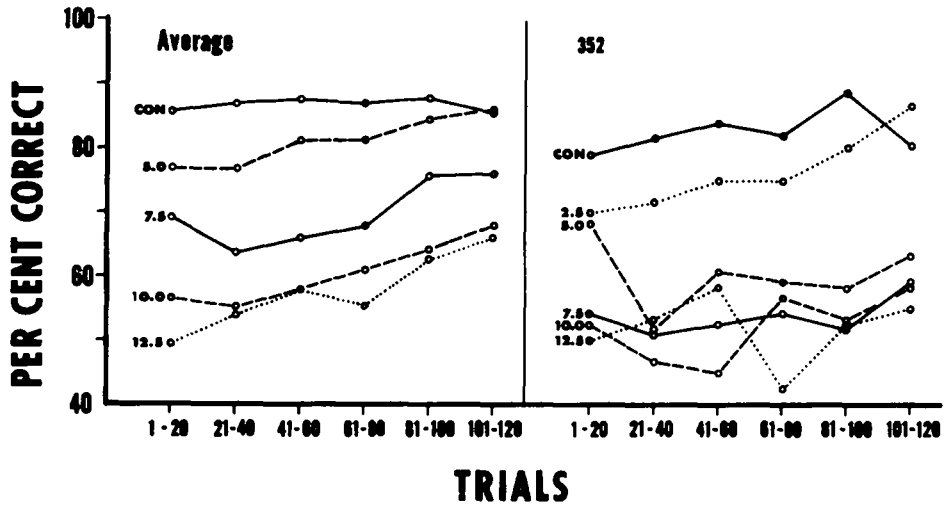

FIG. 4. Percent correct matches as a function of drug dose in blocks of 20 trials for the 120 trial session. CON denotes control session performance. The left panel shows recovery functions averaged for all birds except No. 352, whose data are shown in the right panel.

each dose, with control values plotted as zero dosage. Because of the different orders of magnitude of extra responses, the center and side key data are separately considered. Extra responses on both center and side keys increased considerably under the drug. Most of the extra responses occurred on darkened keys during the intertrial interval, although some of the center key extras were made once the CO stimuli had been presented. At the largest dose used, some birds' functions level off, and it is reasonable that still larger doses would reduce responding still further as anesthetic level is approached.

DISCUSSION

The accuracy decrements observed for this matching-to-sample procedure again confirm that pentobarbital disrupts discriminative control of behavior. The present effects obtained with a 5 alternative matching procedure can be compared with those found in 3 alternative matching studies [4, 5, 8, 9]. Larger accuracy reductions were found for the 5 alternative procedure at both the 5 and 10 mg/kg doses common to both investigations. This comparison is limited, however, because of differences in apparatus and procedures between the two studies.

TABLE 1

MEAN PERCENT CORRECT BY ST AS A FUNCTION OF DOSE

ST DOSE (mg/kg)	CON	2.5	5.0	7.5	10.0	12.5	CON	5.0	7.5	10.0	12.5	CON	5.0	7.5	10.0	12.5
Bird				351					354					360		
Blue	93	-	86	81	62	56	98	90	70	50	54	88	79	80	60	58
Green	91	-	82	69	53	57	97	97	75	67	67	88	82	70	76	72
Red	97	-	89	79	60	55	98	94	74	65	54	96	88	74	34	39
Yellow	87	-	81	65	59	56	91	90	74	65	65	85	77	68	67	60
White	86	-	73	58	49	54	93	87	63	54	53	85	74	60	63	55
Bird				352					355					361		
Blue	81	88	81	67	58	64	86	77	58	52	47	79	75	69	54	43
Green	84	85	87	78	72	74	90	85	74	70	66	74	72	79	56	54
Red	96	58	3	1	17	3	96	87	72	54	54	94	88	60	47	42
Yellow	75	81	69	63	57	58	82	79	65	68	76	75	63	69	67	63
White	77	71	62	60	57	60	85	72	59	63	56	66	68	58	60	56
Bird				353					358					362		
Blue	80	-	83	70	54	42	85	65	52	49	40	78	83	74	72	69
Green	85	-	85	67	65	60	89	81	75	69	76	79	75	76	75	67
Red	93	-	90	72	60	56	97	97	92	65	45	94	90	87	70	66
Yellow	76	-	79	69	63	74	87	78	60	64	65	72	74	67	70	65
White	83	-	81	63	57	59	89	81	66	58	51	80	76	83	64	57

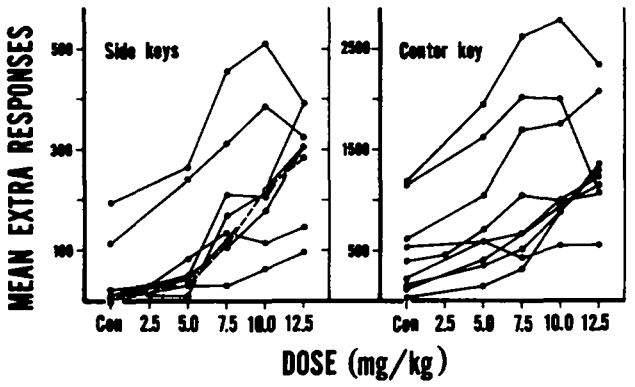

FIG. 5. Left panel shows frequencies of extra responses on the side keys as a function of dose for the individual subjects. The ordinate on the left applies to all solid line functions. One bird exhibited a much greater increase in responding than others, and for graphical presentation its data are plotted as a dashed line, whose values can be read from the ordinate on the right. The right panel shows the frequency of extra center-key responses as a function of dose for all birds.

The reduced accuracy with the drug did not merely represent a "loss of discriminative control". This phrase suggests that a random, uncontrolled performance results; instead, dimensions of control could still be found. Furthermore, the drug did not merely accentuate sources of inaccuracy found in the non-drugged performance. The STs initially matched with higher accuracy and those STs initially matched with lower accuracy both showed decrements with the drug (Table 1). In addition, the particular side or color preferences observed with the drug were not consistently those seen to a lesser degree in the non-drugged performance. Moreover, the drug did not bring out latent side or color preferences which were shared across birds. No particular color and neither side was consistently preferred or avoided.

These results suggest that the drug produced a shift from the relatively complex control of CO-choice by characteristics of the ST (i.e., matching of these colors) to the relatively simple control by particular CO colors or CO side. Such a shift represents a change from control by ST and CO together toward control by CO alone. Similar shifts are suggested in prior work with related procedures [4, 5, 6, 7, 8, 9].

The shift to stimulus preference may represent a different type of control than the shift to side preference. Were the performance to simply become a repetition of motor movements independent of external stimuli, a side preference would result. One possible drug-induced degenerative state might involve such a simple repetition. When a stimulus preference is observed, however, the control by external stimuli is still strong and the motor repertoire of right-key and left-key choices is still not constrained. Therefore, such a shift still represents stimulus control, not motor impairment. Control is simply shifted to other stimulus dimensions and is not lost.

An interesting analysis of measurable alternate performances under pentobarbital is provided by Rosenberg and Woods [18]. Using a signal recognition paradigm, they attempted to distinguish drug-induced changes in discriminative sensitivity from changes in response bias. Pigeons were required to peck right or peck left depending on whether they had just completed a small or large ratio of pecks on a center key. Their response bias was measured through increased tendencies to peck either side key independent of which ratio had been completed (i.e., their response bias was related to our position preference). A systematic relation between dose level of pentobarbital and reduced sensitivity was found, but no systematic relation between dose level and increased response bias was observed. Why Rosenberg and Woods did not find consistent increases in an alternate performance with decreases in accuracy, while the present data show such clear effects may well be related to differences in the number of measurable alternate performances and the types of stimuli used. The ST stimulus in their study was some derivative of number of center-key pecks and/or duration of center-key stimulus. Pentobarbital alters the rate of pecking and therefore most assuredly altered the duration of center-key stimulus for both large and small ratios in their study. Branch [7], using a similar procedure, reported that 6 mg/kg pentobarbital increased center-key rates while 8 mg/kg decreased center-key rates. The effective ST stimulus (perhaps some combination of response-derived and duration-derived internal stimuli) in the Rosenberg and Woods experiment may well have changed in a very direct but complex fashion over the 5.0–15.0 mg/kg dose range used. They report no data to directly confirm this alteration of the ST by the drug. Their finding of a change in sensitivity, however, indirectly confirms such a shift. The lack of clear response bias effects might well result from such a shift in effective STs, since STs which the experimenters refer to as large ratio might, under the drug, fall within the effective range of small ratio stimuli and thus shift the proportion of effective large vs small trials. This shift would have a direct effect on the accuracy and would likely have an indirect, but complex effect on response bias as well.

Though no separate analysis of sensitivity and bias factors is available for the present data, it is unlikely that pentobarbital shifted color sensitivity. The increased tendency to respond to particular incorrect CO-stimuli and/or incorrect CO-side represents an increase in response bias. The use of 5 alternative ST and CO stimuli in the present experiment thus permits a finer resolution of specific, alternative, drug-induced behaviors when compared to the 2 alternative matching procedure of Rosenberg and Woods.

Since the non-drugged performance showed high accuracy, it is tempting to interpret the drug-induced increase in commission errors as a rate-dependent effect. That is, a previously infrequent performance (errors) is increased while a previously frequent performance (correct CO choice) is decreased. Such an assertion would relate the effect of the drug on stimulus control of behavior to the large literature on effects of drugs on schedule-controlled behavior (see [13,14]). In some global sense, this proposal is true. Yet, it should be stressed that of the several available low-rate performances (particular color preferences or avoidances, particular position preference), only some were increased. Further, the degree of increase was not closely related to frequency in the non-drugged performance. Thus, the rate-dependency proposal does not provide a detailed account of these shifts in stimulus control.

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