*PHENCYCLIDINE DISCRIMINATION IN THE
PIGEON USING COLOR TRACKING
UNDER SECOND-ORDER SCHEDULES*

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Pigeons were trained to track different key colors, depending on whether they had been injected with phencyclidine or saline prior to the session. A second-order schedule was used to generate large numbers of responses prior to the initial food delivery. The procedure offers several advantages over traditional procedures for studying drug discrimination.

Key words: drug discrimination, color tracking, second-order schedules, phencyclidine, pigeons

Since the original demonstration by Girden and Culler (1937) that drugs can exert discriminative control over responding, a large literature has developed on the topic (Overton, 1968; Overton & Batta, 1976; Schuster & Balster, 1977; Winter, 1978). A popular design for such studies has been to reinforce responding on one lever in the presence of one drug condition and to reinforce responding on a different lever in the presence of another drug condition. One difficulty with this procedure is that during discrimination training or during tests of stimulus generation, the delivery of a reinforcer can serve as a cue as to which response will be reinforced on subsequent trials (Jenkins, 1965; Kelleher, 1966), which is independent of stimulus control exerted by the drug state. In order to solve this problem, investigators have either used periodic extinction sessions to assess stimulus control by drug states or have used only those responses prior to the first reinforcement in each session (Schuster & Balster, 1977). Both of the procedures may present difficulties. When an extinction procedure is used, failure of responding to produce the reinforcer may also function as a cue. Furthermore, response variability increases during extinction (Antonitis, 1951), which could lead to an apparent loss of stimulus control. Using only the behavior that precedes the first delivery of the reinforcer circumvents some of these problems but pro-

duces other difficulties. If only the first response that the animal makes is considered, the entire evaluation of stimulus control rests on a very small sample of responses. More responses can be measured by using intermittent reinforcement schedules; however, the animal may persist in completing the schedule requirements on one lever once the initial response is made, or may respond on one lever due to cues other than the drug state (Extance & Goudie, 1981).

We have attempted to solve some of these problems by training pigeons to track the location of one color in the drug state and a different color in the nondrug state. By requiring the pigeons to make observing responses that vary the location of the color and by using second-order schedules of reinforcement, many responses were recorded before any cues were provided by the reinforcement schedule. Phencyclidine, which has been shown to function as a discriminative stimulus in rats (Holtzman, 1980; Jarbe, Johansson, & Henriksen, 1975; Overton, 1975), was used as the training drug. A range of doses of phencyclidine was substituted for the training dose once discrimination had been established. Substitution of different doses was done both with traditional substitution methods and with the cumulative dosing procedure recently reported by Wenger (1980).

METHOD

Subjects

Male White Carneaux pigeons, approximately two years of age at the beginning of these experiments and weighing 589 to 703 g

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with free access to food and water, were used in these experiments. The birds were food-deprived to 80% of their free-feeding weights and maintained at these weights throughout the experiments. All birds were experimentally naive at the beginning of the experiments.

Apparatus

The experimental chamber was a Model G-7313 pigeon test cage (Ralph Gerbrands Co.) equipped with three response keys, each of which could be transilluminated with colored lights. The chamber was enclosed inside a Model G7211 sound and light-attenuating enclosure (Ralph Gerbrands Co.). The minimum force required to operate the keys was .05N. A small relay mounted on the chamber operated whenever the key contacts were opened on the two side keys to provide auditory feedback for responses. A houselight illuminated the experimental chamber during the session, except during the feed cycle and the timeout.

Procedure

Pigeons were trained to eat grain from the lighted feeder and then by successive approximations were trained to peck the center key, which was transilluminated with a white light. Each peck produced 4-sec access to grain. Once responding on the center key was established, the reinforcement contingency was changed so that a peck on the white center key extinguished the center key and transilluminated one of the two side keys with a green light. Pecks on the green key produced food. Pecks on the center key or on the darkened side key had no programmed consequences. The location of the green side key varied randomly after each feed cycle. The birds were trained under this schedule for seven sessions.

Ten minutes before the next session, birds were injected intramuscularly with .3 mg/kg phencyclidine hydrochloride in a volume of 1 ml/kg. During this session, pecks on the white center key extinguished the center key and transilluminated one of the two side keys with a red light. A peck on the red key produced food. Pecks on the center key or on the darkened side key had no programmed consequences. The birds were trained under this schedule for seven sessions.

During the next sessions, pecks on the center key extinguished the center key and transilluminated the side keys, one with a red light

and one with a green light. Pecks on the green key produced food if the pigeon had been injected with saline 10 min before the session, and pecks on the red key produced food if the pigeon had been injected with .3 mg/kg phencyclidine 10 min before the session. Pecks on the "incorrect" key produced a 4-sec timeout during which all lights in the chamber were off and key pecks had no programmed consequences. At the end of the timeout, a new trial was signaled by the onset of the houselight and the white key light transilluminating the center key.

After nine sessions under this schedule (five on saline and four on phencyclidine), the schedule was changed so that more than one response was required on the "correct" key. For example, following a saline injection, a peck on the center key lighted the side keys. A peck on either the red or the green key produced a timeout. Food was not produced until the green key had been pecked twice (FR 2 schedule). During subsequent sessions the size of the FR was increased to 10, and the training dose of phencyclidine (PCP) was increased to .6 mg/kg.

After six weeks of training under the schedules described previously, there was only equivocal evidence that a discrimination of the drug state had occurred, so the schedule was changed again. Under the new schedule, a peck on the white center key extinguished the center key and lighted the side keys, one with red light and one with a green light. The pigeons were required to peck a side key five times (red key following drug administration and green key following saline administration). If the bird completed the FR-5 on the "correct" key before completing it on the "incorrect" key, food was produced and a new trial started. If the bird completed the FR 5 on the "incorrect" key first, all key lights were extinguished for .2 sec, after which a new trial started with the transillumination of the center key and onset of the houselight. The location of colors on the side keys varied randomly from trial to trial. During subsequent sessions the number of times that the bird had to complete the FR 5 on the "correct" key was gradually increased to a value of 10, so that in order to obtain food the bird had to complete 10 FR 5s on the green key after saline administration, or 10 FR 5s on the red key after PCP administration before food was given for

the first time. The completion of each FR 5 extinguished all key lights for .2 sec and then lighted the center key, which had to be pecked once before the side keys were lighted again and responses could be made again on the side keys. Completion of the 10th FR 5 on the "correct" key produced 4-sec access to grain. Sessions continued until the birds had received food 10 times. The number of FR 5 components required before food delivery occurred was varied before 10 was set as a permanent value.

Substitution Testing

Once a stable discrimination had been developed, other doses of PCP were administered on Fridays to determine if they would substitute for the training dose of PCP. For these sessions injections were given at the usual time (10 min before the session), but the session continued only until the bird completed 10 FR 5s on one key, at which time food was delivered and the session was terminated. Food delivery was given regardless of which key was the first to have 10 FRs completed on it.

Wenger (1980) recently has reported on a method for determination of cumulative dose-effect curves for drug effects on behavior. In our experiments, an ascending series of doses of PCP was administered to each pigeon during a single session. A .1 mg/kg dose of PCP was administered, the bird was placed in the chamber, and 15 min later the session was initiated. Immediately after the first food presentation occurred, the bird was removed and a second dose was given (.3 mg/kg). Subsequent doses were administered after each food delivery until a dose was reached that eliminated responding for 500 sec, after which the session was terminated and the procedure repeated with another bird. Similar substitution experiments were performed with *d*-amphetamine.

Drugs

Phencyclidine was administered as the hydrochloride and *d*-amphetamine as the sulfate.¹ All doses were calculated as the salts and administered into the breast muscle in a volume of 1 ml/kg of body weight. Saline (.9%) was used as the injection vehicle.

RESULTS AND DISCUSSION

Under the final schedule, clear discrimination of the drug state occurred in three birds after five weeks of training and in all five birds after eight weeks of training. Figure 1 shows performance of four of the five birds during the final four sessions prior to the beginning of substitution testing. Birds 61, 58, and 59 were making few errors at this time; Bird 60 made some errors, although obviously this bird also discriminated the drug state. During these sessions response latencies on the observing key and rates of responding on the choice keys did not differ systematically following PCP and saline. Data from Bird 62 are not shown in the figure due to experimental errors (see next paragraph).

In two instances during training, PCP was injected into Bird 62, but the programming equipment accidentally was set to reinforce responses on the saline key. The bird persisted in responding on the PCP key during these

Fig. 1. Performance under the second-order color tracking procedure following phencyclidine administration (P, unfilled points) or saline administration (S, filled circles). Ordinate: percent of FRs completed on the PCP key. Abscissa: four consecutive sessions just prior to substitution sessions. Values are means for an entire session in individual birds.

¹Phencyclidine was provided by the National Institute on Drug Abuse and *d*-amphetamine was provided by Smith Kline and French, Inc.

sessions. For example, Bird 62 completed more than 70 ratios on the PCP key before completing 10 ratios on the saline key the first time this experimental error occurred. Similarly, during one session Bird 61 was injected with saline, but the programming equipment was set to reinforce responses on the PCP key. Bird 61 completed 184 ratios on the saline key and only one on the PCP key before the session was terminated. Although these experimental errors slowed the training process by temporarily disrupting performance, they demonstrate powerfully the high degree of control of the drug state over behavior.

During the final phase of these experiments, other doses of PCP were substituted for the training dose before Friday sessions in four of the five birds. These data are shown in Figure 2 (filled points). The .1 mg/kg dose of PCP did not substitute for the training dose (.6 mg/kg) in any of the birds. The .3 mg/kg dose of PCP substituted for the training dose in Birds 61 and 59, whereas this dose resulted in responding on both keys for Bird 60. The 1.0 mg/kg dose of PCP substituted for the training dose of PCP in all birds, although Bird 59 did do some responding on the saline key after this dose. When birds were studied four hours after administration of the 1.0 mg/kg dose (filled triangles), one bird responded only on the saline key, whereas the other three birds responded on both keys.

The data for the cumulative dosing with PCP are also shown in Figure 2 (unfilled points). For Birds 60 and 61, the cumulative dose-effect curve was almost identical to the original PCP dose effect curve. For Bird 58, the cumulative dose effect curve was shifted to the left and for Bird 59, it was shifted to the right. The mean cumulative dose-effect curve was almost identical to the original mean dose-effect curve for PCP.

A cumulative dose-effect curve also was done for *d*-amphetamine (data not shown). At doses of *d*-amphetamine that did not eliminate responding (.1 to 1.0 mg/kg), all birds responded on the saline key.

These experiments establish that pigeons can be conditioned to follow the location of a color from one response key to another using only the presence or absence of a drug state as a discriminative stimulus to determine at which key color responses will produce the reinforcer. Certain features of the procedure

Fig. 2. Dose-effect curves for PCP. Abscissa: dose, log scale. Ordinate: percent of FRs completed on the PCP key following various PCP doses. Brackets at C show the range of percentages of the FRs completed on the PCP key after the training dose and after saline. Birds 58 and 61 made all responses on the green key (saline key) after saline injections. Filled points show the PCP dose-effect curve when single PCP doses were substituted during a session. Unfilled points show the PCP dose-effect curve with the cumulative dosing procedure. The upper four frames show individual birds and the lowest frame shows the group dose-effect curve.

may represent a methodological advance in the study of the discriminative stimulus properties of drugs.

First, use of the second-order schedule permits the measurement of a considerable amount of behavior before the delivery of food. If only data prior to the first delivery of food are considered, the bird receives no cues from the reinforcement schedule as to which color is correlated with delivery of the reinforcer. The only available cue is the presence or absence of the drug state. Nevertheless, a considerable amount of behavior is available for analysis. If individual key pecks are considered, at least 50 responses must be completed before food is available. If the FR 5 components of the second-order schedule are

considered, at least 10 of these units must be completed before food delivery. At the end of each unit, the bird must return to the center key to make an observing response and then respond on the appropriate color side key. Thus, the bird must repeatedly choose a color on the basis of the drug state.

Another advantage of the procedure is that the bird is not likely to move into one preferred position to respond until food is delivered. The requirement of movement from the side key to the observing key prevents the bird from responding at a given position throughout the session. A chaining of center-key responding to responding at a given side key position is not favored by the reinforcement schedule. For optimal reinforcement density, the bird must attend to the colors of the side keys after the observing response.

Finally, the cumulative dosing procedure allows the rapid generation of dose-effect curves during generalization testing. It is possible to generate entire dose-effect curves during a single session. This may be of particular advantage in experiments where the degree of stimulus control changes over time, such as might occur in experiments on drug tolerance.

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