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A Comparison of Interoceptive and Exteroceptive Discrimination in the Pigeon

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McMILLAN, D. E., W. D. WESSINGER, M. G. PAULE AND G. R. WENGER. *A comparison of interoceptive and exteroceptive discrimination in the pigeon.* PHARMACOL BIOCHEM BEHAV **34**(3) 641–647, 1989.—In pigeons performing a conditional discrimination under a second-order, color-tracking procedure, stimulus control of responding was established using a blinking versus a nonblinking light as exteroceptive stimuli (light-discrimination group). Another group performing under the same second-order schedule of reinforcement was trained to discriminate the interoceptive stimuli produced by an IM injection of 1.5 mg/kg phencyclidine (PCP) versus saline (drug-discrimination group). In the drug-discrimination group, administration of PCP or pentobarbital resulted in dose-dependent increases in PCP-appropriate responding, while, in general, *d*-amphetamine did not result in appreciable drug-appropriate responding. In the light-discrimination group, all three drugs over the same dose ranges resulted in decreased discriminative control over responding. In both groups, doses of PCP and pentobarbital which resulted in intermediate (30 to 70%) levels of stimulus-appropriate responding were associated with responding at a single key position rather than tracking a key color. In contrast, intermediate responding after *d*-amphetamine administration was not associated with position responding in either group. These results emphasize the similarity between discriminative control maintained by interoceptive drug stimuli and exteroceptive visual stimuli.

Operant behavior Exteroceptive stimulus control Interoceptive stimulus control Drug discrimination
Symbolic, matching-to-sample Position responding Pigeons

RECENTLY there has been a surge of interest in the discriminative stimulus properties of drugs (24). The procedures and concepts used in drug discrimination experimentation resemble the more traditional discrimination studies in which stimuli arising from the environment, such as lights or tones ("exteroceptive stimuli"), come to control behavior. In drug discrimination experiments, the drugs themselves serve as the stimuli (4) and, at least for psychoactive drugs, the discriminative cue or cues are believed to arise within the central nervous system (2). Since drug stimuli arise from within the subject, these stimuli have been termed "interoceptive stimuli."

In previous reports (18,19) it was suggested that the discriminative-stimulus properties of drugs could interact with other behavioral effects of the drugs to modify stimulus control by these drugs. In those studies, pigeons were trained to track the location of a red- or green-key color, dependent on whether phencyclidine (PCP; red key) or saline (green key) had been administered before the session. Under this procedure, after intermediate doses of PCP, the birds frequently confined most of their responses to a particular response location rather than tracking the location of a particular color. Since the colors appeared randomly at each of two key locations, responding occurred to both colors and eventually produced a reinforcer even when the bird responded only at one location ("position responding"). The occurrence of position responding usually resulted in an intermediate level (i.e., 30–70%) of drug-appropriate key responding. Usually, when subjects divide their responses between the drug and the saline keys in drug discrimination experiments, the proportion of responses on the drug key is assumed to reflect the degree of stimulus control exerted by the drug. Such an assumption may not be tenable when drug-induced position responding is responsible for the observed pattern of responding.

The present experiments attempted to differentiate between the discriminative stimulus effects of PCP and its effects on behaviors used to measure stimulus control. This was done by establishing stimulus control over responding using exteroceptive discriminative stimuli, a blinking versus a nonblinking key light, under experimental conditions that were similar to the drug discrimination procedure where PCP versus saline served as interoceptive discriminative stimuli. The effects of drugs on stimulus control by

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the exteroceptive stimulus could then be compared with the effects of these same drugs on stimulus control in the drug discrimination procedure. Studies using exteroceptive stimulus control presumably measure the effects of drugs on stimulus control only. In contrast, studies using animals trained to discriminate drug stimuli measure both the effects of a drug as a discriminative stimulus as well as the effect of that drug on stimulus control.

METHOD

Subjects

For the drug discrimination experiments, five male White Carneaux pigeons weighing between 590 and 675 g at the beginning of these experiments were used. These birds had previously been used for other drug discrimination experiments and had been tested with a variety of psychoactive drugs (14–19). For experiments of exteroceptive stimulus discrimination, five experimentally naive male White Carneaux pigeons weighing between 525 and 600 g at the beginning of these experiments were used. During the experiments all subjects were maintained at 80% of their free-feeding weight by restricted postsession feeding of mixed grain. They were individually housed in a room maintained under a 12-hour normal phase lighting cycle. Tap water and oyster grit were freely available in the home cages.

Apparatus

Standard pigeon operant test chambers (Model G-7313, Gerbrands Corp., Arlington, MA), housed inside light- and sound-attenuating enclosures (G-7211, Gerbrands Corp.), equipped with a fan for air circulation were used. Three translucent pigeon keys (G-6315, Gerbrands Corp.), which could be transilluminated with colored lights, were arranged horizontally in each test chamber 20 cm above the grid floor. Centered below was an opening through which mixed grain could be presented by a grain magazine (G-5610, Gerbrands Corp.) when schedule contingencies were met. Effective key peck responses produced auditory feedback from a relay mounted on the outside of the chamber. The test chambers were illuminated by two houselights (28-V DC) which remained lighted during experimental sessions, except during feed cycles when only the grain hopper was illuminated. White noise was supplied continuously to the room housing the behavioral chambers. Schedule contingencies and data collection were programmed by microcomputers (TRS-80, Model III, Radio Shack) using interfaces (Microcomputer Interface II, MED Associates, Inc., East Fairfield, VT). Real-time records of behavior were recorded by cumulative recorders (Model C-3, Gerbrands Corp.) located in an adjacent room.

Procedures

Discrimination training. The training of the pigeons used in the drug discrimination experiments has been described previously (14,16). Briefly, the pigeons were trained to discriminate 1.5 mg/kg PCP from saline. The schedule of reinforcement used to maintain behavior was a second-order schedule, described by Kelleher (11) as a fixed-ratio10(fixed-ratio5) or FR10(FR5). The training dose of PCP or saline was administered IM and the bird was placed into the chamber. The session began after a 10-min pretreatment period during which the chamber was dark and responses were not counted. At the start of the session, the houselight and center key light (white) were illuminated. A single response to the white center key extinguished it and illuminated the two side keys, one with a red light and one with a green light. To obtain access to mixed grain (8 sec) the pigeons were required to track the location and respond upon either the red or green side key under the second-order schedule, depending on whether PCP (red key correct) or saline (green key correct) had been administered prior to the session. Completion of five responses on either side key [the FR5 unit of the second-order schedule; FR10*(FR5)*] extinguished the side keys and relighted the center key to return the original condition. The position of the red and green side keys varied randomly after each center-key response. Mixed grain was presented only after ten FR5 units [i.e., *FR10*(FR5)] had been completed on the key color appropriate for the training stimulus conditions. The training sessions terminated after six mixed-grain presentations or 20 min, whichever occurred first.

In the pigeons trained to discriminate an exteroceptive stimulus we attempted to establish exteroceptive stimulus control using the same schedule [FR10(FR5)] used for the drug discrimination subjects described above. These pigeons had an extensive training history due to difficulties encountered in establishing conditional exteroceptive stimulus control using several visual and auditory stimuli. Under the final training conditions, the birds were conditioned to discriminate the presence of a blinking (0.8 sec on, 0.2 sec off) versus a nonblinking white light on the center key. To keep the procedure analogous to the drug discrimination training procedure, where drug (1.5 mg/kg PCP) was either present or absent during the entire session, the blinking or nonblinking center-key light remained on during the entire session. Sessions began after a 10-min presession period during which the chamber was dark and responses were not counted. The session began with the illumination of the houselight and center-key light. As in the drug discrimination experiments, a single response to the blinking or nonblinking center key turned on the side keys, one red and the other green, however, the stimulus conditions on the center key remained present. The position of the red and green side-key stimuli varied randomly with each presentation. Five effective key pecks to either side key extinguished the side keys returning the original condition of only the center key being lighted. When the center key was blinking, only responses on the red key were reinforced, and when the center key was not blinking, only responses on the green key were reinforced. As with the drug discrimination experiment, under this second-order FR10(FR5) schedule, the pigeons were required to complete ten FR5 units on the appropriate side key to produce 8-sec access to mixed grain during training sessions.

These discrimination procedures could, alternatively, be described as a simultaneous, symbolic, matching-to-sample paradigm [see (5) for review]. Using this terminology to describe the procedures, the presence or absence of drug would be considered the sample stimuli for the interoceptive discrimination group, and the blinking or nonblinking center-key light would be the sample stimuli for the exteroceptive discrimination group. The red or green side-keys would be considered the symbolic matches or choice stimuli for the appropriate interoceptive or exteroceptive sample stimuli. Although these procedural descriptions are also appropriate, this paper will continue to discuss the procedures using terminology more typical of discrimination paradigms.

Drug testing. Testing of drug effects was conducted in the same manner for both the interoceptive and exteroceptive discrimination groups. After stimulus control was established, training of both experimental groups continued on Monday through Wednesday or Thursday. Drug tests were conducted on Thursdays or Fridays if stimulus control was maintained on the preceding training days. In order to test drug effects, cumulative-dosing procedures [e.g., (15)] were used. This procedure had the advantage that dose-effect curves for an individual subject could be determined within a single session. The test sessions were divided into multiple response periods (a total of 4 response periods/test session). Increasing doses of drug (in one-quarter or one-half log unit increments) were administered before each response period. Thus, each response period was preceded by an IM injection

which was followed by a 10-min pretreatment period before the houselights and key lights were illuminated. During the response period, the completion of ten FR5's on *either* key color was reinforced. Immediately after food delivery, the bird was removed from the chamber, given another injection, placed back into the chamber and 10 min later another response period ensued. Repetitions of the procedure continued until a cumulative dose was reached that disrupted responding such that the pigeon did not obtain food within 10 min, or until a predetermined maximum cumulative dose was reached. In addition to drug testing, 4 consecutive saline injections (1 ml/kg) were tested in an analogous fashion in order to insure that a particular pattern of responding did not develop as a result of the multiple-trial testing procedure. Cumulative dose-effect curves were determined for PCP (0.3–1.7 mg/kg), *d*-amphetamine (0.3–3.0 mg/kg) and pentobarbital (3.0–17.0 mg/kg). For the exteroceptive light discrimination experiments the order of drug testing was PCP, *d*-amphetamine, then pentobarbital, with a dose-effect curve for each drug being determined first when the center key light was blinking and then under the nonblinking stimulus condition. For the interoceptive drug discrimination group the order of testing was PCP,*d*-amphetamine, then pentobarbital; then these dose-effect curves were redetermined. Thus, for both groups, each dose-effect curve was determined twice in each subject. In addition to drug testing, for both groups, the effects of successive saline administrations were determined before any drug tests were conducted, and again after all drug testing had been completed.

Data analysis. Data from test sessions were analyzed in terms of drug effects on the percent of total responses occurring on the PCP-appropriate key (drug discrimination group) or the correct exteroceptive stimulus-appropriate key (light discrimination group). Drug effects on side-key response rate (responses/sec), which refers to only side-key (both red and green) responding with the observing-key response latencies and reinforcement time omitted, are also presented. Data were calculated for individual subjects and are presented as the mean and standard error of the mean calculated for the group. When responding during a 10-min response period was not sufficient to result in food presentation, the percent PCP-appropriate or percent correct responses were not included in the average; however, all response rate values were used. Group means for percent correct responses and percent PCP-appropriate responses were not plotted unless sufficient responses were emitted for food presentation on 40% of the occasions that a particular dose was studied. For analysis of position responding, that is, the tendency for the subjects to adopt a strategy of responding on only one of the two side keys, the percent of responses occurring on the "preferred key" (i.e., the key on which greater than 50% of the responses were made) was determined.

Drugs. Phencyclidine hydrochloride (National Institute on Drug Abuse, Rockville, MD), pentobarbital sodium (Sigma Chemical Co., St. Louis, MO) and *d*-amphetamine sulfate (Sigma Chemical Co.) were dissolved in 0.9% physiological saline to concentrations allowing an injection volume of 1 ml/kg and administered IM into a breast muscle. Physiological saline was also used for the consecutive saline injections. Each successive injection was into muscle on alternate sides of the breast. Doses are expressed as mg/kg and refer to the salt. Doses shown in the figures are the total dose administered (e.g., where 0.56 mg/kg of PCP is indicated, this represents the first response period dose of 0.3 mg/kg plus the subsequent second response period dose of 0.26 mg/kg for a total test dose of 0.56 mg/kg, etc.).

RESULTS

Figure 1 shows the effects of successive administration of saline and cumulative doses of PCP, pentobarbital and *d*-amphetamine on stimulus control maintained by PCP (upper panel) and on response rate (lower panel) in birds trained to discriminate PCP from saline. Successive saline administrations did not result in appreciable PCP-appropriate responding and did not affect response rate. The overall average response rate for the group for the saline sessions was 1.52 responses/sec. With increasing doses of PCP there was a dose-dependent increase in percentage of responses on the PCP-appropriate key. The highest cumulative dose of PCP, 1.7 mg/kg, decreased response rate by about 50% (compared to the effects of successive doses of saline) and after this dosage subjects were not reinforced on 4 of the 10 occasions that this dose was tested. Pentobarbital, at doses of 3.0–10.0 mg/kg, resulted in a nearly equal distribution of responses on the PCP and saline keys, but at the highest dose tested (17.0 mg/kg) the birds responded primarily on the PCP-appropriate key (group average, 79%). This dose decreased response rate by about 60% and one bird did not respond at all on the two occasions when tested at this dose. Doses of *d*-amphetamine resulted in responding primarily on the saline key. The two highest doses of *d*-amphetamine (1.7 and 3.0 mg/kg) resulted in decreased response rates. At

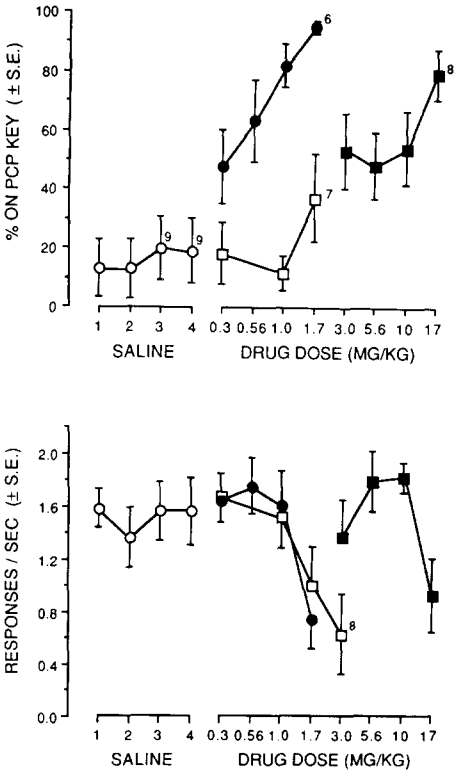

FIG. 1. Effects of successive saline administrations (open circles) and dose-effect curves for cumulative doses of PCP (closed circles), pentobarbital (closed squares) and *d*-amphetamine (open squares) in pigeons trained to discriminate interoceptive stimuli (1.5 mg/kg PCP from saline). The mean percent PCP-appropriate responding (upper panel) and mean side-key response rate (lower panel) are on the ordinates with the cumulative drug dose (log scale) or number of successive saline injections shown on the abscissa. The vertical lines indicate the standard errors. The effects of each treatment were usually determined 10 times (2 determinations in each of 5 pigeons), except where indicated by number in the lower panel. When responding during a response period did not result in reinforcer delivery, the percent PCP-appropriate responding data was excluded from the mean calculation (each point is the mean of 10 values unless indicated by number, upper panel). Points where subjects obtained reinforcer on fewer than 40% of the trials are not shown in the upper panel.

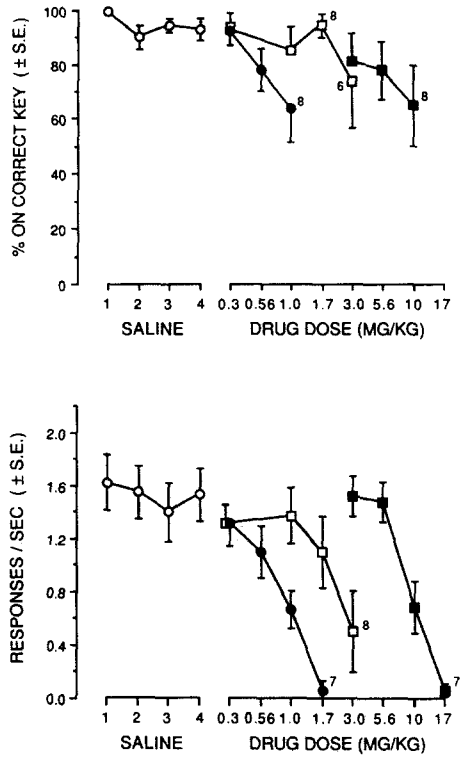

FIG. 2. Effects of successive saline administrations (open circles) and dose-effect curves for cumulative doses of PCP (closed circles), pentobarbital (closed squares) and *d*-amphetamine (open squares) in pigeons trained to discriminate exteroceptive stimuli (blinking from nonblinking light). The mean percent stimulus-appropriate responding (upper panel) and mean side-key response rate (lower panel) are on the ordinates with the cumulative drug dose (log scale) or number of successive saline injections shown on the abscissa. The vertical lines indicate the standard errors. The effects of each treatment were usually determined 10 times (2 determinations, once with the nonblinking light stimulus and once with the blinking light stimulus, in each of 5 pigeons), except where indicated by number in the lower panel. When responding during a response period did not result in reinforcer delivery, the percent on correct key data was excluded from the mean calculation (each point is the mean of 10 values unless indicated by number, upper panel). Points where subjects obtained reinforcers on fewer than 40% of the trials are not shown in the upper panel.

3.0 mg/kg responding was disrupted to the extent that reinforcement resulted on only 3 of the 8 occasions this dose was tested, however, those two subjects distributed an average 79% of their responses on the PCP-appropriate key.

The effects of these same drugs on exteroceptive stimulus control maintained by the presence of the blinking or nonblinking light are shown in the upper panel of Fig. 2 and the lower panel shows the effects on response rates. Successive saline injections did not affect exteroceptive stimulus control or response rate. The overall average response rate for sessions when saline was administered to the group discriminating exteroceptive stimuli was the same as the overall average session response rate under these conditions in birds trained to discriminate PCP from saline (1.52 responses/sec). PCP resulted in dose-dependent decreases in correct key selection and dose-dependent decreases in response rate. At the highest dose tested, 1.7 mg/kg, the number of responses emitted was insufficient to result in reinforcer delivery except in 1 of the 7 occasions this dose was tested. The results with pentobarbital were similar. For both PCP and pentobarbital response rate was affected to a greater degree and at lower doses than was observed in birds trained to discriminate PCP from saline. *d*-Amphetamine also disrupted stimulus control by the blinking or nonblinking light stimulus, but only at the highest dose tested (3.0 mg/kg). The dose-dependent suppression of response rate was similar to that observed in the birds trained to make interoceptive drug discriminations.

Table 1 shows the degree of position responding which occurred when responding was distributed on both key colors (i.e., when stimulus control was low). When only 30 to 70% of the responses occurred on the correct key (light discrimination) or on the PCP-appropriate key (drug discrimination) there was a strong tendency for the subjects to respond primarily at one key location (the "preferred key") after PCP or pentobarbital. At these "intermediate levels of generalization" both the light discrimination and the drug discrimination birds often distributed greater than 80% of their responses on the preferred key (identified by the single asterisks in Table 1). This tendency to respond on the preferred key was also often two or more standard deviations greater than the key preference exhibited under saline conditions (denoted by the dagger in Table 1). In contrast, in instances when there was a loss of stimulus control following *d*-amphetamine administration, it was not associated with position responding in either the exteroceptive or interoceptive discrimination groups. Similarly, in those few instances when saline administration resulted in a loss of stimulus control (i.e., when the percent stimulus appropriate responding was between 30 and 70%), position responding (i.e., selection of the preferred key >80%) did not occur.

DISCUSSION

The present experiments suggest that behavior maintained by interoceptive conditional discriminative stimuli can be affected by drugs in much the same way as behavior maintained by exteroceptive conditional discriminative stimuli. In the present experiments, increasing doses of PCP or pentobarbital disrupted the exteroceptive stimulus control that a blinking or nonblinking light maintained over responding. At least one mechanism by which the discrimination was disrupted by PCP and pentobarbital was through the production of position responding. Position responding was also observed when doses of PCP or pentobarbital resulted in intermediate levels (i.e., 30–70%) of PCP-appropriate responding in subjects trained to discriminate the presence or absence of an interoceptive stimuli, 1.5 mg/kg PCP. The production of position responding in conditional discriminations is not, however, an inevitable effect of all drugs. In previous experiments, position responding was observed following PCP or pentobarbital, but not *d*-amphetamine administration (18,19). Similar results were also obtained in the present experiments where *d*-amphetamine did not produce appreciable PCP-appropriate responding in PCP-trained subjects, but did decrease response rate in a dose-dependent manner. In the exteroceptive discrimination subjects, *d*-amphetamine disrupted stimulus control maintained by the light and also decreased response rate, effects which were similar to those of PCP or pentobarbital in these subjects. However, *d*-amphetamine administration again did not result in the production of position responding. It is interesting to note that *d*-amphetamine produces stereotyped behavior in a variety of other operant situations (13,22), since position responding might be considered a form of stereotyped responding.

Other investigators have also compared the properties of drugs as interoceptive conditional discriminative stimuli with the properties of exteroceptive conditional discriminative stimuli. The rate of acquisition of conditional discriminative stimulus control over

TABLE 1

POSITION RESPONDING AFTER DRUGS[a] OR SALINE IN PIGEONS TRAINED TO DISCRIMINATE EXTEROCEPTIVE STIMULI (LIGHT DISCRIMINATION) AND IN PIGEONS TRAINED TO DISCRIMINATE INTEROCEPTIVE STIMULI (DRUG DISCRIMINATION)

	Light Discrimination Group				Drug Discrimination Group			
Drug	Bird	Dose (mg/kg)	% Correct	% Preferred Key	Bird	Dose (mg/kg)	% PCP Key	% Preferred Key
Phencyclidine								
	P139	0.3[b]	62	80*	P59	0.3[b]	49	98*†
		0.56[b]	62	100*†	P60	1.0[c]	46	97*†
		1.0[b]	53	94*†	P61	0.3[c]	41	62
		1.0[c]	61	52	P62	1.0[b]	59	82*
	P140	0.56[c]	31	81*†		1.0[c]	45	100*†
	P141	0.3[b]	61	64				
		0.56[b]	60	84*				
	P142	0.56[c]	58	78†				
		1.0[c]	44	100*†				
	P143	1.0[b]	53	100*				
Pentobarbital								
	P139	3.0[b]	63	63	P58	17.0[b]	63	94*†
		5.6[b]	60	73	P59	3.0[b]	58	99*†
		10.0[b]	58	83*		10.0[b]	59	88*
		3.0[c]	67	80*	P60	5.6[b]	38	100*†
	P141	5.6[b]	60	80*		10.0[b]	67	93*†
	P142	5.6[c]	55	95*†		5.6[c]	41	100*
	P143	10.0[c]	30	68	P61	5.6[b]	47	63
					P62	17.0[b]	58	82*
						17.0[c]	38	100*†
d-Amphetamine								
	P139	0.3[b]	38	56	P61	1.7[b]	44	58
	P141	1.7[c]	67	61		3.0[b]	64	72
	P142	3.0[c]	43	66		0.3[c]	68	60
						1.0[c]	57	76
Saline[d]								
	P139		90 ± 11	62 ± 12	P58		7 ± 8	57 ± 6
	P140		92 ± 13	62 ± 9	P59		0 ± 1	65 ± 13
	P141		89 ± 14	69 ± 15	P60		8 ± 14	66 ± 12
	P142		99 ± 3	60 ± 8	P61		6 ± 13	66 ± 8
	P143		100 ± 1	71 ± 16	P62		57 ± 46	67 ± 14

[a]Data are included for drugs only when 30 to 70% of the responses were on the correct key (light discrimination) or the PCP key (drug discrimination).

[b]Data from the first determination of the dose-effect curve.

[c]Data from the second determination of the dose-effect curve.

[d]Saline data are means ± S.D. for all 8 observations.

*Eighty percent or more of the responses occurred at one key position.

†The percent responding on the preferred key was 2 or more S.D.s greater than the individual subject's mean following saline administrations.

behavior does not seem to depend upon the "source" (i.e., interoceptive versus exteroceptive) of the stimuli, but rather depends upon other characteristics of the stimuli itself. Investigators have found that interoceptive drug stimuli were more effective than exteroceptive stimuli (20,23), less effective than exteroceptive stimuli (7), or equally effective (12,21), in establishing stimulus control. Like the effects seen when exteroceptive stimuli are quantitatively varied in intensity, the strength of the behavioral control maintained by interoceptive drug stimuli are dependent upon drug dose [e.g., (23)]. Thus, in experiments in which subjects were trained to discriminate combined interoceptive and exteroceptive stimuli, the relative strength of interoceptive drug stimuli was shown to vary with dose (6, 9, 10). There is little evidence in these studies to suggest that behavioral control maintained by exteroceptive stimuli is intrinsically different from that maintained by interoceptive stimuli.

In the present study there were differences in the effects of PCP and pentobarbital on response rate between pigeons trained to discriminate a blinking from a nonblinking light and those trained to discriminate PCP from saline. The exteroceptive group was more sensitive to the response rate-decreasing effects of these drugs than was the drug discrimination group. This difference in sensitivity between the two experimental groups did not extend to *d*-amphetamine. One explanation for these differences could be that the animals trained to discriminate PCP from saline developed tolerance to the rate-decreasing effects of PCP and pentobarbital due to their long history of treatment with PCP for drug discrimination training and testing. If this were the case, however,

tolerance must have developed differentially to the response rate-decreasing effects since tolerance did not appear to develop to the discriminative stimulus properties of PCP. This is evidenced by the fact that the PCP generalization dose-effect curves determined in the present study were essentially the same as those generated in these same subjects on several other occasions over a five-year period (15). Even following a 60-day period during which these subjects received no training or drug treatments the generalization dose-effect curve for PCP was unchanged, thus any tolerance which might have developed did not diminish during this period of nontreatment (15). If tolerance did develop to PCP's effects on response rate, but not to its discriminative stimulus effects, then the possibility that a similar cross-tolerance developed to pentobarbital, but not *d*-amphetamine must be considered. While a number of published studies have investigated tolerance to PCP [see (1) for review] few have examined cross-tolerance between PCP and barbiturates or amphetamines. Wenger (25) did not find evidence of cross-tolerance between PCP and pentobarbital in pigeons responding on a multiple fixed-ratio, fixed-interval (mult FR, FI) schedule of food presentation following 35 days of chronic PCP. Brocco *et al.* (3) also failed to demonstrate cross-tolerance between PCP and pentobarbital or *d*-amphetamine in rats responding on a food maintained mult FR, FI schedule following 84 consecutive days of PCP exposure. In contrast, Flint and Ho (8) demonstrated cross-tolerance between PCP and pentobarbital in mice treated with PCP for 7 days and tested using the barbiturate-induced sleeping time assay. Whether tolerance to the effects of PCP and pentobarbital on response rate can explain the differences in the response-rate dose-effect curves between the interoceptive and exteroceptive groups remains unclear. Another possible explanation of the different effects observed could be attributed to differences in the degree of stimulus control associated with the stimuli that direct the behavior of the two groups. If, for example, the stimulus control associated with the discrimination of the exteroceptive stimuli were "weak" relative to that associated with differential responding in the drug discrimination group, then one might expect responding to be more susceptible to disruption by drug effects in the exteroceptive group. However, the effects of *d*-amphetamine on response rate were similar for the two groups. This might not be expected if differences in the degree of stimulus control were responsible for the differing sensitivity of the two groups for the effects of PCP and pentobarbital on response rate. Unfortunately, the strength of stimulus control was not directly measured in the present studies.

This study was an attempt to examine the similarities and differences in the effects of drugs in animals trained to discriminate interoceptive stimuli (drug discrimination) and in animals trained to discriminate exteroceptive stimuli (light discrimination). It is difficult to separate the effect a drug has on an operant task used to measure behavior from its effects on the ability to discriminate between stimuli. Nevertheless, there is little evidence that discriminative stimulus control maintained by drugs differs fundamentally from such control maintained by exteroceptive stimuli. The similar effects of PCP, pentobarbital or *d*-amphetamine on the discriminative stimulus properties of PCP and on the discriminative stimulus properties of lights emphasizes the similarity of the drug discrimination procedure to other discrimination procedures.

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