**EFFECTS OF CHLORDIAZEPOXIDE AND
d-AMPHETAMINE ON RESPONDING SUPPRESSED
BY CONDITIONED PUNISHMENT**

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Key pecking by two pigeons, maintained under a variable-interval two-minute schedule of food presentation, was suppressed when each response produced a five-second visual stimulus that was occasionally paired with shock. Stimulus-shock pairings occurred independently of responding according to a variable-time six-minute schedule for one bird or once per session for the other bird. The effects of chlordiazepoxide and *d*-amphetamine were assessed on this baseline of behavior suppressed by conditioned punishment. Chlordiazepoxide produced dose-related increases in the rate of punished responding, whereas *d*-amphetamine produced only decreases. In addition, chlordiazepoxide produced dose-related increases in response rate during the response-produced and response-independent stimulus presentations; *d*-amphetamine, however, only decreased responding during stimulus presentations.

Key words: conditioned punishment, punishment, conditioned suppression, chlordiazepoxide, *d*-amphetamine, pigeons

In several experiments it has been shown that barbiturates and minor tranquilizers such as chlordiazepoxide produce increases in punished responding while morphine, the phenothiazines, and the amphetamines tend only to decrease further responding suppressed by punishment (McMillan, 1975). However, gross generalizations can be misleading, since it has also been shown that the effects of drugs on punished responding can be influenced by a host of variables (McKearney & Barrett, 1978; McMillan, 1975).

Relatively little attention has been directed toward the role of the type of punishing stimulus in determining drug effects on punished behavior. With the exception of a few studies in which the presentation of quinine-adulterated water (Margules & Stein, 1966) or pressurized air (Spealman, 1979) served as the punishing event, most experiments on the effects of drugs on punished responding have used electric shock as the punishing stimulus. Stimuli such as blasts of pressurized air and quinine-adulterated water share characteristics similar

to electric shock in that, under certain conditions, they have been demonstrated to reduce responding without a prior history of conditioning. Under these conditions, they may be referred to as unconditioned punishers.

It should be possible to employ stimuli that reduce responding by virtue of their prior association with unconditioned punishers. Following the convention of conditioned reinforcement, Hake and Azrin (1965) have termed such procedures conditioned punishment. Although the development of conditioned punishment can be accomplished by the pairing of a stimulus and unconditioned punisher, another procedure, referred to as timeout, is often classified as conditioned punishment (Azrin & Holz, 1966). Timeout involves the response-produced presentation of a stimulus in the presence of which reinforcement does not occur. Several studies have examined the effects of drugs on responding suppressed by timeout (Branch, Nicholson, & Dworkin, 1977; McMillan, 1967).

In the Branch et al. (1977) study, the effects of pentobarbital on responding suppressed by electric shock were compared with those on response-produced timeout. Intermediate doses of pentobarbital increased responding suppressed by electric shock, but had little or no effect on responding suppressed by timeout presentations or on unpunished responding. The authors concluded that pentobarbital has

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selective punishment-attenuating properties that depend on the nature of the punisher.

At present, there are no published studies on the effects of drugs on responding suppressed by a response-produced stimulus that is occasionally paired with electric shock. By pairing a response-independent stimulus with shock, Hake and Azrin (1965) have demonstrated a method for maintaining the effectiveness of a conditioned punisher over extended periods of time. The procedure produces a uniform and stable baseline of behavior that is not only valuable for behavioral analysis, but also for pharmacological studies.

The present experiment was designed to determine the effects of a range of doses of chlor-diazepoxide and *d*-amphetamine on responding suppressed by conditioned punishment. The conditioned punisher was established through the use of the Hake and Azrin (1965) procedure with slight modifications.

METHOD

Subjects

Two adult White Carneaux pigeons were maintained at 80% of their free-feeding weights. Both subjects were experimentally naive at the start of the experiment and were trained to key peck using the method of successive approximations. Neither subject had previously received drugs.

Apparatus

Experimental sessions were conducted in a single-key pigeon chamber (27 by 30.5 by 26 cm) enclosed within a ventilated, sound-attenuating enclosure supplied with white noise. A response key (R. Gerbrands Co.) was centered 22 cm above the floor and was mounted behind a 2-cm diameter opening on the front wall. The key could be transilluminated by separate pairs of 7-W colored lamps. Directly below the key, a 4.5 by 5-cm opening provided access to grain. A peck on the key with a minimum force of .15 N provided an audible click of a relay mounted behind the front wall and was recorded as a response. Food availability was programmed on a punched tape and timing was interrupted when food was made available. During 5-sec presentations of food, white lights illuminated the grain magazine while the keylight was extinguished. Shock (110 V ac, 200 msec) was delivered through series resis-

tance to gold electrodes implanted around the pubis bones (Azrin, 1959). Shock intensity was monitored constantly by a Simpson model #1257 alternating current meter. A phone jack connected to a swivel located at the top of the chamber was plugged into a receptacle secured on the pigeon's back by a vinyl harness. The electrical resistance of each bird was checked periodically throughout the experiment. Scheduling and recording equipment were located in an adjoining room.

Procedure

Both pigeons initially responded under a variable-interval (VI) 2-min schedule of food delivery. Under this procedure, key pecking in the presence of a green key-light stimulus produced food on the average of once every 2 min (constant probability VI, Catania & Reynolds, 1968). The VI 2-min schedule remained in effect throughout all subsequent phases.

During the next phase each response produced a change in key color from green to red for 5 sec; responses occurring during the 5-sec stimulus had no effect on its duration. Following several sessions, presentations of the response-dependent stimulus were discontinued and response-independent stimulus presentations were introduced. During this procedure, a 5-sec change in key color from green to red occurred, independent of responding, on the average of once every 6 min (variable-time or VT 6-min schedule). Both of these procedures allowed for the assessment of any suppressive effects of the response-dependent and response-independent stimulus due to novelty.

Next, shock was presented at the termination of the response-independent stimulus (conditioned suppression). Shock intensity was 3 mA for P-890 and 4 mA for P-2305.

The conditioned-punishment procedure was introduced after the conditioned-suppression procedure had been in effect for approximately 20 sessions. During the first several sessions under the conditioned-punishment procedure, both birds responded under the VI 2-min schedule of food presentation, each response produced the 5-sec response-dependent stimulus, and response-independent stimulus presentations followed by shock occurred on the VT 6-min schedule. However, because rates were very low in the beginning of each session for P-890, an effect similar to that noted previously (Azrin, Holz, & Hake, 1963), it was neces-

sary with this bird to add a contingency which specified that four food presentations had to occur before the VT 6-min tape scheduling the stimulus-shock pairings would begin. In addition, the length of the session was shortened from two hours to one hour for both birds. These manipulations effectively eliminated the long pause in responding shown by P-890 at the beginning of the session.

Also, because of the severity of suppression with P-2305 after conditioned punishment was introduced, only one response-independent stimulus-shock pairing per session was necessary to suppress responding. For P-2305, the time of delivery of the response-independent stimulus followed by shock was controlled by a clock and was varied randomly from session to session with delivery times being chosen from a table of random numbers. During the terminal condition, then, responding was maintained by the VI 2-min schedule of food presentation, each response produced the 5-sec response-dependent stimulus, and the response-independent stimulus was paired with shock either on a VT 6-min schedule for P-890 or once per session for P-2305.

The response-independent stimulus could begin during the response-dependent stimulus. When this occurred, the stimulus duration lasted for the 5-sec period plus whatever time accumulated as a result of the response-dependent stimulus. Reinforcers that became available on the VI 2-min tape but were not collected were cancelled both by the termination of the response-dependent stimulus and by the onset and termination of the VT 6-min response-independent stimulus. This manipulation assured that reinforcement frequency remained comparable both during and in the absence of the stimulus, thus reducing the probability that the first response following the offset of the stimulus would produce food.

During the first session under the conditioned-punishment procedure for P-2305, the response-independent shock was discontinued after approximately 30 min at which time the response-dependent stimulus was introduced. This procedure permitted an assessment of the time course of extinction of the conditioned punisher in the absence of response-independent stimulus-shock pairings. Shock was reintroduced in the next session.

The effects of chlordiazepoxide and *d*-amphetamine were evaluated after the condi-

tioned-punishment procedure had been in effect for approximately two weeks. The birds first received injections of chlordiazepoxide hydrochloride (1.0 to 10.0 mg/kg for P-890; 1.0 to 17.0 mg/kg for P-2305) in an irregular dose series. The effects of *d*-amphetamine sulfate (.1 to 3.0 mg/kg) were studied following those of chlordiazepoxide with injections also being administered in an irregular dose series.

Both drugs were dissolved in .9% sodium chloride and were injected in a volume of 1.0 ml/kg into the pectoral muscle. *d*-Amphetamine was given immediately before the session whereas chlordiazepoxide was given 60 min prior to the start of the session. Throughout the entire study, sessions were conducted five days per week, Monday through Friday. Daily sessions lasted one hour. Given that responding was stable, drugs were administered Tuesdays and Friday, with Thursdays serving as noninjection control sessions. At least two determinations were made at each dose level.

RESULTS

Behavioral Effects

The entire sequence of experimental conditions and corresponding mean response rates are presented in Table 1. Representative performances showing overall rates and patterns of responding under the conditioned suppression and conditioned-punishment procedures are shown in Figure 1. Under the VI 2-min schedule (Panel A), responding was characterized by moderate-to-high steady rates typical of those found with VI schedules (Ferster & Skinner, 1957). Introduction of the response-dependent stimulus and the VT 6-min schedule of response-independent stimulus presentations had little effect on response rates either in the absence of or during the stimulus, indicating there were no suppressive effects due to novelty (Table 1).

When shock followed each presentation of the 5-sec response-independent stimulus (conditioned suppression), responding in the absence of the stimulus was initially suppressed by about 50%. Over several sessions, responding in the absence of the stimulus gradually increased until the mean response rates for the last four sessions under this procedure were comparable to rates occurring during the first three procedures. Response rates during the stimulus, however, fell to and remained near

Fig. 1. Cumulative response records for P-890 and P-2305 taken from representative portions of three of the experimental conditions. Ordinate: cumulative responses; abscissa: time. Panel A: Variable-interval 2-min food schedule under which a response, on the average of once every 2 min, produced food. Panel B: Variable-interval 2-min food schedule plus variable-time 6-min schedule of 5-sec stimulus-shock presentations (conditioned suppression). Panel C: Variable-interval 2-min food schedule plus variable-time 6-min schedule of 5-sec stimulus-shock presentation where each response produced the 5-sec response-dependent stimulus (conditioned punishment). Records shown in Panels A and B were taken from 2-hour sessions. Diagonal displacements of the response pen denote food delivery. Displacements of the event pen represent response-independent presentations of the 5-sec stimulus followed by shock.

zero (Table 1). Representative performances during the conditioned-suppression procedure immediately prior to the introduction of conditioned punishment are shown in Figure 1, Panel B.

With Bird P-2305, during the first session following the conditioned-suppression procedure, the response-dependent stimulus was introduced when shock delivery following presentations of the response-independent stimulus was simultaneously discontinued. Figure 2 shows the cumulative response record for this session. During the first 30 min of the session, the conditioned suppression procedure was in effect. With the introduction of the response-dependent stimulus, response rates immediately decreased. However, in the absence of continued pairings of the response-indepen-

dent stimulus and shock, rates gradually increased to prepunishment levels. These data are similar to the findings of Hake and Azrin (1965) showing the reduced effectiveness of a conditioned punisher in the absence of continued pairings of the response-independent stimulus and shock.

Introduction of the conditioned-punishment procedure reduced response rates approximately 70% for P-2305 and P-890 (Table 1). Responding of both birds was characterized by low stable rates. A response initiated the response-dependent stimulus during which few responses would occur; a slight pause would follow the termination of the stimulus succeeded by another response which again produced the stimulus, thus repeating the process. With P-2305, the use of a single presentation

Table 1

Sequence of Experimental Procedures and Response Rates (Responses Per Second) During Each Phase

Rates During				Rates During			
Procedure	Stimulus Absence	Stimulus	Number of Sessions	Procedure	Stimulus Absence	Stimulus	Number of Sessions
Bird P-890				Bird P-2305			
I	1.19 (.05)	—	5	I	.81 (.02)	—	9
II	1.46 (.09)	1.43 (.09)	4	II	.86 (.03)	.82 (.03)	15
III	1.69	1.40	1	III	.92 (.02)	1.04 (.05)	13
IV	1.60 (.07)	.05 (.01)	24	IV	.83 (.05)	.02 (.01)	18
V	.34 (.02)	.09 (.01)	55	V	.29 (.05)	.05 (.01)	47
Drug				Drug			

KEY: I VI 2-min
 II VI 2-min + each response produces 5-sec stimulus
 III VI 2-min + presentation of response-independent stimulus
 IV Conditioned suppression
 V Conditioned punishment

Note: Response rates represent the mean response rate for the last four sessions under each of the different procedures except where the total number of sessions was less than four. In those cases, mean response rates are given for the total number of sessions under that procedure. Numbers in parentheses are standard errors of the mean.

of the response-independent stimulus-shock per session did not result in a discriminative effect as measured by any gross changes in baseline behavior following shock presentation. Typical control performances under the conditioned-punishment procedure are shown in Figure 1, Panel C.

Drug Effects

The effects of chlordiazepoxide and *d*-amphetamine on response rate in the absence of the stimulus and on overall response rates under the conditioned punishment procedure are shown in Figure 3. With chlordiazepoxide, doses of 1.0 to 5.6 mg/kg for P-890 and 1.0 to

10.0 mg/kg for P-2305 produced increases in response rates in the absence of the stimulus with peak effects occurring at 5.6 mg/kg for both birds. Doses of 10.0 mg/kg chlordiazepoxide decreased response rates in the absence of the stimulus with P-890, whereas decreases in responding with P-2305 were seen only after doses of 17.0 mg/kg. *d*-Amphetamine produced only dose-related decreases in response rates in the absence of the stimulus with both birds.

The effects of chlordiazepoxide and *d*-amphetamine on overall response rates were similar to those obtained with rate of responding in the absence of the stimulus. Once again, *d*-amphetamine produced only dose-related de-

Fig. 2. Cumulative response record of P-2305 during the first session following the conditioned-suppression procedure. During the first 30 minutes of the session, the conditioned-suppression procedure remained in effect. The arrow indicates the introduction of the response-produced stimulus and simultaneous removal of the shock that followed the response-independent stimulus. Details are the same as for Figure 1.

Fig. 3. Effects of chlordiazepoxide and *d*-amphetamine on responding suppressed by conditioned punishment for P-890 and P-2305. The unfilled circles represent response rate in the absence of the response-dependent and response-independent stimulus, whereas filled circles denote overall response rate. Means and ± 1 standard error of control rates are presented above point C. Vertical lines associated with drug points represent the range. Where there are no vertical lines, all measures fell within the point.

creases, while chlordiazepoxide produced increases in overall response rate.

Dose-effect curves showing changes in responding during the stimulus under chlordiazepoxide and *d*-amphetamine are presented in Figure 4. During control conditions, responding during the stimulus occurred at a low rate with both birds. Increases in responding during the stimulus occurred with chlordiazepoxide at doses of 5.6 and 10.0 mg/kg for P-2305, and 3.0, 5.6, and 10.0 mg/kg for P-890. *d*-Amphetamine produced only decreases in responding during stimulus presentations.

DISCUSSION

Although a few studies have employed other stimuli as punishers, most experiments examining the effects of drugs on punished responding have used response-produced electric shock as the suppressing event. The present experiment was designed to develop a behavioral baseline of responding suppressed by a stimu-

lus occasionally paired with response-independent shock (conditioned punishment). Once this baseline was established, it provided a uniquely suitable means for examining the generality of the effects of chlordiazepoxide and *d*-amphetamine on responding suppressed by an event other than response-produced electric shock.

The effects obtained in the present study under each of the various behavioral procedures are in agreement with previous reports on conditioned punishment (Hake & Azrin, 1965). In analyzing the effectiveness of the response-dependent stimulus in suppressing ongoing behavior, it is important to make baseline comparisons against the conditioned-suppression procedure. Before pairing the stimulus with

Fig. 4. Effects of chlordiazepoxide and *d*-amphetamine on response rates of P-890 and P-2305 during the response-dependent and response-independent stimulus. Details are the same as for Figure 3.

shock during the conditioned suppression procedure, it had no suppressive effect when it followed a response. After being paired with shock, responses producing the stimulus were reduced. Hake and Azrin (1965) have argued that the maintained effectiveness of the conditioned punisher is a result of its occasional pairing with the unconditioned stimulus. However, several other equally tenable explanations must be considered. After repeated exposures to the conditioned-punishment procedure, factors other than the occasional pairing of the stimulus with shock may contribute to the effectiveness of the conditioned punisher in suppressing responding. During the first few exposures to the conditioned punishment procedure, response suppression is undoubtedly a result of the stimulus having been paired with shock. However, after several sessions in which response suppression during the stimulus decreases the number of reinforcers obtained, discriminative properties correlated with decreased reinforcement frequency may eventually play a more important role in keeping responding suppressed. Morse and Skinner (1957) have demonstrated quite clearly that responding may be suppressed during a stimulus that is adventitiously correlated with a decreased frequency of reinforcement.

In addition, because the response-dependent and the response-independent stimulus were allowed to overlap, it could be argued that the response suppression which occurred under the conditioned-punishment procedure was a result of responses producing a stimulus that was followed by shock. Although no quantitative measurement was made to determine the number of times the two stimuli overlapped, with P-2305 it is unlikely that the frequency of occurrence was high enough to produce the amount of suppression observed. With P-2305, only one response-independent stimulus-shock pairing occurred per session, yet the amount of response suppression both during and in the absence of the stimulus was comparable to that of P-890. Also, responding during the conditioned-suppression procedure occurred at a high rate making it likely that some responses occurred during the onset of the response-independent stimulus followed by shock. Yet, no persistent rate decreases were observed in the absence of the stimulus during the conditioned-suppression procedure.

It may be exceedingly difficult to separate

completely the discriminative properties of the stimulus from the effects of its being paired with electric shock. Studies which rely on a pharmacological intervention may prove to be the most useful means of disentangling these effects. If, indeed, the processes responsible for the suppression of responding with a response-dependent stimulus that is correlated with shock are different than those of a stimulus that is correlated with periods of nonreinforcement or response-produced electric shock, then they may be differentially sensitive to the effects of drugs. For example, in the study by Branch et al. (1977), pentobarbital produced different effects depending on whether responding was suppressed by electric shock or timeout. Also, McMillan and Leander (1975) found differences in the effects of chlordiazepoxide depending on whether or not suppression was a result of response-dependent or response-independent shock. More recently, Miczek and Luttinger (1979) reported differential effects of *d*-amphetamine, pentobarbital, and methysergide on different types of conditioned suppression. They concluded that decreases in responding by a prefood stimulus and a preshock stimulus may represent different processes of behavioral suppression. Whatever processes are responsible for behavioral suppression in the present study, the pharmacological results indicate that suppression produced by conditioned punishment was affected similarly to that in studies using response-produced electric shock.

From a pharmacological point of view, the major advantage of the conditioned-punishment procedure is that durable punishing effects can also be obtained with stimuli other than response-produced electric shock. In contrast to punishment studies using response-produced electric shock and conditioned-suppression studies that rely on response-independent shock, the present experiment allowed for the assessment of drug effects on behavior that was suppressed to a comparable degree by a response-produced conditioned stimulus.

In many pharmacological studies employing response-produced electric shock, the shock has been delivered according to some ratio schedule of presentation. In these studies, the number of shocks delivered is directly proportional to the rate of responding. Thus, under conditions of drug administration, any drug that increases response rates also increases the fre-

quency of shock delivery. Because of the possibility of an interaction between the drug and shock, studies which employ alternative punishing stimuli are particularly appealing. In the present study, although increases with chlordiazepoxide resulted in an increase in the number of response-dependent stimulus presentations, the frequency of stimulus-shock pairings remained constant.

The present experiment, along with several other studies (Margules & Stein, 1966, McMillan, 1967; Spealman, 1979), suggest that similar drug effects can be obtained regardless of whether the punisher is electric shock or some other event. Other studies (Branch et al., 1977), however, have reported differential effects depending on the nature of the punishing event. It was once thought that drug effects on responding were independent of the events maintaining behavior. Current research, however, suggests that the maintaining event may be an important determinant of a drug's effects on behavior (Barrett & Katz, 1980). It is as yet too early to draw any conclusions regarding the effects of drugs on responding suppressed by different events. The few studies that have attempted to examine the effects of drugs on responding suppressed by events other than electric shock have differed considerably with regard to the species under study, schedule of reinforcement, and the schedule under which the event is presented.

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