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Suppression of Cocaine Self-Administration by Extinction and Punishment[1,2]

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GROVE, R. N. AND C. R. SCHUSTER. *Suppression of cocaine self-administration by extinction and punishment.* PHARMAC. BIOCHEM. BEHAV. 2(2) 199–208, 1974. – After training on a multiple FR-1 FR-1 cocaine reinforcement schedule, responses were extinguished in one component of the schedule. Extinction responses declined to near-zero levels within 4 sessions for 3 of 4 monkeys. Response rate during the non-extinction component increased for a time in 2 of 3 animals exposed to prolonged extinction sessions. Three monkeys were then retrained to the multiple FR-1 FR-1 reinforcement schedule, after which each response in one component was followed by a brief electric shock as well as a cocaine infusion. Shocked responses decreased as shock intensity increased. Non-shocked response rates increased in a few sessions but this effect was transitory. Doubling the unit dose reduced baseline rate but failed to alter the relative suppressant effect of shock. Attenuation to intense shock occurred when the response-shock interval was increased to 18 sec.

Drug self-administration Cocaine Stimulants Punishment intensity Shock delay Extinction Reinforcement magnitude Behavioral contrast

THE EFFICACY of reinforcing drugs is defined in part by the range of environmental conditions under which they are self-administered. One parameter of the efficacy question is the ease with which ongoing drug self-administration can be suppressed. Experimental suppression of drug intake by changing dosage [10], increasing the response requirement on reinforcement schedules [10], or by pre-session drug "satiation" [13] have been reported. Ethanol drinking [9] and cigarette smoking [11] have been suppressed by concurrent brief electric shock punishment in man.

This report is concerned with the modification of intravenous cocaine self-administration patterns by two behavior-suppression techniques: extinction and punishment. A multuple schedule procedure [3] was used to assess whether the frequency of drug intake during the unchanged components would be altered by extinction-induced (Experiment 1) or punishment-induced (Experiment 2) reduction of drug intake in alternate components of a multiple schedule. Unit dosage was also manipulated in the second experiment to assess whether punishment-induced suppression could be attenuated by increasing the magnitude of reinforcement.

EXPERIMENT 1: DIFFERENTIAL EXTINCTION OF COCAINE SELF-ADMINISTRATION

Method

Animals. Four naive male rhesus monkeys weighing between 4.3 and 4.7 kg were used.

Apparatus. Details of the topography of the experimental chamber have been published elsewhere [2]. Monkeys were individually housed in 131 × 131 × 92 cm experimental cubicles. Two Plexiglas-faced 10 × 10 × 15 cm steel boxes were mounted on either side of a removable feeding cup centered 21 cm from the bottom of the front door panel. Each box contained a lever (LVE 121-07) and above each lever, four 5 W stimulus lights, two of one color (e.g., red), two of another (e.g., blue). In addition, a 25 W house light was mounted in a 20 × 20 × 30 cm Plexiglas-faced steel box bolted to the ceiling.

Each animal was fitted with a stainless steel harness [16], connected to a steel spring restraining arm [2]. A siliconized rubber catheter was implanted in a jugular (or femoral) vein and run subcutaneously to the back of the harness, exiting into a protected connector and then

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through the flexible steel arm into a Cole-Parmer peristaltic pump delivering solution at 6 ml/min. The pump was fed by a reservoir containing the drug solution.

The experimental chambers were connected to the relay programming apparatus in another room via cables. Lever presses and infusions were recorded on print-out counters and cumulative recorders.

Procedure. During adaptation to the harness, arm, and experimental chamber, a 3-hr daily session of multiple stimulus (i.e., S^D) light presentation was initiated. S^D1 (e.g., red lever lights) altered with S^D2 (e.g., blue lever lights) every 30 min. At first pressing either bar produced a 9 sec cessation of the appropriate lever light and concurrent 9 sec presentation of a white houselight. Response rates on both levers were recorded and a lever preference was established.

An indwelling jugular (or femoral) catheter was surgically implanted and animals were again exposed to the above schedule of stimulus presentation. In addition a 9 sec 0.9 ml isotonic saline infusion was made contingent on depression of the previously non-preferred lever for approximately 3 sessions.

Cocaine, 100 μg/kg/infusion was then substituted for saline. A multiple (S^D1: FR-1: cocaine) (S^D2: FR-1: cocaine) reinforcement schedule was instituted. Each response in either alternating 30 min S^D component produced a cocaine infusion signalled by the onset of the pump and overhead chamber lights. The 3-hr sessions always began with the presentation of the S^D1 stimulus. For later reference this condition will be referred to as the multiple baseline schedule.

Nine or more multiple baseline sessions were conducted to establish stability, defined as a change of not more than ± 10% in total infusions over three successive sessions. At this point differential extinction sessions were initiated. The schedule for a differential extinction session was mult (S^D1: FR-1: cocaine) (S^D2: FR-X: no consequence). As in the baseline condition each response in the presence of S^D1 was consequated by cocaine infusion. In the presence of S^D2, however, responding produced neither cocaine nor any of the stimuli correlated with infusion. Therefore, S^D2 may be considered by definition as S^Δ, i.e., a stimulus in the presence of which a response when emitted is not reinforced. For brevity this procedure will be called a mult extinction schedule (Table 1).

The sequence of mult baseline and extinction sessions varied across animals as shown in Fig. 1. In general either one or both of two different between-session sequences were programmed for each animal. In one sequence, the sequential extinction series mult extinction sessions were continuously in effect. In the other sequence, the alternating extinction series, mult baseline sessions alternated with mult extinction sessions. The former permitted some estimate of the response-suppressant function to prolonged extinction, unconfounded by other treatment variables. The later sequence, alternation, was used to assess potential interaction between the mult baseline and extinction schedules since a similar alternation technique was to be used in the subsequent punishment experiment.

Finally, 2 additional manipulations were made on a probe basis: (1) saline was substituted for cocaine in the S^D2 components of one session for A109, and (2) the order of component presentation was reversed for 3 sessions for A098 so that those sessions began with S^D2 (or S^Δ)-extinction component followed by the S^D1-reinforcement component. Rhesus A098 was exposed to the mult extinction schedule for 37 continuous sessions; Rhesus A109 to the alternating extinction procedure for 24 sessions, returned to baseline for 7 sessions and then exposed to sequential extinction trials for 11 more sessions. Rhesus A102, to the alternating extinction procedure for 6 sessions, and Rhesus 72147, to 40 alternating baseline and extinction sessions, followed by 5 additional baseline sessions and finally 6 sequential extinction sessions.

TABLE 1

EXPLANATION OF THE COMPONENT SCHEDULE CONDITIONS USED IN THE CONTROL (MULTIPLE BASELINE), EXTINCTION AND PUNISHMENT CONDITIONS. ACROSS ALL CONDITIONS S^D1 SIGNALLED FR-1 ACCESS TO DRUG IN THE 1ST, 3RD AND 5TH HALF-HOURS OF EACH SESSION. S^D2 SIGNALLED FR-1 DRUG ON CONTROL SESSIONS OR EXTINCTION OR SHOCK IN TREATMENT CONDITIONS. SEE TEXT FOR DETAILS.

STIMULUS CONDITIONS		REINFORCEMENT SCHEDULE CONDITIONS		
DISCRIMINATIVE STIMULUS	SIGNALLED COMPONENTS	MULTIPLE BASELINE	MULTIPLE EXTINCTION	MULTIPLE PUNISHMENT
S^D_1	1, 3, 5	FR-1: DRUG	FR-1: DRUG	FR-1: DRUG
S^D_2	2, 4, 6	FR-1: DRUG	EXT.	FR-1: SHOCK + DRUG

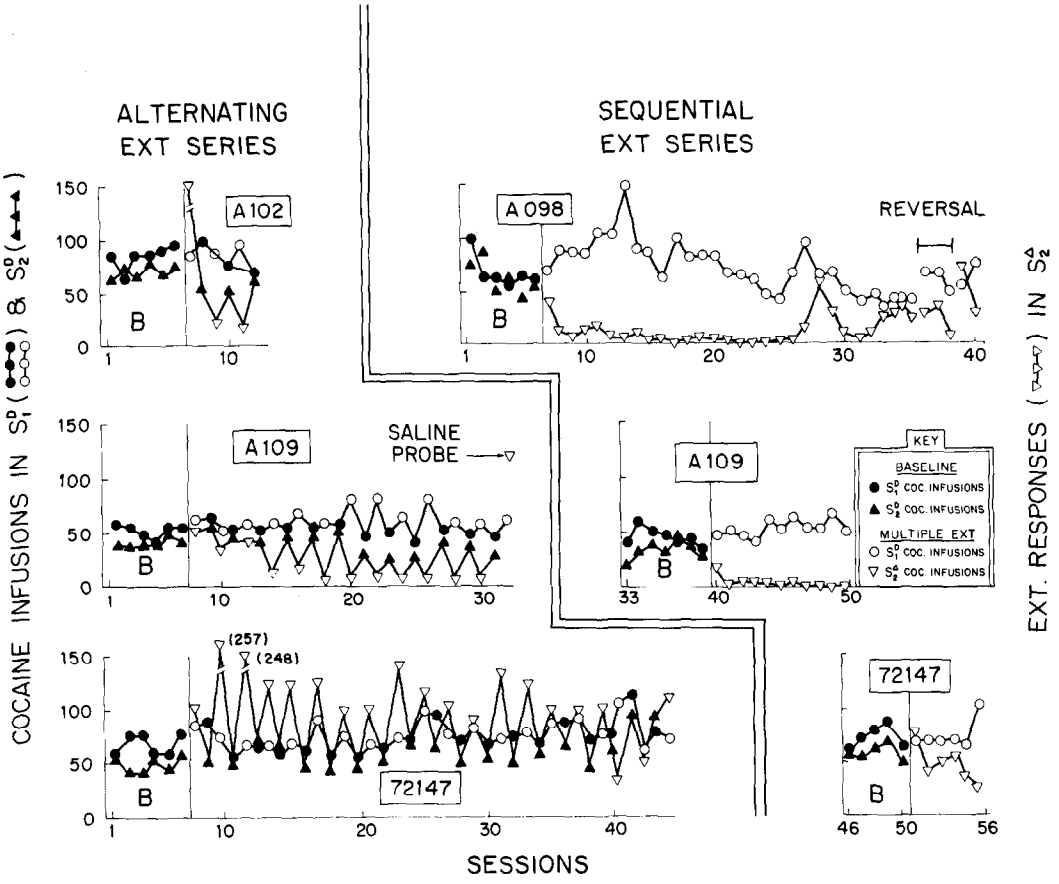

FIG. 1. Number of infusions or extinction responses (open triangles) per schedule component (see key) across sessions for each subject. B denotes mult baseline sessions. See text for details.

Results

The results of the various extinction procedures are shown across sessions for each animal in Fig. 1. For Rhesus A098 responding in the extinction component dropped abruptly on the second mult extinction session and remained at near-zero values for 21 sessions after which the extinction responses gradually returned to near-baseline values. Infusions during the reinforcement components of the same mult extinction sessions on the other hand showed a gradual increase, peaking in the seventh session with about 50 percent more infusions than during baseline sessions. Cocaine infusions then decreased to control values throughout the remaining mult extinction sessions. The within-session S^D component sequence (i.e., S^D1, then S^D2) was then reversed (S^D2, then S^D1) for 3 sessions to test for order effects; responses during extinction components continued to be less than during reinforcement components. The original mult extinction procedure was then reinstated for the 2 final sessions, and the prior differential output was again observed.

Rhesus A109 was exposed first to the alternating extinction procedure; extinction responding decreased after the fifth session and remained at near-zero values across all remaining extinction sessions. Infusion frequency during the cocaine-reinforced components of the multiple extinction schedule, on the other hand, increased to about 40% above baseline values by the thirteenth and fifteenth sessions and then returned toward control values by the twenty-first sessions. Saline was substituted for cocaine during the extinction component of the twenty-fifth session; approximately 3 times as many saline infusions were recorded as cocaine infusions. The number of cocaine infusions during Session 25, however, did not differ from control values. Finally after 7 more baseline sessions A109 was then exposed to 11 sequential extinction sessions where cocaine infusions in the unchanged component again showed a slight increase above control range while extinction responding remained at near-zero values. Rhesus 72147 was exposed to first the alternating, then the sequential extinction session sequences. The data indicate that no systematic changes were apparent in the number of infusions taken during the cocaine reinforcement components of the multiple extinction schedule across 39 sessions. However, a two-fold increase in extinction responding was seen in the second extinction session and extinction responding remained high throughout most sessions. Some below-baseline suppression became evident for 72147 only during the last two extinction sessions in the sequential extinction series.

Rhesus A102 was exposed to only 3 alternating extinction sessions. No reliable change was noted in the cocaine

infusion output in the unchanged component of the multiple extinction schedule; extinction output, however, at first increased and then decreased from control values across sessions.

Discussion

Extinction. These data indicated that the removal of all cues associated with a drug infusion lead to a rapid decrement in responding within 1, 2, or 3 sessions for 3 of 4 animals. Reinstatement of these cues with saline substituted for drug in one animal (A109) led to a considerable increase in responding, a finding previously reported in studies of morphine self-administration in the Rhesus monkey [12].

It is interesting to note that only one animal, A109, demonstrated consistent near-zero suppression across a prolonged series of extinction sessions. Rhesus A098 also exhibited rapid near-zero extinction output for 20 sessions, but thereafter, responding began to increase towards control values. Finally Rhesus 72147 showed little evidence of any response suppression during most extinction components. These between-animal differences may be attributed to the failure to add a response-pause requirement [3] to the changing of schedule components between cocaine reinforcement and extinction. Animals A098 and 72147 tended to respond towards the end of the 30 min extinction periods, a response pattern similar to that maintained by a schedule where the reinforcer is delivered independently of responding on a fixed time base [5]. Thus the extinction responding may be maintained in these animals by the adventitious reinforcement of extinction responding by the contiguous onset of the S^D1 stimulus signalling the cocaine reinforcement component.

Limited access. The other interesting aspect of these data are the apparent interactions between extinction responding and cocaine infusions within the same session. Of the 3 animals exposed to prolonged extinction sessions, A098, A109, and 72147, two animals, A098 and A109, showed a transitory 40 to 50 percent increase in S^D1 cocaine infusions as extinction responding concurrently decreased. This effect first appeared on the seventh extinction session for both animals even though one, A109, was exposed to the alternating extinction series while the other, A098, was exposed to the sequential series. Since similar transitory phenomena were found in the following experiment, the implications of the effects of limited-access procedures will be postponed to the final discussion.

EXPERIMENT 2: DIFFERENTIAL PUNISHMENT OF COCAINE SELF-ADMINISTRATION

Method

Animals. Three animals used in the previous experiment, A102, A109 and 72147, were used.

Apparatus. The equipment was the same as in Experiment 1, except that a LVE constant current shock generator was added to the program. Shock electrodes were implanted subcutaneously at the base of the skull, the wires exiting through a puncture wound into the backpack and through the steel arm into the programming room. The bipolar 4 cm dia. stainless steel electrodes were spaced 3 cm apart and anchored to a 5 × 2 × 0.5 cm plastic plate. The electrodes were attached to 18-ga stranded stainless steel, teflon-coated wire 20 cm long. Resistance typically ranged from 10K to 50K ohms between animals at the shock source.

Procedure. As in Experiment 1, the mult baseline schedule was the control condition for this experiment. During the punishment sessions a multiple (S^D1: FR-1: cocaine) (S^D2: FR-1: shock + cocaine) schedule was in effect. This will be referred to as the mult punishment schedule (Table 1). The S^D1 lever light, on during the first, third and fifth 30 min components of the 3 hr session, set the occasion for a 9.0 sec cocaine infusion if a response was emitted. The S^D2 lever light, on during the second, fourth and sixth components, set the occasion for a brief, immediate response-contingent shock as well as a 9.0 sec cocaine infusion. Shock duration was 200-msec for A102 and 300-msec for A109 and 72147. Responses emitted during infusions were also shocked during the punishment condition. Since only one response was typically emitted per infusion, shock frequency was behaviorally equivalent to infusion frequency during this study.

Shock intensity was the independent variable at 2 unit doses of cocaine. Shock intensity was first scheduled in a descending series, varying from 10.0 ma to 0.5 ma across all animals. The intensity function was then replicated in an ascending series across the same range. A given intensity was held constant throughout the three shock components of each punishment session. Each punishment session was separated by 1 to 7 mult baseline sessions to assure a return to control values and to minimize order effects. Intensity increments and decrements were adjusted individually for each animal, as can be seen by examining Fig. 2.

Once the descending-ascending intensity series was completed, another unit dose of cocaine was used to maintain lever-pressing behavior and the intensity series was replicated. The initial dose was 100 μg/kg/infusion for two animals, A102 and 72147, but 200 μg/kg/infusion for A109. The replicate doses were 200 μg/kg/infusion for A102 and 72147, and 100 μg/kg/infusion for A109. When changed to the second dose, a series of at least nine mult baseline sessions were run until less than ± 10% variability was observed over 3 successive sessions.

The effects of punishment delay were than examined in two animals, A109 and 72147, by increasing the time between response and shock presentation from 0, 4.5, 9.0 to 18.0 sec.

Results

The change in infusion rate during both the non-shock (S^D1) and shock (S^D2) components as a function of S^D2-shock intensity for each animal is shown in Fig. 2. The upper graphs show the intensity function at the 100 μg/kg/unit dose; the lower graphs, at the 200 μg/kg/unit dose.

In general infusions during the shock components decreased as the intensity increased while little systematic change in infusion rate was observed during the non-shock components. Inspection of the individual shock intensity-functions in Fig. 2 shows that the suppression curve generated in the initial descending intensity series was generally replicated in the ascending intensity series. Order effects were apparent only at the 100 μg/kg/unit dose for A102, where less suppression was observed in the ascending series than in the initial descending series. When the unit dose was raised to 200 μg/kg, however, A102 showed no order effects.

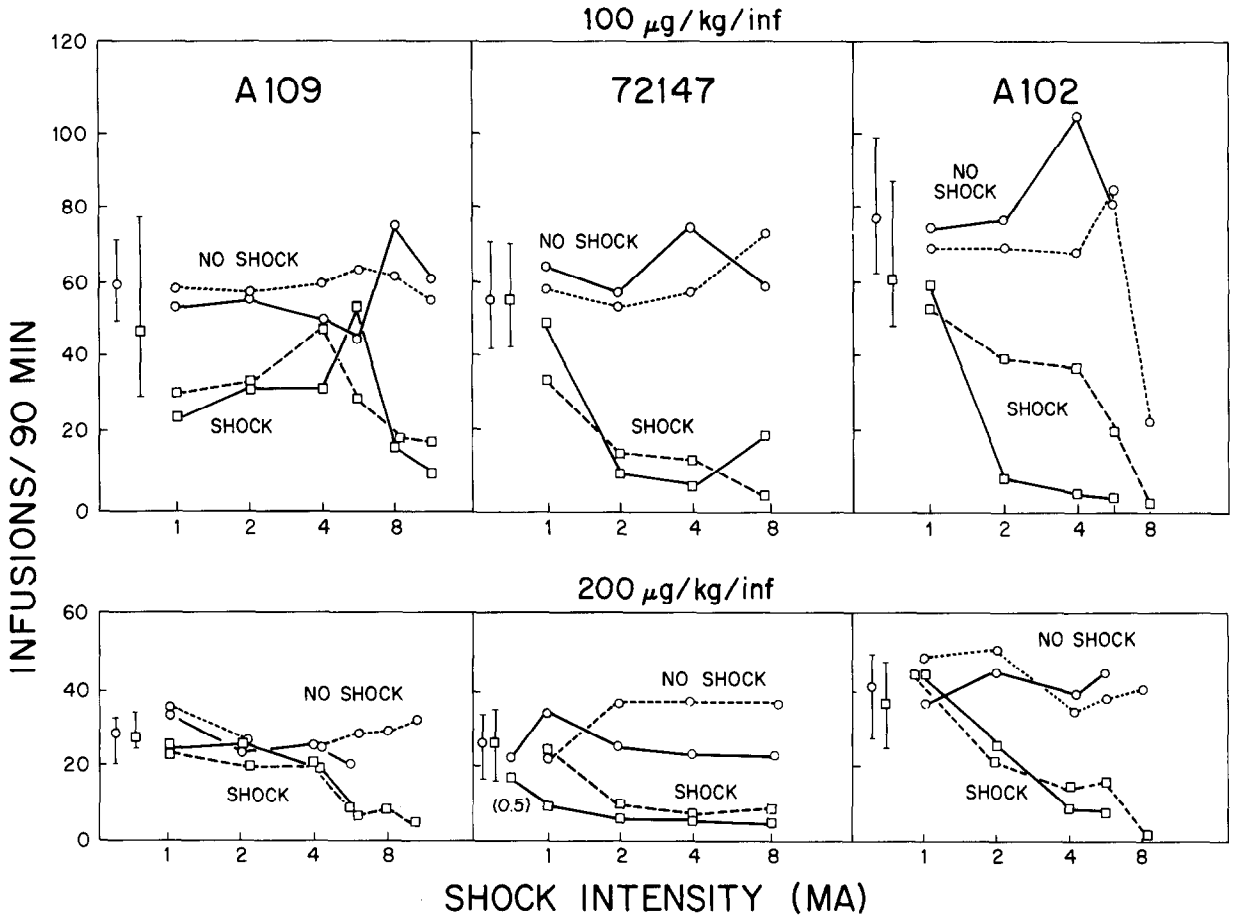

FIG. 2. Each cell represents an individual shock intensity suppression function S^D1 non-shock infusion rates are plotted as circles; S^D2 infusions as squares. The range of baseline infusion rates in S^D1 and S^D2 is represented by vertical bars on the left of each cell. Initial descending shock series are represented by the solid lines; replicate ascending series, by the dotted lines. Animals are shown by columns; unit dose, by rows.

Figure 2 also indicates individual sessions in which the rate of non-shock infusions appears to equal or exceed the range for control rates. This effect was transitory, however, and was not directly related to intensity of shock or unit dose of cocaine across animals.

In Fig. 2, Animal A109 shows an inverted-U shaped suppression-intensity function during the shock components at the 100 μg/kg unit dose; however, the variability of S^D2 responding during control sessions was considerably higher than for other animals. This variability reflects a continuation of S^D2 suppression during repeated post-shock control sessions indicating a lack of recovery of baseline conditions following shock sessions. This phenomenon was unique to this animal at this dose; doubling the dose to 200 μg/kg/injection produced a more linear intensity-suppression function in this same animal.

For Animal A102 at the 100 μg/kg unit dose, infusion rate during the non-shock components fell drastically at 8 ma (Fig. 2). Inspection of the bottom cumulative record in Fig. 3 indicates that this decrease is due to a lack of responding during the second and third presentations of S^D1 following a single delivery of the shock during the first S^D2 component of the session. Except for that bottom cumulative record, Fig. 3 is representative of the way in which the distribution of cocaine intake was disrupted at 100 μg/kg/infusion for all animals. In general as shock intensity increased the spacing of responding during the shock components increased. The distribution of infusions during the non-shock components shifted to the left. That is, more infusions were taken in the first half of the non-shock components than in the last half, although total drug intake was not markedly altered from control values.

Figure 4 shows representative cumulative records at 200 μg/kg/infusion for 74124. These records are qualitatively similar to that for the 100 μg/kg unit dose except that the baseline infusion rate is lower at this dose, and there was no marked change in distribution of infusions during the non-shock components at high shock intensities.

When shock component data at 100 and 200 μg/kg doses are replotted as percent of non-shock control baseline infusions (Fig. 5) no systematic difference was found between the relative suppression functions for the two cocaine doses.

Figure 6 shows the change in infusion rate as the R-S interval is lengthened. A 6 ma shock produced little suppression at any delay interval for A109. However, 8 ma

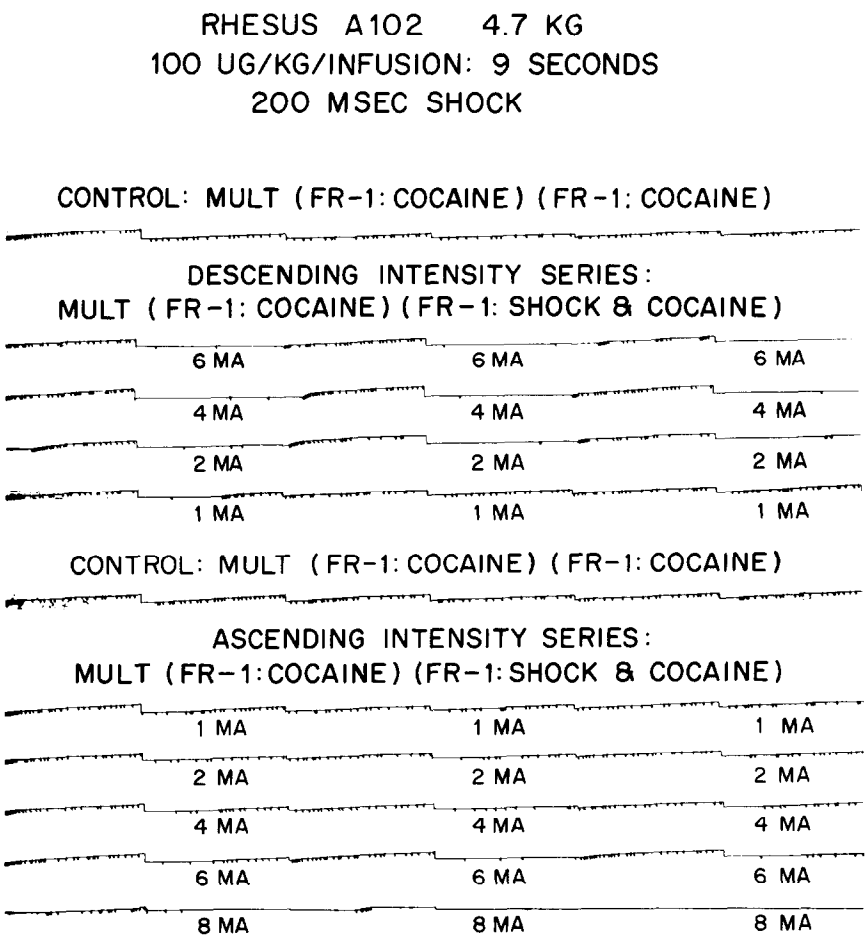

FIG. 3. Representative cumulative records of 3 hr control and multiple punishment sessions at 100 μg/kg unit dose for A102. Each pip represents an infusion, the pen resetting every 30 min. Shock intensities are inscribed below the appropriate component of the records.

suppressed immediate (0-sec) shocked responding for 74147 and this suppression was attenuated to nearly pre-shock levels by delaying shock for 18 sec.

DISCUSSION

These data indicate that brief response-contingent shock suppresses cocaine intake in an intensity-dependent fashion, and, more importantly, that the degree of suppression is not altered by increasing the magnitude of reinforcement. Furthermore when shock delivery suppressed cocaine intake in the shock components of the multiple schedule, enhanced drug intake was sometimes seen during the adjacent non-shock components for two animals but the effect was transitory.

Extinction vs. Punishment

These results are generally consistent with the empirical generalizations concerning the behavior-suppressant effects of comparable extinction and punishment procedures on operants reinforced by consequences other than drugs [1]. As with operants maintained by other reinforcers on multiple schedules, cocaine-reinforced behavior was suppressed and transitory post-suppression contrast effects were occasionally observed in the unchanged component under both extinction and punishment conditions.

It should be noted that more variability was observed across the mult extinction sessions (Fig. 1) than across the shock intensity series (Fig. 2). This may reflect less precise behavioral control under the extinction condition than with punishment; however, the two experiments are not directly comparable. Chronic constant-intensity punishment sessions were not conducted in a fashion analogous to that for extinction.

Magnitude of Reinforcement

Perhaps the most interesting finding was that the suppressant effect of the shock was independent of the dosage of cocaine used to maintain the lever pressing response (Fig. 5). These isomorphic intensity functions may be due to non-reinforcement parameters of cocaine dose such as a lack of discriminability between the 100 and 200 μg/kg unit doses. This seems unlikely, however, because in doubling the unit dose the baseline rate was reduced by one-half. Furthermore, cocaine dosage-choice studies [7], have shown that 100 is preferred over 50 μg/kg per infusion, i.v., suggesting that the present doses may also be discriminably different. The magnitude-independent suppression function may also be attributable to a carry-over suppression effect from the first unit dosage series to

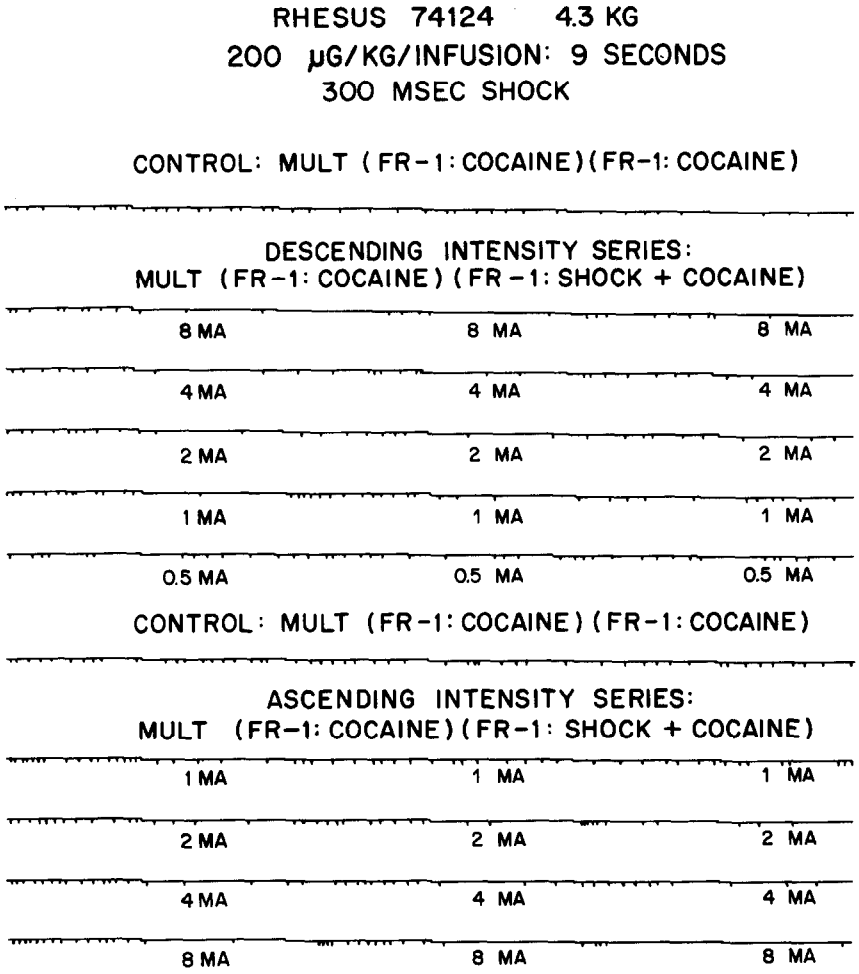

FIG. 4. Same as Fig. 3 except that records of Animal 74124 at the 200 µg/kg unit dose are shown.

the second. However, this also seems unlikely because the order of presentation of unit doses varied between animals. If carry-over effects explained the results, one would expect to find markedly different intensity functions depending on the order of unit dosage, rather than magnitude. This was not observed.

There are few studies comparing directly the interactions of reinforcement and punishment magnitude. The effects of shock punishment on a discrete trial complex maze-running discrimination task in rats were partially attenuated by increasing the magnitude of reinforcement [4]. There appear to be no directly analogous studies relating amount of reinforcement to amount of punishment in a free-operant paradigm. However, if one grants that reinforcement frequency is at least provisionally related to reinforcement magnitude, studies on reinforcement frequency and the rate of free-operant punished behavior are relevant to this discussion. Using a multiple VI-VI schedule design, the rate of shock punished responding in pigeons was found to be directly related to the relative frequency of food reinforcement [8].

Both of these studies imply that punishment effects are attenuated by increasing reinforcer strength or efficacy (i.e., magnitude and/or frequency), a generalization inconsistant with the results of Experiment 2. This disparity may be related to differences in reinforcers, contingencies, species, procedures or other experimental parameters. Therefore, it is premature to attribute a unique punishment effect to the magnitude of reinforcement of cocaine, as compared to other reinforcers.

Unit Dose, Patterning and Reinforcement Magnitude

The magnitude-independent shock-suppression function is particularly relevant to speculations concerning the variables controlling cocaine patterning in rhesus monkeys and rats [14]. Using simple fixed-ratio schedules, the distribution of cocaine infusions has been found to be directly dependent on unit dose across a wide dose range, with little variability in the inter-fusion intervals. Some investigators [14] have proposed that the dose-dependent regular spacing of infusions may be due to (1) the initial primary drug effect which reinforces and maintains emission of the operant, and (2) a delayed inhibitory or aversive component which suppresses responding until the unit drug effect has subsided. In this model the frequency of infusion

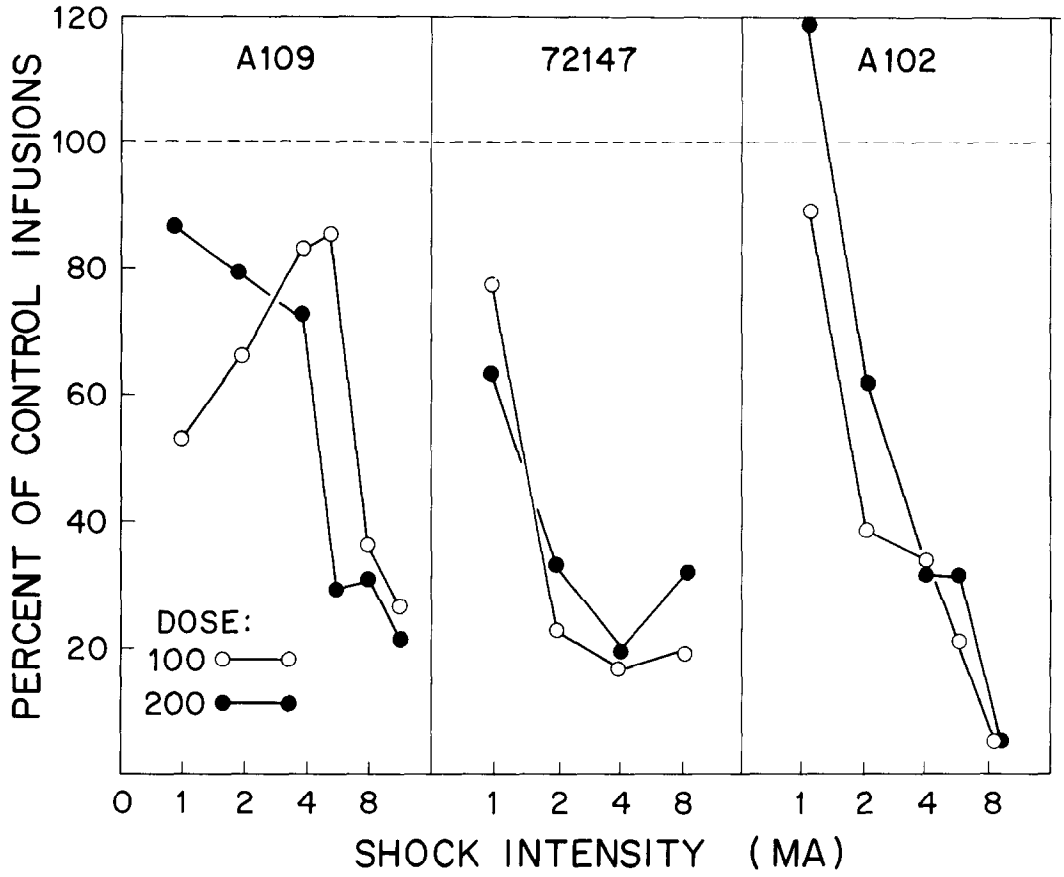

FIG. 5. Percent of mean S^D2 control (non-shock) infusion rate across the averaged S^D2 infusion rate over each replication of a shock intensity. Plotted for both high (200 μg/kg) and low (100 μg/kg) unit dose. The reference (100%) infusion rate was determined as the mean of S^D2 infusions during mult baseline control conditions.

is determined primarily by the duration of the later aversive or inhibitory component, which in turn is dependent primarily on the unit dose. The present data suggest that the suppressant effect of punishment is not counteracted by increasing the magnitude of cocaine reinforcement as defined in terms of unit dose. Thus, the proposed initial reinforcement (i.e., behavior maintaining) function of cocaine may be asymtotic at both unit doses. If so, the behavior-suppressing effects of equivalent intensities of response-contingent shock may be expected to contribute equally to the overall rate suppression regardless of unit dose. In other words, shock may have equivalent suppressant effects for both high and low unit doses because the two doses of cocaine were equally reinforcing even though cocaine inter-infusion intervals were dose-dependent. Reinforcement magnitude may not correspond isomorphically to unit dose. This possibility is admittedly post hoc but may be clarified by further studies examining the functions relating response-shock delay at different unit doses.

Behavioral Contrast

Transitory increases in drug intake during the non-extinction components of Experiment 1 and the non-shocked components of Experiment 2 were observed in some, but not all animals. This is similar to descriptions of behavioral contrast observed in the unchanged components of other multiple schedule studies [8,15].

Inspection of the cumulative records in Figs. 3 and 4 suggest that the contrast effect in this case may be similar to the warm-up effect for cocaine animals beginning a session. During sessions of maximal contrast, drug intake was at zero (extinction) or near-zero values (punishment) for the 30-min session segment. During the subsequent 30-min unchanged component, however, responding resumed at a high initial rate for many infusions and then returned to baseline-like patterning (Figs. 3 and 4). Since this pattern is very similar to the initial warm-up effect, it is suggested that part of the explanation for contrast may be that the 30 min of limited access reduces blood levels of cocaine to pre-session values, in which case the animal effectively begins the session anew in the next component. However, the fact that contrast was a transitory phenomenon in all cases here agrues that the warm-up explanation is insufficient, since upon repeated sessions this pattern drops out. Perhaps part of this problem could be resolved by using intermittant schedules which allowed a greater baseline behavioral output than was observed here. The atten-

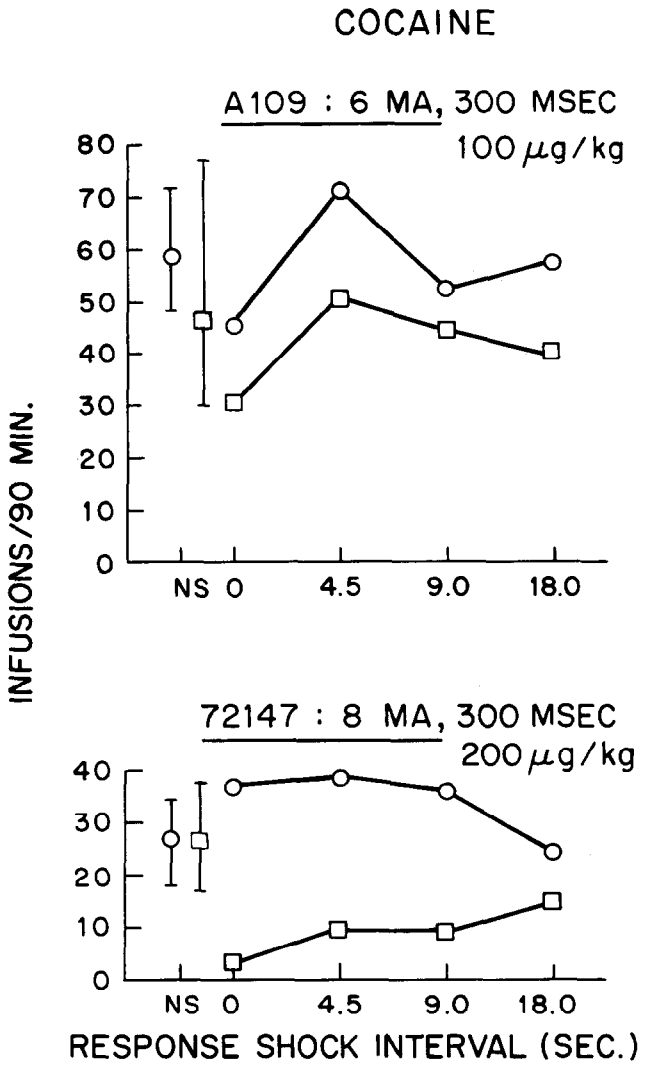

FIG. 6. Changes in S^D1 (circles) and S^D2 (squares) infusion rate for 2 animals as the interval between response and shock delivery is lengthened from 0 to 18 sec. Vertical bars are ranges. Note that 6 ma produced no suppression at any interval for A109, but that the marked suppression at 8 ma was attenuated by lengthening the interval for 72147.

uation of contrast may then be quantified more precisely.

In summary, the observed contrast effect is probably not attributable solely to the limitation of drug availability by extinction or punishment. It remains to be demonstrated, however, whether behavioral variables associated with contrast effects in other, non-drug experiments [15] are functionally analogous to the transitory effects observed here.

Delay of Punishment

A clear punishment delay gradient was not found at moderate (6 ma) intensities for A109. However, somewhat less suppression was observed as the R-S interval was lengthened at high (8 ma) intensities for 72147 (Fig. 6). This effect is consistent with punishment delay functions found for non-drug reinforced behaviors [1].

Non-reinforcement Functions of Cocaine

Because each session began with 30 min of unrestricted cocaine access, the animals were functionally pre-treating themselves with a fixed amount of cocaine. Cocaine not only reinforces operant behavior but may alter subsequent responding by other, non-reinforcement behavioral mechanisms as well. Thus the extinction and punishment results here may be influenced by non-reinforcement behavior-modifying functions of cocaine in addition to the behavior modifying functions of extinction and punishment procedures per se. For example, amphetamine has been found to increase the threshold for shock intensity in titration-avoidance/escape schedules [6]. Given that cocaine shares other behavioral properties in common with amphetamine, it is possible that prior self-administrated cocaine could have altered the intensity-suppression functions of Experiment 2 by modifying the effective intensity of the shock.

In a more general sense, the modification of operant responding by drug extinction or punishment procedures may be unintentionally confounded by the behavior-modifying effects of prior self-administered drug. This is a complication not usually pertinent to the analysis of behavior-suppression procedures using other classes of reinforcers to maintain operants.

Apart from these considerations on possible unique properties of reinforcing drugs, the results obtained in the present experiment are generally consistant with those found when behavior maintained by other non-drug reinforcers are extinguished or punished. These data add to the notion that reinforcing drugs share characteristics in common with other reinforcers and that their effectiveness can be modified by analogous environmental manipulations.

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