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SCHEDULES USING NOXIOUS STIMULI. II: LOW INTENSITY ELECTRIC SHOCK AS A DISCRIMINATIVE STIMULUS

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The presence or absence of pulses of low intensity electric shock was used as a discriminative stimulus to control responding under fixed ratio reinforcement in the squirrel monkey. Initially brief periods of nonreinforcement were lengthened only when discriminative control was evident. Discriminative control was studied by (1) varying the duration of nonreinforcement periods; (2) reversing the stimulus conditions correlated with reinforcement and nonreinforcement periods; and (3) determining the minimum shock intensity necessary to maintain discriminative control. Stimulus control was not reliably affected by *d*-amphetamine, chlorpromazine, or morphine. The discriminative control by pulses of low intensity electric shock was similar to that by other discriminative stimuli, except that the control developed slowly and was better when the pulsing shock was correlated with reinforcement than when correlated with nonreinforcement.

A stimulus that controls behavior through different behavioral processes is said to have separate functions or properties (Skinner, 1938, Ch. 6). The mode of behavioral control by a stimulus depends upon how it is scheduled; for example, Azrin (1958) used intense noise as a discriminative stimulus to control rate of responding, as a punisher to suppress ongoing behavior, and as a reinforcer to sustain ongoing behavior. Also, the way a stimulus modifies behavior can depend upon its intensity. Characteristically, low intensity lights and sounds are used as discriminative stimuli correlated with conditions of reinforcement and high intensity lights and sounds are used as reinforcers and punishers (Azrin, 1958; Kaplan, 1956).

Holz and Azrin (1961, 1962) found that the effects of brief response-produced electric shocks were greatly modified when shocks were selectively paired with periods of nonreinforcement or reinforcement. Response-produced shocks of low intensity that initially did not suppress responding did reduce responding when selectively paired with periods of extinction; conversely, response-produced shocks of higher intensity that initially did suppress responding were less suppressive, or actually enhanced responding when selectively paired with periods of reinforcement. Azrin and Holz (1966) suggest that the "discriminative properties" of response-produced shocks may have been involved in many previous experiments on punishment. In view of the theoretical importance of their analysis, it seemed desirable to study the discriminative control exerted by electric shock under conditions similar to those used to study the discriminative control exerted by other stimuli.

The present experiments attempted to establish pulses of low intensity electric shock as discriminative stimuli by correlating the presence (or absence) of the pulsed shock with a fixed ratio schedule of reinforcement. The pulsed shock had no discernible eliciting or punishing properties at the intensities used. The procedure differed from that used by Holz and Azrin (1961, 1962) in that the pulsed shock was not response-produced but rather was present throughout periods of reinforcement or nonreinforcement. Observations were also made on the effects of three drugs known to increase the intensity at which an electric shock is tolerated (Weitzman and Ross, 1962).

METHOD

Subjects

Four squirrel monkeys (S-59, S-62, S-76, and S-80) with no previous training and weighing

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between 700 and 1000 g under a regimen of free food and water were reduced to 80% of their free-feeding weights. They were maintained at 70% to 80% of free-feeding weight throughout the experiment.

Apparatus

A restraining chair similar to the one described by Hake and Azrin (1963) was used. The monkey was restrained in the seated position by a waist lock, and its tail held motionless by a small stock. Electric current could be delivered through the tail by two hinged brass plates which rested lightly on a shaved portion of the tail. The tail was massaged with a noncorrosive electrode paste (EKG Sol) to insure a low resistance electrical contact between the plates and the tail. The electric shock was 110 v ac, 60 cps, delivered to the plates through a series resistance of about 180 k ohms. The shock intensity was decreased by appropriately increasing the series resistance. During the periods of shock the pulses were 30 msec in duration and occurred every 300 msec.

The response key (Lehigh Valley Electronics rat lever, LVE 1352) was mounted on the right side of the front panel facing the monkey. When the key was pressed with a minimum force of 30 g, a response was recorded. Each response produced an audible relay click. Centered in the front panel was a circular recessed opening with a hole through which a solenoid-operated dipper provided access for 3 sec to 0.25 ml of liquid food (Ellison and Riddle, 1961). During food delivery the recessed opening was illuminated by two 6-w bulbs. The entire chair unit was enclosed in a ventilated soundproofed chamber (Industrial Acoustics Co. Model AC-3). White noise was always present. During the experiment the chamber was illuminated by a 25-w bulb. Conventional programming and recording equipment were used.

Procedure

Subjects were trained, with a food reinforcer, to press the key. Performance was maintained on a fixed-ratio schedule (FR) of reinforcement, which was gradually increased to 20 responses (10 responses for S-76). The fixed-ratio schedule was always programmed during one stimulus condition (S^D) that alternated with nonreinforcement periods during another stimulus condition (S^Δ). Except during initial training, sessions lasted 45 min.

The shock levels to be used as S^D or S^Δ were determined by applying the shock pulses to the experimenters' fingers. Shock levels which were detectable, but not uncomfortable (.5—.8 ma) were used. Pulsed shock, rather than continuous shock, was chosen, because the finger tests showed that low levels of continuous shock were not detectable after a few seconds.

The "shaping schedule" determining the occurrence of S^D and S^Δ periods was changed for each monkey as stimulus control by the electric shock developed. When the cumulative records indicated shorter S^D latencies and decreased S^Δ responding, the S^Δ periods were gradually lengthened.

S-59 (shock as S^Δ). After two sessions on FR 20, a 0.6-ma pulsed shock was introduced as S^Δ for 2.5 sec immediately after the end of each reinforcement cycle. The S^Δ period was lengthened by 2.5-sec steps over the next 10 sessions until it reached 30 sec. To eliminate responding in the latter portion of S^Δ periods, each response in the last 5 sec of S^Δ delayed termination of the S^Δ period by 5 sec. Gradually both the total duration of the S^Δ period and the portion of the period delayed by responses were increased. By session 55, the S^Δ periods were randomly presented for durations of 30 or 60 sec, and each response during the S^Δ period initiated the period again.

S-62 (shock as S^D). After seven sessions of FR 20, a 0.5-ma pulsed shock (S^D) was present at all times, except during the reinforcement cycle. In session 9, a 2.5-sec S^Δ period (no shock) was introduced at the end of each reinforcement cycle. As soon as S^Δ periods were introduced, responding during the terminal portion of S^Δ delayed its termination. Over the next 25 sessions the S^Δ periods were gradually lengthened. The shock intensity in S^D was changed to 0.6 ma. After session 37 the S^Δ periods were randomly either 30 or 60 sec with each response initiating the period again.

Monkeys S-76 and S-80 were trained with procedures found most effective with the other two monkeys. The most important features were that S^Δ periods varied randomly in duration when first introduced and that responses in an S^Δ period initiated the period again.

S-76 (shock as S^D). After three sessions on FR 10, a 0.6-ma pulsed shock was correlated with the FR condition. The duration of S^Δ

periods varied randomly, beginning with durations of 2 and 4 sec and over sessions gradually increasing to durations of 30 and 60 sec. Each response in S^{Δ} periods initiated the entire period again. By session 17, S-76 appeared to be under stimulus control with random presentations of S^{Δ} periods of 30 and 60 sec alternating with S^{D} periods correlated with pulsing shock.

S-80 (shock as S^{Δ}, then shock as S^{D}). After 12 sessions on FR 20 a 0.6-ma pulsed shock was introduced as S^{Δ} at the end of the reinforcement cycle. The S^{Δ} periods were initially 2 and 4 sec and over sessions gradually increased to 20 and 30 sec. Each response in an S^{Δ} period initiated the period again. The behavior of S-80 was poorly controlled by the shock as the S^{Δ} periods were lengthened. After 82 sessions with the pulsed shock as S^{Δ}, the stimulus conditions were reversed; the 0.6-ma pulsed shock was correlated with the fixed-ratio schedule and no shock was present during the S^{Δ} periods. After session 87 the S^{D} periods were terminated by reinforcement or after 1 min had elapsed. The S^{Δ} periods were gradually lengthened. By session 122, in which random presentations of 60- and 90-sec S^{Δ} periods alternated with S^{D} periods correlated with pulsing shock, S-80 appeared to be under stimulus control.

Additional Experiments

After stimulus control had been established with S^{Δ} periods of 30 and 60 sec, S^{Δ} durations were abruptly changed to 60 and 90 sec (first to 30 and 90 sec and then 60 and 90 sec for monkeys S-59 and S-60).

The effects of reversing the stimuli were also examined. On two occasions the stimuli were accidentally reversed for S-59. The stimuli were permanently reversed for S-80 when good stimulus control failed to develop. The effects of varying the intensity of the pulsed shock were also studied in monkeys S-59 and S-62.

Drugs were administered in mixed order to S-59 and S-62. *d*-Amphetamine sulfate, chlorpromazine hydrochloride, and morphine sulfate, dissolved in water, were injected in volumes of less than 1 ml over a 0.1 to 1 mg/kg (dosage as the salt) range. The drugs were injected intramuscularly 5 min before the session was to commence and not more often than twice weekly.

RESULTS

The presence and absence of the pulsed shock quickly developed some control over responding, though minimally for S-80. The S^{Δ} periods were initially brief and followed immediately after the reinforcement cycle ended. At this stage, the control of responding was undoubtedly multiply determined, in part by the pulsed shock and in part by introducing S^{Δ} immediately after reinforcement. There was no indication, however, that the pulsed shock had any discernible eliciting or punishing properties. When the S^{Δ} periods were longer and of variable duration all subjects responded in S^{Δ} periods despite attempts to introduce the pulsed shock in such a way as to minimize S^{Δ} responding.

The gradual development of discriminative control, characterized by decreased response latency in S^{D} periods and reduced responding in S^{Δ} periods, is illustrated by the cumulative records of Fig. 1 and 2. In Fig. 1 the pulsed shock was correlated with S^{Δ} periods (recording pen down) for S-59 and with S^{D} periods (recording pen up) for S-62. The top records show the first session in which the durations of S^{Δ} periods were randomly 30 and 60 sec. Both monkeys responded during many S^{Δ} periods and S-59 occasionally paused during an S^{D} period. Later performances at these same parameter values are shown in the middle records. Fewer responses occurred in S^{Δ} periods and S-62 seldom responded in S^{Δ} periods except at the beginning of each session. Monkey S-59 paused slightly in several S^{D} periods towards the end of the session. Representative terminal performances at S^{Δ} durations of 30 and 60 sec are shown in the bottom records. For S-59, some responding occurred in a few of the S^{Δ} periods, and a long pause occurred at *a* in an S^{D} period. For S-62 a few responses occurred at the beginning of S^{Δ} periods throughout the session; at *b* a response occurred late in an S^{Δ} period and delayed its termination.

Figure 2 shows the development of discriminative control for S-76 and S-80. For S-76 the pulsed shock was correlated with S^{D} periods; for S-80 the shock was correlated with S^{Δ} in the top record and with S^{D} in the middle and bottom records. Monkey S-76 quickly came under stimulus control. The top record shows the first session in which the duration of S^{Δ}

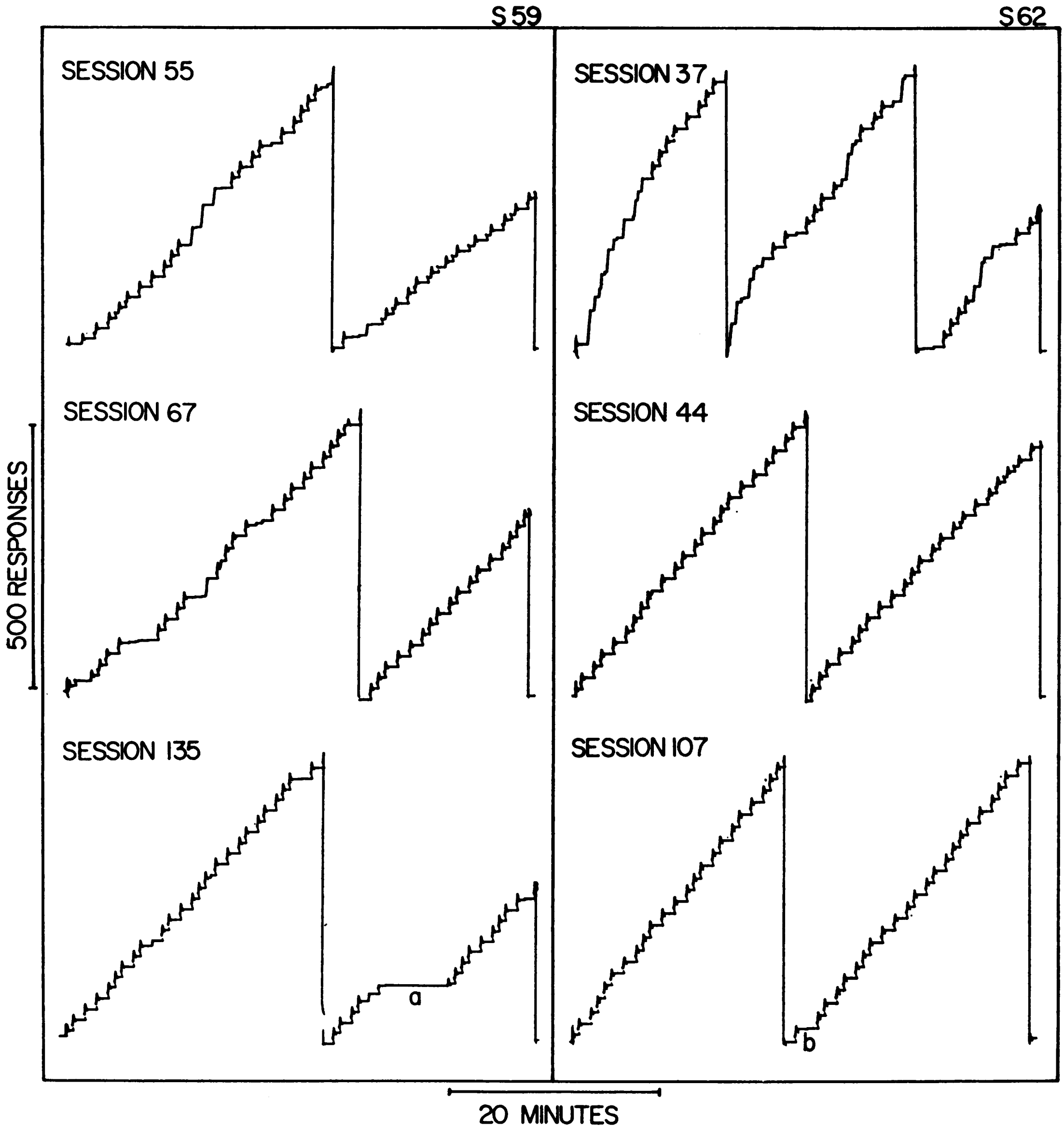

Fig. 1. Development of discriminative control by pulsed electric shock. The recording pen was displaced downward during S$^{\Delta}$ periods. The schedule of reinforcement during S^{D} periods was FR 20 and the S$^{\Delta}$ periods were either 30 or 60 sec in duration. A 0.6-ma pulsed electric shock occurred during S$^{\Delta}$ periods for S-59 and during S^{D} periods for S-62. See text for further explanation of figure.

periods was randomly 30 and 60 sec (session 12). There were responses in many S$^{\Delta}$ periods and a 5-min pause occurred in one S^{D} period. In session 14 (middle record), S-76 made only 10 responses during S$^{\Delta}$ periods. The bottom record (session 18) for S-76 shows the first session with S$^{\Delta}$ durations of 60 and 90 sec. There was a 1-min pause in the initial S^{D} period and some responses occurred in three of the S$^{\Delta}$ periods.

Stimulus control of responding did not develop in monkey S-80 with shock correlated with the S$^{\Delta}$ periods. The top record shows the last session with shock correlated with S$^{\Delta}$ periods; considerable responding occurred in almost all S$^{\Delta}$ periods. The middle record shows the performance on the next day after the pulsed shock had been correlated with the S^{D} periods. Responding occurred throughout the session in S$^{\Delta}$ periods, and during S^{D} periods

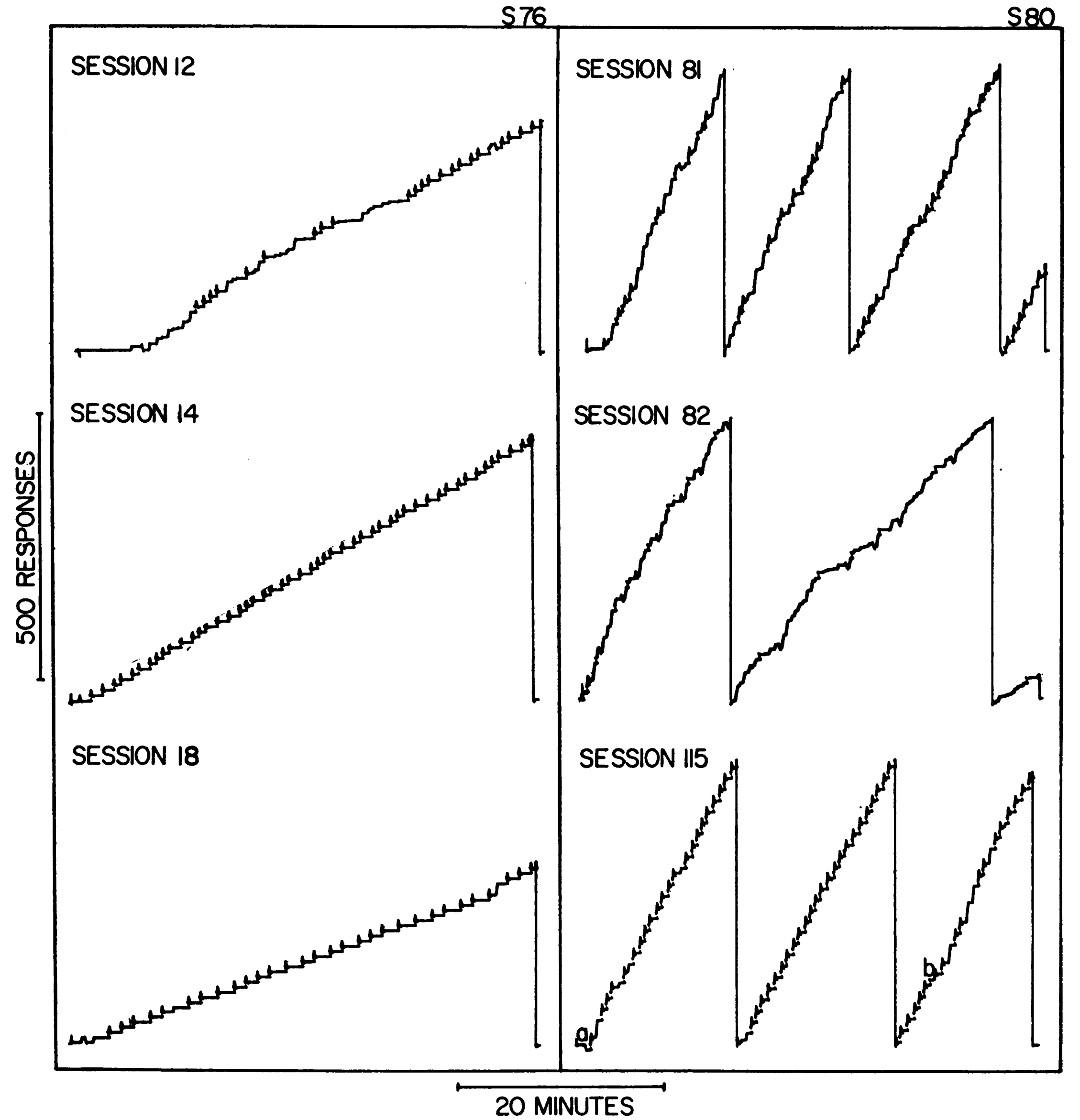

Fig. 2. Development of discriminative control by pulsed electric shock. Recording as in Fig. 1. For S-76, the discriminative control by the pulsed shock of 0.6 ma correlated with S^D periods developed rapidly. The schedule was FR 10 during S^D periods and the durations of S^Δ periods were 30 and 60 sec in sessions 12 and 14, and 60 and 90 sec in Session 18. For S-80 the schedule was FR 20 in S^D periods and the durations of S^Δ periods were 20 and 30 sec. Session 81 was the last day in which the pulsed shock of 0.6 ma was correlated with S^Δ periods; responding occurred during many of the S^Δ periods. Beginning with session 82, the pulsed shock was present only during S^D periods. Initially the performance was disrupted (session 81), but subsequently (session 115) responding came under the discriminative control of the pulsed shock during S^D periods. See text for further explanation of figure.

the monkey often stopped responding before 20 responses were emitted. During subsequent sessions, with shock correlated with S^D periods, the number of responses in S^Δ periods increased further and the rate of responding in S^D periods became lower still, suggesting that some discriminative control had indeed developed under the original conditions. The bottom record shows the terminal performance at S^Δ durations of 20 and 30 sec. Though responding occurred in some S^Δ periods, discriminative control is clear. At *a*, the S^D period ended without a response, and at *b*, there was an initial pause; otherwise S-80 began responding at the start of each S^D period.

The pulsing shock developed discriminative control better when it was correlated with S^D periods than when correlated with S^Δ periods. This is shown both by the change in the performance of S-80 when the conditions were reversed and by a comparison of the developing performances of S-59 and S-62 in Fig. 1.

The behavioral control exerted by the pulsed shock continued to improve during the drug experiments, the experiments on variation in S^Δ duration, and the experiments on shock intensity. Representative performance at the termination of the experiment are shown in Fig. 3. In all instances responding began at the start of each S^D period and was maintained at a high rate until reinforcement was delivered. Monkeys S-59 and S-76 made virtually no responses during S^Δ periods. Occasionally, both S-62 and S-80 responded a few times at the beginning of an S^Δ period, and at *a*, S-80 responded late in an S^Δ period.

Further Evidence of Stimulus Control

Some indication of the degree of discriminative control exerted by the presence or absence of the shock can be seen in the performance immediately after changes in the S^Δ durations. After stable performances had developed at S^Δ durations of 30 and 60 sec, the S^Δ periods were increased to 60 and 90 sec (for S-59 and S-62 the S^Δ durations were first changed to 30 and 90 sec for three sessions and then to 60 and 90 sec). The characteristics of responding in S^D and S^Δ periods before and after the change to the 60- and 90-sec parameter values are shown in Table 1. In no instance did changing the duration of the S^Δ periods disrupt the control that had developed in the presence and absence of the shock. Figure 4 shows cumulative records for S-59 immediately before and after changes in the duration of S^Δ periods. The discriminative control during the first session after S^Δ was increased to 30 and 90 sec is less than on the day before, but the control during the first session with durations of 60 and 90 sec is better than on the day before. There is no evidence in these records that lengthening the S^Δ periods disrupted the performance.

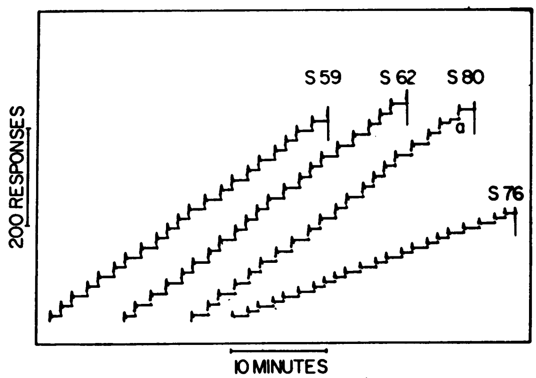

Fig. 3. Performances of four monkeys under the discriminative control of pulsed electric shock. Recording as in Fig. 1. The schedule of reinforcement during S^D periods was FR 20 (FR 10 for S-76) and S^Δ periods were either 60 or 90 sec in duration. A 0.6-ma electric shock of 30 msec duration occurred every 300 msec during S^Δ periods for S-59 and during S^D periods for S-62, S-76, and S-80. The recording pen was displaced downward during S^Δ periods. Each monkey began responding at the start of each S^D period and except at *a*, responses never occurred during the terminal part of S^Δ periods. (Sessions 190, 165, 104, and 134 for S-59, S-62, S-76, and S-80, respectively.)

Table 1

Effects of changes in S^Δ duration on rate of responding in S^Δ and S^D and response latencies in S^D.

Subject	*Session*	*Parameter S^Δ in sec*	*Responses/sec S^D*	*Responses/sec S^Δ*	*% S^D latencies below 4 sec*	*Number of S^D latencies above 18 sec*
S-59	140	30 & 90	3.50	.04	97	0
	141	60 & 90	3.47	.06	97	0
S-62	122	30 & 90	3.81	.10	97	0
	123	60 & 90	4.02	.04	97	0
S-76	17	30 & 60	1.34	.00	77	1
	18	60 & 90	1.25	.02	77	1
S-80	121	30 & 60	2.18	.07	96	1
	122	60 & 90	2.55	.05	98	1

Another indication that the pulsed shock had developed discriminative control of responding came from experiments in which the shock conditions correlated with S^D and S^Δ periods were reversed. The pulsed shock had initially been correlated with S^Δ periods for S-80; when satisfactory discriminative control did not develop, the stimulus conditions were reversed. The performance after reversal indicated that the previous stimulus conditions had developed some control (see Fig. 2). In two instances the pulsing shock was accidentally correlated with S^D periods for part of a session for S-59. Figure 5 shows the performance when the stimulus conditions were reversed at the start of a session. Responding did not occur for several minutes in the first S^D period. After the first reinforcement, responding during the next S^Δ period was marked by bursts characteristic of the usual S^D rate. When S^D finally occurred again, S-59 failed to resume responding. At this time the normal stimulus conditions were reinstated (at the arrow) and the usual session continued. This record shows a degree of discriminative control by the presence and absence of the pulsed shock that was characteristic at this stage.

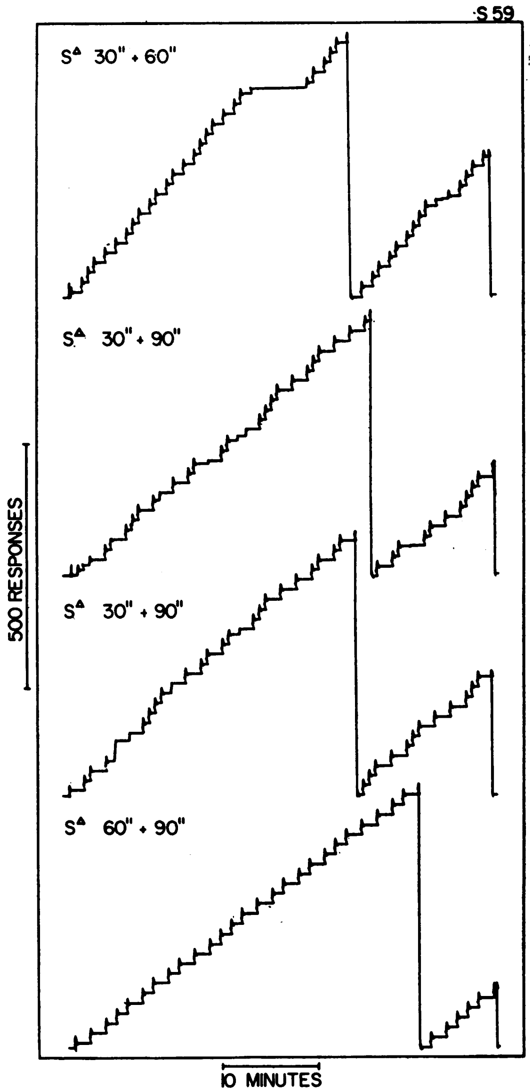

Fig. 4. Influence of S^Δ duration on the discriminative control by pulsed electric shock correlated with S^Δ periods. The schedule during S^D periods was FR 20 (recording pen up). The top two records show respectively the last session with S^Δ durations of 30 and 60 sec, and the next session with S^Δ durations of 30 and 90 sec. The bottom two records show respectively the last session with S^Δ durations of 30 and 90 sec and the next session with S^Δ durations of 60 and 90 sec. Note that the performance was not disrupted by the increase in S^Δ duration to 60 and 90 sec.

Variation in Shock Intensity

The minimum shock intensity under which control of responding could be maintained was determined for S-59 (shock as S^Δ) and S-62 (shock as S^D). Every other day the monkeys were tested with a shock intensity of 0.6 ma, the intensity at which they had been trained. In alternate sessions the monkeys were tested at progressively lower shock intensities (one sesison at 0.5 ma, one at 0.4 ma, *etc.*) until discriminative control was lost. The rates of

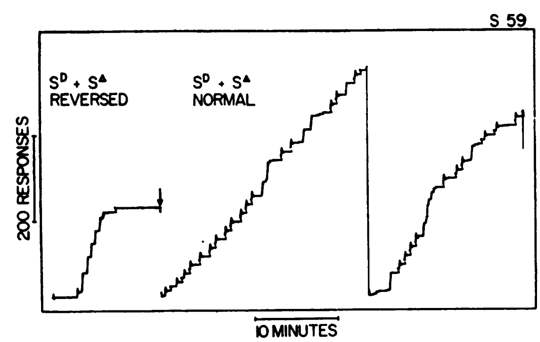

Fig. 5. Effect of reversing S^D and S^Δ stimulus conditions. The schedule had been FR 20 in S^D periods alternating with S^Δ durations of 60 and 90 sec correlated with the pulsed shock. At the start of the session the pulsed shock was present during the S^D periods and not during S^Δ periods (recording pen displaced downward). Responding occurred mainly in the absence of the shock, which had been the S^D condition but was now the S^Δ condition until the normal stimulus conditions were reinstated.

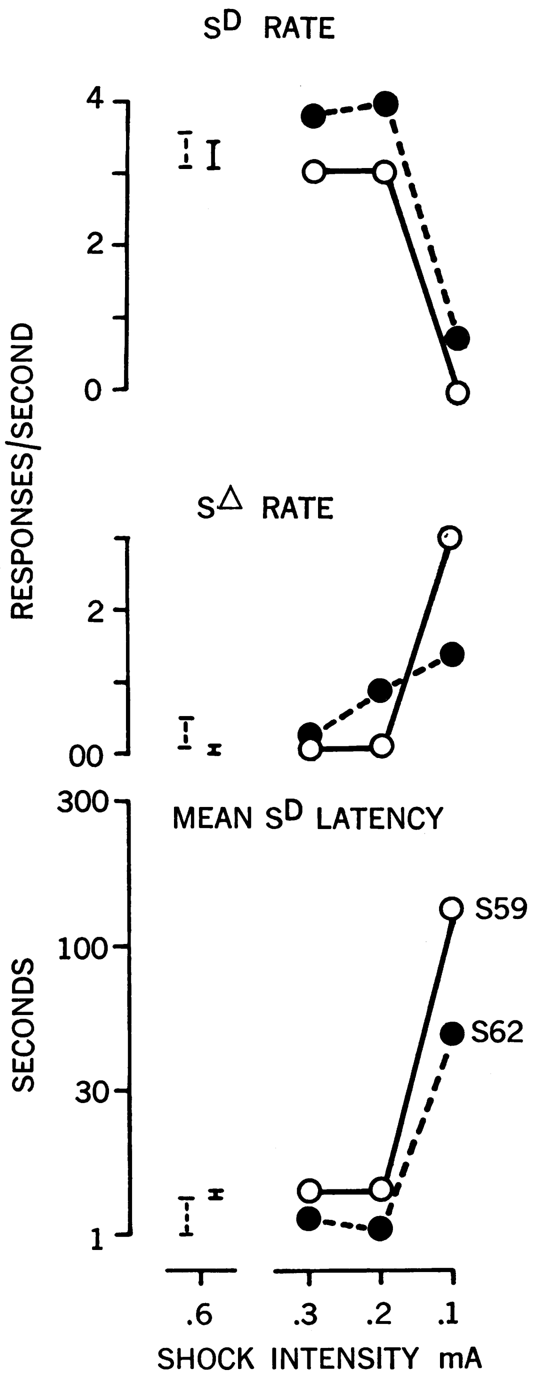

Fig. 6. Discriminative control by pulsed shock at different shock intensities. The pulsed shock was present during S^D periods for S-62 and during S^Δ periods for S-59. The upper two graphs show the rate of responding during S^D periods and during S^Δ periods as the shock intensity was decreased down to 0.1 ma. The bottom graph shows the mean S^D latency at decreasing shock intensities. All aspects of discriminative control were affected at the 0.1 ma shock intensity.

responding during the S^D and S^Δ periods and the mean S^D latencies have been plotted in Fig. 6 at different shock intensities. There was no loss in stimulus control in either monkey with shock intensities as low as 0.3 ma. At the 0.2 ma intensity, S-62 responded more during S^Δ periods; during S^D periods the monkey responded with the usual short latency and high fixed ratio rate. At an intensity of 0.1 ma all aspects of the performances of both monkeys were affected. The performances were characterized by long latencies in S^D periods before completion of the FR 20 at a high rate; responding during S^Δ periods before completion of the FR 20 at a high rate; responding during S^Δ periods increased for both monkeys. The loss of control at the 0.1 ma intensity suggests that a threshold value for the pulsed shock as a discriminative stimulus falls at about 0.1 ma. It did not seem to matter whether the shock functioned as the S^D or the S^Δ stimulus.

Drug Experiment

Morphine and chlorpromazine had slight and inconsistent effects on responding below doses that abolished responding completely. Amphetamine increased responding during S^Δ periods on some occasions and suppressed it at other times, as shown in Table 2. Although graded dose effects with amphetamine were not obtained, increased responding during S^Δ periods relative to S^D periods was evident for both monkeys. Figure 7 shows cumulative response records of increased responding during S^Δ periods under amphetamine. In the record for S-62, sustained responding postponed termination of the first S^Δ period for 10 min; responding was disrupted in the next two S^D periods and then ceased entirely.

DISCUSSION

The present experiments show that responding came under the discriminative control of a pulsing electric shock correlated either with periods of reinforcement under a fixed ratio schedule or with periods of nonreinforcement. The results suggest that the control developed better when the pulsing shock was correlated with the S^D condition than when it was correlated with the S^Δ condition.

We do not know why responding only slowly came under control of the pulsed shock. Among others, Terrace (1963) has shown that

Table 2

Rate of responding in S^D and S^Δ following saline and *d*-amphetamine.

		S-59		S-62	
	Dose	*Responses/sec* S^D	*Responses/sec* S^Δ	*Responses/sec* S^D	*Responses/sec* S^Δ
Saline		1.44	0.02	3.03	0.06
		3.42	0.02	3.76	0.05
		3.77	0.02	3.00	0.08
d-Amphetamine	0.1 mg/kg	3.02	0.31	2.88	0.05
	0.3 mg/kg	0.15	0.03	0.07	0.09
	0.1 mg/kg	3.55	0.12	0.03	0.29

the condition under which stimuli are presented and the intensities of the stimuli can greatly change the development of stimulus control. Since these were initial experiments using low intensity pulsing shock as a discriminative stimulus, it would hardly be expected that all the conditions of the experiment would be optimum, although an attempt was made to choose the procedures and parameters known to be effective for developing stimulus control (Blough, 1958; Terrace, 1963). The shock parameters of 30-msec pulses initiated every 300 msec were chosen partly because the punishing effect of 30-msec pulses following responses had been studied in other experiments (Morse, 1964; Kelleher and Morse, 1964) and partly because no change was observed in the perceived intensity of pulses at this frequency when we tested ourselves.

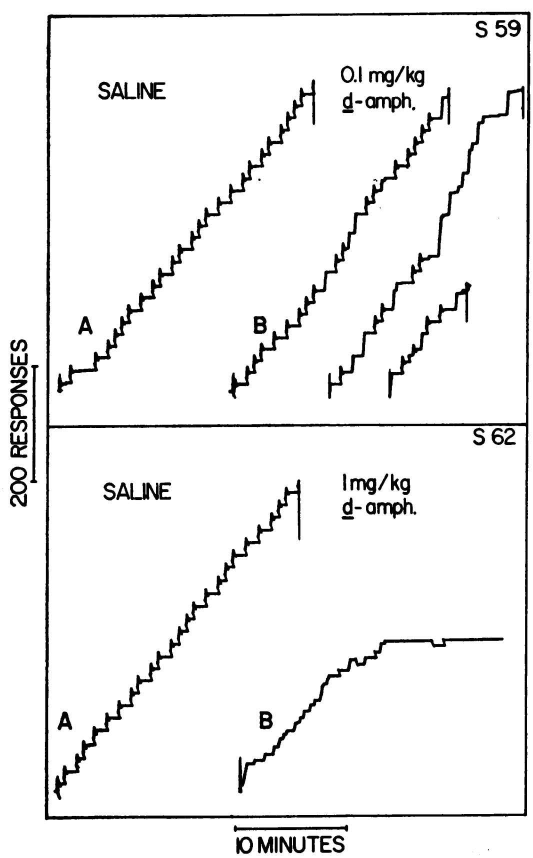

Fig. 7. Sample performances following *d*-amphetamine. Recording as in Fig. 1. The records were chosen to illustrate instances of increased responding during S^Δ periods following *d*-emphetamine. The pulsed shock was present during S^Δ periods for S-59 and during S^D periods for S-62.

The use of electric shock as a discriminative stimulus may be restricted by its inherent characteristics. The range over which electric shocks can be used as a discriminative stimulus without also modifying behavior through the processes of reinforcement or punishment is narrow. When pulsing electric shocks were delivered through brass plates lying on the experimenter's finger, the range of discernible but not unpleasant intensities was only about three-fold. Little is known about how the stimulus parameters of electric shock modify its behavioral effect. For example, adaptation quickly occurs to the eliciting effects of continuously presented alternating current. The performance of S-59 and our estimations of the intensity of the pulsed shock make it unlikely that adaptation to the pulsed shock weakened its discriminative control in these experiments. The S^D and S^Δ periods differed in that the S^D periods ended with presentation of the reinforcer and a change in the shock condition, whereas S^Δ periods ended only with the change in the shock condition. Thus, if there were a difference between the control by the onset and by the termination of the pulsed shock, it would give a plausible explanation for the greater effectiveness of the shock as S^D than as S^Δ.

The three drugs studied all affect responses to noxious stimuli (Weitzman and Ross, 1962), so they were examined on the chance that they might modify control by the shock. That none of the drugs had a dose-dependent effect on the stimulus control is consistent with previous results. The drug experiments were begun only after the discriminative performances were well developed, and the drug-produced attenuation of stable stimulus control is usually slight (Dews, 1955; Kelleher, Riddle, and Cook, 1962).

The present experiment used procedures modeled after those used in other studies on stimulus control to study the discriminative control of responding by low intensity electric shock. Previously, Holz and Azrin (1961, 1962) found interactions between the discriminative and punishing properties of response-produced electric shock. Although the use of a stimulus to control behavior through one behavioral process may simultaneously involve other behavioral processes, separate stimulus functions are typically studied using different procedures. In studying interactions between different properties of a stimulus, it is desirable to be able to isolate and control the separate properties experimentally. The present experiments established conditions under which low intensity pulses of electric shock correlated with periods of reinforcement developed discriminative control. The eventual control by the pulsed shock was similar to that of other discriminative stimuli, except that the control developed slowly and was more effective when the pulsed shock was correlated with reinforcement periods than when correlated with nonreinforcement.

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