BRIEF EXPOSURE TO CONTINGENT REINFORCEMENT PRODUCES A SUSTAINED INCREMENT IN THE STRENGTH OF AN ELICITED RESPONSE

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Squirrel monkeys' lever pressing produced by response-independent shock was measured before, and for an extended period following, exposure to a shock-avoidance procedure. Following avoidance training, the frequency of responding increased by multiples of 10 to 50 across subjects and evidence little or no decrement for up to 6 months of postreinforcement testing. Manual responding produced by intense environmental stimulation may be substantially strengthened by a brief history of reinforcement, such that it is sustained over long periods without reinforcement.

Key words: response-independent shock, avoidance, reinforcement history, noxious stimuli, shock postponement, shock, biting attack, lever press, squirrel monkeys

The delivery of noxious stimuli can directly produce several distinct classes of complex responding. Biting attack (Azrin, Hutchinson, & McLaughlin, 1965; Hutchinson, Azrin, & Hake, 1966), drinking (Hutchinson & Emley, 1977), eating (Antelman & Szechtman, 1975), and copulation (Caggiula & Eibergen, 1969) have each been demonstrated to occur promptly following discrete episodes of noxious stimulation. Maintenance of such behavior seems not to depend upon consequences of the behavior, for in restricted environments where explicit response consequences are limited or absent, noxious stimuli or previously neutral stimuli that have accompanied noxious events still can reliably evoke tactile and manipulative responses. For example, primate subjects have manually pressed a lever or pulled a chain following shock or during preshock stimuli even though minimal contingent environmental stimulation resulted. Such patterns may be produced at steady, substantial levels for months or years without decrement (Hutchinson, 1977; Hutchinson, Renfrew, & Young, 1971). The high probability and short latency of such reactions fol-

lowing stimulation provide apparent evidence of a reflex relationship. Further evidence for such a view is provided by the finding that such responses can be conditioned in discrete form by classical, or Pavlovian, conditioning procedures. Thus, originally neutral stimuli after temporal correlation with noxious stimulation can come to produce at least one class (biting) of these behavior patterns (Hutchinson et al., 1971). Yet the topographic form of such reactions is not invariant. Both the performances of physical approach to and contact with animate or inanimate environmental stimuli are influenced by momentary variation in response-consequent environmental stimulation. For example, if alternate environmental stimuli differing in texture, size, or proximity are available, preliminary approach responses will shift appropriate to specific environmental options (Azrin et al., 1965) and the ensuing performance, such as biting attack, may also change in relation to the availability, over space or time, of particular features of the environment (Azrin, Hutchinson, & Sallery, 1964).

Although previous investigations have demonstrated that approach and contact performances elicited by intense stimulation may be strengthened by contingent reinforcement (Brogden, Lipman, & Culler, 1938; Hutchinson & Renfrew, 1978; Konorski & Miller, 1937), what effect brief instatement of such procedures might have upon later extended tests of evoked performances has not been examined. The purpose of the present experi-

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ment was to assess the effect of relatively brief exposure to a shock-postponement contingency upon subsequent shock-produced lever-pressing behavior during an extended later period when the postponement contingency was no longer in effect.

METHOD

Subjects

Three adult (1 male MC-1, 2 females MC-26 and MC-29) squirrel monkeys (*Saimiri sciureus*) weighing 850 to 1,000 g were tested over a series of daily sessions. Subjects were maintained on ad-libitum food and water in temperature- and humidity-controlled colony home cages. The test chamber permitted the measurement of biting attack and manual lever pressing during schedules of periodic delivery of brief electric shocks. All subjects had previous histories of response-independent shock testing during earlier experiments that studied the effects of drugs on these reactions.

Apparatus

The test chamber consisted of a 30.5 by 22 by 52-cm space in which the subject was temporarily restrained in a seated position by a waist panel. The upper torso, head, and arms remained free while the feet rested on a 1-cm-diameter rod. A stockade device allowed electrode placement upon the shaved and cleansed, electrode-paste treated, distal portion of the tail. A 3-cm-wide response lever was mounted 10 cm above the waist panel, 1.5 cm to the left of center and protruding 1.5 cm into the chamber. The lever required a downward force of 0.21 N for a response to be recorded. Each response produced an audible click of a relay mounted on the rear side of the intelligence panel. Suspended between the right and left walls of the chamber, 20 cm above the waist panel and 9 cm in front of the subject, was a gum-rubber hose of 1-cm inner diameter and wall thickness of 0.25 cm. This hose was connected to a pressure-wave sensing switch adjusted to selectively detect biting-attack responses. Although it was physically possible for a subject to actuate the manual response lever by biting, frequent visual observation verified that all biting was directed at the rubber hose. Electric shock of 400 V ac was delivered for 200 ms through a series resistance of 50 k Ω . The constant-current features of the stimulator circuit and stable sub-

ject resistance values produced a current level of 7.5 mA. The test chamber was enclosed in a sound-attenuating, temperature-controlled cubicle and was remotely connected to a programming and recording apparatus in an adjoining room. Experimental sessions were conducted Monday through Friday at the same time each day.

Procedure

The testing sequence involved measurement of hose biting and manual lever pressing during sessions of response-independent shock, during sessions in which manual lever pressing could avoid a shock, and during a return to sessions of response-independent shock. During both initial and final testing phases, shocks were delivered by a clock every 4 min. A 4-min observation period following the final shock resulted in a session length of 64 min. In the middle phase, Sidman's (1953) avoidance procedure was used: If manual lever pressing did not occur within a specified time (response-shock [RS] interval), shocks were delivered periodically (shock-shock [SS] interval) until a response did occur. Additional responses reset the response-shock timer, thus postponing the shock. Avoidance sessions were 60 min in length. As described below, several RS and SS intervals were used during the intermediate avoidance phase. The rubber hose was occasionally removed to assess the influence upon manual responding of the absence of the opportunity to attack.

RESULTS

During initial testing for each subject, the delivery of response-independent shock produced both biting and lever pressing (Hutchinson, 1977; Hutchinson & Emley, 1972; Hutchinson et al., 1971). After each shock, subjects grasped the rubber hose and commenced biting for 10 to 30 s, biting 1 to 10 times after each shock. Following shock, subjects might also manually depress the lever several times. Later, as shock time approached, subjects occasionally reached forward and down with the right or left hand and began recurrently depressing the lever from 0 to 7 times. For 2 monkeys, lever pressing was progressively more frequent as shock time approached, producing a positively scalloped temporal pattern, although decelerations in response rate occasionally were noted

Fig. 1. Left: Frequency of lever pressing over consecutive days of the three-phase experiment. Filled circles indicate five-session averages of total responses per session during response-independent shock delivery. Unfilled circles indicate five-session averages of responding during avoidance conditioning. Right: Individual daily records of lever pressing for Subject MC-29 on the last day of initial response-independent shock (Day 25), the last day of shock-avoidance reinforcement (Day 52), and on Day 10 and Day 150 following return to response-independent shock. The downward deflections of the record indicate delivery of shock. The intershock interval is 4 min, except in the record of avoidance responding.

just prior to shock delivery. The average rates in each minute of the 4-min intershock interval for the last five sessions of the preliminary response-independent shock condition were MC-1: 2.96, 0.74, 2.96, 47.4 R/hr; MC-26: 20.74, 2.96, 4.44, 2.96 R/hr; MC-29: 4.44, 0, 16.29, 52.59 R/hr. Because each subject had extensive earlier exposure to identical schedule conditions immediately preceding the present tests (MC-1, 851; MC-26, 758; MC-29, 765 sessions), the positively accelerated pattern of lever pressing late in the intershock intervals was evident from the beginning of the current experimental series. The number of baseline sessions conducted under this phase for each subject and the numbers of bite and lever-press responses recorded are presented

in the upper portion of Table 1. Table 1 presents lever-press and hose-bite data for each subject in each phase of the experiment. For purposes of condensation, data are, where possible, presented as average daily response rates (responses per hour) computed across blocks of five sessions.

Average rates of lever pressing in the first experimental phase varied between 7/hr and 28/hr for the 3 subjects, as indicated in Table 1 and in the left portion of Figure 1. Biting attack averaged between 133/hr and 271/hr. A typical record of stable lever pressing for Subject MC-29 is illustrated in the lower right portion of Figure 1.

Avoidance conditioning of lever pressing was next begun for each subject with a shock-shock

Table 1

Bites and lever presses per hour, and numbers of sessions in each condition, for each of 3 monkeys. Where possible, data are presented as average daily response rates computed across blocks of five sessions. NA indicates that the hose had been removed and was not available.

Condition	MC-1		MC-26		MC-29	
	Lever		Lever		Lever	
	Bite	press	Bite	press	Bite	press
4-min FT shock	18 sessions		30 sessions		25 sessions	
	150	11	170	11	251	14
	133	15	171	7	271	12
	161	15	166	9	256	19
			171	8	231	28
			177	7	157	20
			145	8		
Avoidance						
60-s SS, 60-s RS	22 sessions		5 sessions		5 sessions	
	146	50	363	25	391	50
	54	187				
	21	304				
	9	406				
30-s SS, 60-s RS			3 sessions		3 sessions	
			330	34	453	138
10-s SS, 60-s RS			5 sessions		19 sessions	
			NA	88	NA	225
					NA	269
					NA	295
					NA	262
4-s SS, 60-s RS			38 sessions			
			NA	124		
			NA	131		
			NA	197		
			NA	253		
			NA	357		
			NA	334		
			NA	408		

Table 1 (Continued)

Condition	MC-1		MC-26		MC-29	
	Lever		Lever		Lever	
	Bite	press	Bite	press	Bite	press
4-min FT shock	118 sessions		62 sessions		102 sessions	
	75	579	81	588	168	279
	112	266	102	453	160	377
	92	145	157	464	286	383
	83	289	191	539	291	400
	68	253	192	492	267	351
	89	237	231	476	253	315
	65	240	238	466	266	365
	59	190	262	438	219	319
	59	149	221	502	173	316
	67	214	208	494	152	223
	68	192	284	585	227	223
	78	168	260	508	222	219
	65	130	242	542	202	241
	67	151	NA	548	243	274
	84	168	NA	432	300	303
	71	180	NA	479	286	363
	71	138	254	498	277	314
	62	138	269	517	278	325
	64	170	369	542	205	267
	64	203	364	496	221	279
	68	154	275	540	NA	362
	81	144	323	485	NA	293
	80	171	323	603	NA	272
	62	148	341	522	141	375
	NA	191	392	580	223	450
	NA	209			250	381
	NA	176			235	366
	66	99			163	437
	83	114			216	382
	97	116			183	335
	91	94			217	351
	80	97			222	450
	67	81			230	388
	70	94				
	69	110				

interval (time between shocks in the absence of responding) of 60 s and a response-shock interval (time each response postponed shock) of 60 s. The bite hose was present for all subjects during initial tests. For 1 subject (MC-1), lever pressing soon increased to higher frequencies such that by Day 20, responding at a rate of approximately 400 lever presses per hour had reduced shock frequency to 1.6/hr. Biting attack following shock was consequently also reduced to low levels. For the other 2 subjects, avoidance conditioning proceeded more slowly and conditions were altered. The hose was removed to reduce available response alternatives and the SS interval was reduced to increase both the response-absent shock frequency and the discrimina-

bility of response-produced change in shock frequency. Under these conditions, Subjects MC-26 and MC-29 each developed efficient lever-press avoidance. By Day 51, MC-26's responding had stabilized at approximately 420 lever presses/hr and 1.3 shocks/hr. By Day 27, MC-29 evidenced 245 lever presses/hr, reducing shocks to 0.5/hr. The final stable pattern of avoidance performance for an entire session for Subject MC-29 is illustrated in the right portion of Figure 1. At this point, all 3 subjects were returned to the original 4-min response-independent shock schedule with the bite hose present. Lever pressing did not return to levels originally evoked by shock. Rather, for each subject, responding was now elevated approximately tenfold for MC-1 and

by multiples of 50 for MC-26 and 25 for MC-29.

Continued daily testing over a period of from 4 to 6 months demonstrated persistent responding. Although MC-1 evidenced some decrease in response rate over 6 months to levels five times greater than those prior to avoidance training, Subjects MC-26 and MC-29 displayed no response decrement over 4 and 5 months, respectively. These effects are illustrated in Table 1 and in the left portion of Figure 1. For each subject a positively accelerated temporal pattern of lever pressing was noted in postavoidance tests, as it was before avoidance contingencies were in effect. After avoidance, the average rates in each minute of the 4-min inter shock interval for the first five sessions of the response-independent shock condition were MC-1: 111.1, 374.8, 1042.96, 618.52 R/hr; MC-26: 228.1, 418.5, 947.4, 584.4 R/hr; MC-29: 117.7, 240, 386.6, 288 R/hr. Postshock biting attack was increased in postavoidance tests for Subject MC-26, biting was unchanged for Subject MC-29, and biting decreased for Subject MC-1. Removal of the bite hose for 15 sessions during the last experimental phase produced slight temporary elevations in lever-press responding for 2 subjects (MC-1 and MC-29). In general, these findings demonstrate that a marked, long-term elevation in evoked, temporally patterned responding can be produced by interposition of a brief history of response-contingent shock postponement.

DISCUSSION

The instatement of the avoidance contingency in the present series resulted in subjects being initially exposed to more frequent shock delivery. As avoidance performance later developed, shock frequency was reduced to near-zero levels for extended periods. Thus a question arises as to whether later increases in evoked responding observed in the third phase of testing were the result of (1) the interposition of a history of more frequent shock or (2) an extended period of additional shock delivery, rather than being the result of the history of response-contingent shock reduction. Several factors argue against these alternative possibilities. In the present experiment, although for Subject MC-26 the frequency of biting increased following exposure to the avoidance procedure, the other 2 subjects

showed little or no change in biting across the final extended series of sessions with response-independent shock. Thus, no general pattern of enhanced effects due to time or shock was found for a separate shock-evoked response that was not afforded a history of negative reinforcement. In addition, each subject had been tested daily under identical response-independent shock conditions for over 750 days prior to the beginning of the present series, and responding had remained stable for this extended period. Further, our prior research has shown that increased shock frequencies actually produce response habituation rather than behavior increases (Hutchinson, 1973, 1977; Hutchinson et al., 1971).

Two additional features of these results may deserve comment. Monkeys MC-26 and MC-29 are female and each was exposed to the avoidance-conditioning procedures in the absence of the bite hose. These 2 subjects demonstrated the greatest elevation in evoked lever pressing. Although we have occasionally observed high levels of evoked lever pressing by female subjects in earlier studies, the effect has not been consistent. Additional research is necessary to explore the possibility of gender differences. Alternatively, removal of the opportunity for bite attack has been found to increase both postshock and preshock evoked lever pressing (Hake & Campbell, 1972; Hutchinson, 1977; Hutchinson & Emley, 1972) in a manner similar to increases in shock intensity. However, no carry-over effects to later test periods have been noted. Thus, it is at least possible that the absence of the opportunity to attack during the avoidance schedule contributes to the subsequent influences upon avoidance demonstrated here. Again, further research is necessary to test this possibility. Nevertheless, inasmuch as both male and female subjects demonstrated these sustained increases after avoidance, with or without availability of the opportunity to attack, the history of shock postponement is shown to be a sufficient condition for the subsequent long sustained elevations in the evoked manual responding.

Several previous studies have reported sustained responding following termination of a shock-avoidance contingency during periods of continued shock or shock-correlated stimulus delivery (Herrnstein & Sidman, 1958; Kelleher, Riddle, & Cook, 1963; Sidman,

Herrnstein, & Conrad, 1957; Waller & Waller, 1963). In those studies, original examination of behavior began with the operant conditioning of lever pressing or panel pressing with reinforcement via food delivery and/or shock avoidance. Because response-independent shock delivery was not arranged prior to conditioning, the direct production of responding by shock and shock-correlated stimuli was not observable. The responding later noted following discontinuation of the avoidance contingency was therefore regarded as the original result of avoidance conditioning, and its continuing strength was attributed to ongoing superstitious reinforcement. Kelleher et al. (1963), however, noted several features of such results that are not readily compatible with a superstition analysis. The present results demonstrate the initial existence of evoked response strength prior to avoidance conditioning, and the substantial and sustained increase in strength of an evoked performance of essentially identical topographic and temporal character subsequent to delimited reinforcement experience. It is thus most parsimonious to view the effect of the operant reinforcement history as influencing the overall strength, but not the existence or the temporal or topographic pattern, of the behavior.

The current experiments demonstrate that the continuing direct production of manual responding by intense environmental stimulation is substantially increased for prolonged periods by a brief history of exposure to contingent reinforcement. Such functional relationships may be important in understanding and predicting responding that occurs either in the absence of contemporary or recent contingent positive reinforcers, or that continues in the presence of contingent negative reinforcers.

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