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CHAINING AND SECONDARY REINFORCEMENT BASED ON ESCAPE FROM SHOCK[1]

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Three white rats were trained to press a bar while being shocked. This produced a white noise. After 30 sec they were allowed to terminate both the shock and the noise by nosing a pigeon key. Comparison of the rates of pressing before and after the onset of the noise indicated that the noise itself was the immediate reinforcing agent for pressing. Furthermore, control tests showed that pressing was maintained only if it produced the noise: either omission of the noise or elimination of the dependency of the noise on the occurrence of the response led to a gradual abolition of pressing. When automatic termination of the shock was substituted for the key nosing requirement, however, only the key nosing extinguished. This indicated that the effectiveness of the noise as a reinforcer did not depend on its status as a discriminative stimulus for some other form of operant behavior.

INTRODUCTION

Casual observation would suggest that a sequence of behavior leading to the termination of shock should be as easy to establish and maintain as a comparable chain leading to the production of food. Furthermore, the establishment and maintenance of such a chain would imply that much of the behavior involved must be supported by positive secondary reinforcement, as in the appetitive case. And yet, previous attempts to demonstrate the specific point that stimuli associated with the termination of shock can acquire reinforcing properties have usually led to negative results. Moreover, such positive findings as have been reported have been subjected to severe criticism by Nefzger (1957), Hughes (1959), and, in a careful review of the literature, by Beck (1961). Beck's conclusion is that "there is almost no evidence to show that secondary reinforcement can be established by the association of a neutral stimulus with noxious-drive reduction" (p. 43). It is the purpose of the present report, then, to provide evidence previously lacking for this relationship.

METHOD

Without an effective procedure to serve as a basis of comparison, it is impossible to say why a given procedure is not effective. We therefore not only surveyed previous work on escape behavior and on appetitively derived secondary reinforcement but also conducted additional pilot work to obtain preliminary indications of the best procedure to use.

To obtain sufficiently large and sufficiently long-continued effects for convenient study, it seems to be necessary in most cases to maintain the effectiveness of the secondary reinforcer by continued association with the primary reinforcer. Furthermore, a number of writers have suggested that in the appetitive case, at least, "in order to act as an S^r [secondary reinforcer] for any response, a stimulus must have status as an S^D [discriminative stimulus] for some response" (Keller & Schoenfeld, 1950, p. 236). These considerations led us to examine the operation of secondary reinforcement within an intact chain of behavior, in which one response produces and is maintained by the discriminative stimulus for another response.

To keep the two performances as independent as possible of one another, we selected two forms of behavior that appeared to have little overlap: depressing a bar for the secondarily reinforced member of the chain and nosing a pigeon key for the primarily reinforced member. The bar and the key were placed at opposite ends of the box. For the

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secondary reinforcer we chose a stimulus that should be relatively uniform throughout the box and should therefore be difficult for the animal to avoid—namely, white noise.

Previous experience and direct pilot work with escape techniques convinced us that it was desirable to reduce the animal's tendency to develop unauthorized competing responses by keeping him as busy as possible while the shock was present. We therefore decided to place the bar pressing on a low and variable ratio schedule for production of the white noise. In choosing a schedule for the key nosing, however, it was necessary to recognize the danger of providing direct primary reinforcement, through subsequent termination of the shock, for the pressing. We met this problem by imposing a temporal criterion: even after the white noise had appeared, key nosing was not reinforced until a fixed interval had elapsed since the last depression of the bar. Thus, key nosing was maintained in the presence of the noise on a special type of interval schedule.

The basic test procedure therefore involved the following chain: when the shock came on, a variable number of presses was required to turn on white noise. In the presence of the noise, after 30 sec without a further bar press, nosing the key terminated both the noise and the shock for 2 min. Any press occurring during the noise, however, set the animal back to the beginning of the 30 sec interval.

Subjects

Four male white rats were used, one for pilot work and the other three for the experiment proper. E12 was used as a pilot animal from an age of approximately 3½ months to 6½ months; F14, I7, and I9 were studied from an age of seven months to approximately 20 months, 13 months, and 13 months, respectively. They had free access to food and water between experimental sessions.

Apparatus

The experimental box measured 9⅞ in. long, 5⅝ in. wide, and 6¾ in. high on the inside. The bottom consisted of five lengths of ⅝ in. diameter brass tubing, the side walls of aluminum, and the top of transparent plastic. An illuminated pigeon key was mounted behind a circular opening 1 in. in diameter and ⅛ in. in depth, the center of which was 2½ in. above the floor and 1⅜ in. from the left wall at one end of the box. A pressure of 4 gm displaced the armature of this key sufficiently to separate the normally closed switching contacts and deactivate a Potter and Brumfield KRP11DG relay mounted just outside the box, producing an audible click. During the later stages of the experiment a crossbar 2½ in. long and 5/16 in. in diameter was mounted on a Switchcraft Lev-R switch No. 3002 laterally centered 3½ in. above the floor at the opposite end of the box. This required a force of 26 gm. to activate programming equipment; no auditory feedback was provided, as this might generalize with feed-back from the key. The experimental box was enclosed in a light-proof and sound-resistant chamber furnished with a 15 CFM blower.

A current stabilized shock stimulator (Dinsmoor 1960, 1961) delivered 0.8 ma. (0.5 ma. for rat E12) of half wave rectified direct current through a Lehigh Valley 1311 scanning switch (polarity alternator) to the five lengths of tubing that made up the grid floor and to the walls and bar, which together served as the sixth electrode. White noise was provided by a three in. speaker connected to a Grason-Stadler 455B generator set at maximum output.

Procedure

Experimental sessions lasted approximately 5 hr and were typically begun at the same time each day, but no attempt was made to hold constant the time between sessions. Successive phases of the procedure will be described with the corresponding results for each stage of the experiment. The number of the last session under each procedure will be found in Table 2.

KEY NOSE TRAINING

On the first experimental session the rats were trained by successive approximation to nose the pigeon key, with 1 min of time out from the shock as reinforcement. For the remainder of the session all responses were reinforced.

Discrimination training was begun on the second session. After a variable interval (mean 20 sec) of exposure to the shock, the white noise was presented. The first nosing of the key in the presence of the noise terminated the shock. The number of sessions employed with each animal and the mean level of performance for the last four sessions are presented in Table 1.

Table 1.

Key Nosing Performance at End of Discrimination Training (Mean of Last Four Sessions)

	E12	*F14*	*I7*	*I9*
Number of Training Sessions	12	24	22	22
Latency to Noise (Sec.)	1.0	1.0	2.4	3.3
Equivalent Resp./Min.	61.2	59.9	24.8	17.9
Resp./Min. Prior to Noise	6.7	0.4	0.9	0.3
Noise Rate/Sum of Rates	0.90	0.99	0.97	0.98

ESTABLISHMENT OF CHAIN

The ultimate chain of behavior used to demonstrate the secondary reinforcing effects of the white noise was approached through several successive steps. First, the bar was mounted on the end wall of the box opposite the key. Each animal was trained by approximation to press the bar, which then produced the white noise. Once the noise had appeared, nosing the key terminated the shock as before, but now for 2 min. This procedure was completed within a single session for each animal. The schedule for production of the noise was then raised from a ratio of one to a variable ratio of three.

At this point the data remained ambiguous, because termination of the shock itself came soon after the presentation of the noise and might have served as a delayed primary reinforcer for the pressing. Rat E12 was therefore used to estimate the minimal delay that would effectively suppress the behavior in the absence of noise. The noise generator was turned off and a delay interval was introduced between the last bar press and the possibility of terminating the shock by nosing the key. At 5, 10, and 20 sec delay, the disruption of the chain proved temporary for this animal, but at 30 sec a progressive decline was noted following the initial disruption. This value was then accepted as a suitable delay for all four animals.

A corresponding delay was therefore gradually introduced for the other three rats on successive sessions, keeping the noise. In other words, even after the noise had appeared, nosing the key did not terminate the shock until 30 sec had elapsed without a depression of the bar. All four animals were maintained on this procedure for several sessions. Rates of pressing prior to the production of the noise were then tabulated and averaged for the last four sessions for each animal. The results are presented in Table 2, along with mean rates for later phases of the experiment.

ELIMINATION OF KEY NOSING REQUIREMENT

The successful maintenance of bar pressing with the original chaining procedure provided a positive result that could serve as a basis of comparison for any negative results which might be obtained under other conditions. The original experimental design could therefore be extended to include the testing of a less optimal procedure. A number of writers (*e.g.*, Dinsmoor, 1950; Keller and Schoenfeld,

Table 2.

Bar Presses per Minute Prior to Onset of White Noise (Mean of Last Four Sessions under Each Procedure) With Number of Last Session under Each Procedure

	E12		*F14*		*I7*		*I9*	
Procedure	*Last Session*	*Rate*	*Last Session*	*Rate*	*Last Session*	*Rate*	*Last Session*	*Rate*
Intact Chain	52	4.3	42	7.9	47	15.9	36	12.1
No Key Nosing Required		—	63	6.9	69	14.1	40	19.6
No Pressing Required		—	72	2.2	84	0.4	64	1.5
Pressing Reconditioned		—	81	6.6	90	10.8	93	13.8
White Noise Omitted	36	0.7	112	0.1	100	0.1		—

1950; Schoenfeld, Notterman, and Bersh, 1950) have suggested that in the appetitive case, at least, the effectiveness of a stimulus as a secondary reinforcer depends on its effectiveness as a discriminative stimulus for some behavior that produces the primary reinforcer. If this applies to the aversive case, extinguishing the key nosing should extinguish the bar pressing even if the stimulus events continue as before. To test this hypothesis, we therefore disconnected the pigeon key from the programming circuitry but arranged for the shock to be terminated automatically as soon as the usual 30 sec had elapsed since the last depression of the bar.

Table 3.

Key Noses per Minute in Presence of White Noise (Mean of Last Four Sessions under Each Procedure)

Procedure	*F14*	*I7*	*I9*
Intact Chain	36.7	18.0	10.6
No Key Nosing Required	1.0	0.2	2.0
No Pressing Required	0.4	0.0	0.3
Pressing Reconditioned	0.7	0.0	0.7

As may be seen in Table 3, eliminating any systematic relationship between the nosing of the key and the termination of the shock leads to the expected reduction in the rate of nosing. Erratic recoveries were occasionally observed, possibly due to accidental reinforcements in the relatively short interval between the onset of the stimulus (noise) for nosing and the termination of the shock, but on some sessions no key nosing whatsoever was recorded.

The corresponding rates of pressing on the bar may be found in Table 2. No systematic change could be detected in any of the subjects in this performance: the effectiveness of the noise as a reinforcing agent does not seem to depend on the strength of the key nosing. We cannot, of course, rule out the possibility that some superstitious chain of behavior has been substituted for the key nosing (Ferster, 1953), but it is difficult to see how a contingency that would not maintain a previously trained response could condition and maintain a substitute response.

Before moving on to the next phase of our procedure, let us take a brief look at the pressing that occurs after the noise has come on. Earlier studies of escape and of discrimination behavior (*e.g.*, Keller, 1942; Dinsmoor, Hughes, and Matsuoka, 1958; Russell, 1961; Winograd, 1961) have reported a tendency for additional or "extra" responding to occur during the first few seconds after the termination of the stimulus. The conditions giving rise to this "after-discharge," however, have not as yet been satisfactorily isolated. A similar tendency was evident in the present study: the animals continued to press the bar for the first few seconds after the white noise had appeared. This tendency was quite evident to anyone listening to the recording apparatus, but to provide a quantitative demonstration we tallied the presses during the first 5 sec of each period of white noise for rat F14 for two blocks of 10 consecutive sessions. Although these 5 sec represented less than 17% of the 30 sec or more of noise, they accounted for a mean of 64.7% of such responding during the first block and 85.2% during the second block.

ELIMINATION OF PRESSING REQUIREMENT

To demonstrate that the maintenance of pressing did depend on its production of the noise, we next disconnected the bar from the appropriate branch of the programming circuitry, so that a press was never immediately followed, except by accident, by the onset of the noise. However, to keep all other conditions as similar as possible to those prevailing during previous sessions, we arranged for the noise to come on whenever an interval of time had elapsed which was equal to that previously required by the rat to turn it on by pressing. This interval was determined by the mean time required on the last four previous sessions. For rat F14 this was 22 sec; for rat I7, 23 sec; and for rat I9, 16 sec.

The first major change noted in the animals' behavior was that when the onset of the noise was programmed independently the rate of pressing during the noise immediately dropped virtually to zero. Mean rates before and after the onset of noise are presented for the first such session in Table 4. These data suggest that the presence of the rat at the bar at the onset of the noise was a necessary condition for most of the pressing that had been occurring during the noise in previous sessions. In other words, the after-discharge may represent simply a lag in the cessation of responding which corresponds to the latency required in other contexts for the initiation of responding.

Table 4.

Bar Presses Per Minute during First Session in Which No Pressing Was Required

	F14	*I7*	*I9*
Prior to White Noise	15.7	17.8	36.1
During White Noise	1.2*	0.3	0.5

* Data lost; estimated maximum presented.

Once the after-discharge had been eliminated, the previously established discrimination between the absence and the presence of the noise was excellent. This discrimination provides important support for our contention that the noise served as a reinforcing agent for the pressing. For unless some more direct effect can be discovered and reconciled with the remainder of the data, differential performance under two stimulus conditions implies that differential consequences follow the animal's responding under either condition. The pressing that occurred before the onset of the noise evidently was reinforced; pressing after the onset of the noise evidently was not. But the only event that intervened between the two conditions was the onset of the noise, and this must therefore have constituted the reinforcing agent.

The second major change in the animals' performance lends further support to our analysis. Once the dependence of the noise on the pressing has been eliminated from the

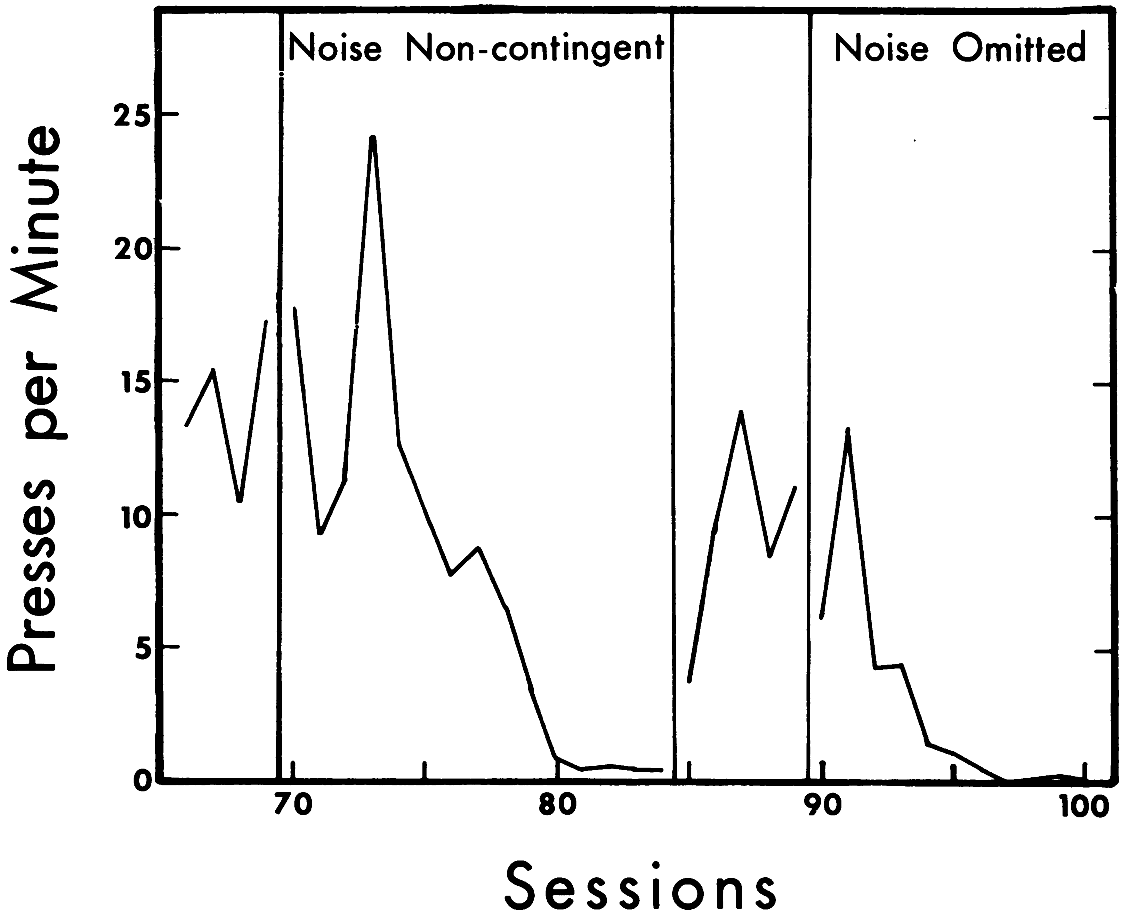

Fig. 1. Rate of pressing by rat I7 from the 66th to the 100th session. In the first and third panels, pressing was reinforced by the production of the noise on a variable ratio schedule. In the second panel, the noise was presented arbitrarily, without regard to the animal's pressing, and in the fourth panel, the noise was not presented at all.

proceedings, a gradual decline occurs in the rate of pressing. This is illustrated by a plot of I7's performance on successive sessions (Fig. 1) and by the numerical data from all three animals (Table 2). Since the interval between the appearance of the shock and the onset of the noise is brief, coincidental reinforcement of the pressing is likely and may account for occasional inversions in the early stages of the decline in rate. No attempt was made to complete the extinction process, as this might have led to subsequent difficulties in reconditioning the response.

RECONDITIONING OF BAR PRESSING

This phase had two purposes. First, reconditioning of the bar pressing response after prolonged absence of key nosing would show more clearly than before that the strength of the latter response was irrelevant to the effectiveness of the noise as a reinforcer. Second, restoration of the bar pressing would provide a starting point and comparison performance for the final phase of our procedure, in which the white noise was to be eliminated.

Automatic production of the white noise was now discontinued and a mean of three bar presses required once again. Referring once more to Table 2, we see that pressing was reconditioned for all three animals.

OMISSION OF WHITE NOISE

As a final demonstration that bar pressing was maintained by secondary reinforcement—onset of the noise—rather than by delayed primary reinforcement—termination of the shock—we turned off the white noise generator and continued as before. Animal I9 did not provide a fair test, as he developed at this point a persistent habit of lying on his back on the grid, despite the removal of hair from this part of his anatomy. For the other animals, as may be seen in Fig. 1 and Table 2, the result was a systematic decline in the rate of pressing. These data corroborate our previous conclusion that the pressing had been maintained by the conditioned or secondary reinforcing effects of the white noise.

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