The secondary positive reinforcing properties of the cue in "automated" discriminated escape conditioning*

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Two albino rats were given extensive discriminated escape training where a leverpress on a VR-5 schedule produced an auditory S^D, in the presence of which a pigeon key response terminated a light and brief shock. Following leverpress extinction, Ss received either the S^D or a neutral S^N on a VI-5 schedule, but no escapes. Each of the four tests involving S^D for each S showed greater R reacquisition than for S^N tests, demonstrating that the S^D functioned as a secondary positive reinforcer.

Previous research in our laboratory (Davenport & Lerner, 1968) utilizing a one-way, two-compartment escape-conditioning box has indicated that a cue (S^D) in discriminated escape would function as a secondary reinforcer (S^r) in the acquisition of a new response. Even with only 12 animals, the training procedure, which involved handling Ss on each trial, was extremely taxing for the E.

The present study describes our procedure for utilizing operant-conditioning apparatus with automated programming to minimize E's fatigue and to aid in the generalizing of the situations under which a cue in discriminated escape functions as a secondary positive reinforcer.

A previous report by Dinsmoor & Clayton (1963) has presented positive evidence for this phenomenon utilizing operant-conditioning techniques. Their procedure involved testing for secondary reinforcement while primary reinforcement was still present, a strategy common to "experimental analysis of behavior" research. Although a reasonable amount of evidence was provided to suggest that the effects obtained were due to the secondary reinforcer and not due to delayed escape, the present procedure attempted to eliminate that alternative entirely.

SUBJECTS

The Ss were four albino rats approximately 90 days old at the initiation of training; they were maintained throughout on ad lib food and water and a reverse day-night schedule. Only two Ss reached the training criterion, and these were tested through all phases of the experiment. The data presented are for those two Ss. Although less individual attention was required, the experiment took nearly a year to complete.

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APPARATUS

The apparatus consisted of a single-lever Gerbrands-Skinner box, enclosed in a sound-attenuating chamber. In addition to the standard lever, a Lehigh Valley pigeon key was mounted on the side wall 5 cm above the grid floor and 10 cm from the lever. All programming and recording was automatically controlled. Shock was presented by a Lehigh Valley constant-current shocker to the grid floor, and the tone by a Foringer multiple-stimulus panel to a 3-in. speaker located inside the chamber. Two cue lights mounted on the intelligence panel above and to each side of the lever were illuminated while animals were receiving shock.

PROCEDURE

Initially, Ss were given a "fear" training procedure which involved presenting the cue lights for 2 min and then off for 2 min. During the lighted interval, electric shocks of ½-sec duration occurred approximately six per minute. This was followed by escape training. Thus, while the light was on and accompanied by the irregular shocks, pressure (usually by the nose) on the pigeon key terminated the light and stopped the train of shocks. Eventually, a discrimination requirement was introduced such that only a nose response which followed onset of a tone was successful in terminating the light and shocks. Finally, the tone was present only if the S made a lever response. The result was a two-response heterogeneous chain mediated by a tone, the primary reinforcement being a time-out from the light and irregularly presented shock.

This was followed by the introduction of a Zimmerman (1957) type of double-intermittent reinforcement schedule for strengthening both parts of the chain. A wide variety of parameter values for shock intensity, shock frequency, length of time-out from light plus shocks, utilizing both variable-interval and variable-ratio schedules, were used in an attempt to obtain stable performance for all four Ss under the same values. Finally, as indicated earlier, two Ss were discarded and extended training with the following values was given to the remaining two Ss: With cue light on and a .8-mA shock of ½-sec duration presented on a VI 30-sec schedule, responses on the lever produced a tone (S^D) on a VR-5 schedule. On 50% of the tone (S^D) occurrences, the tone, lights, and shock train were terminated for 60 sec by pressure on the pigeon key. On the other 50% of the tone presentations, the tone alone was terminated and lever responses on the VR-5 schedule were again required to produce the tone. Sessions lasted from 4 to 6 h with Ss trained every other day.

In addition, an irrelevant auditory stimulus (S^n)–in this case a low frequency clicking sound of 1-sec duration clearly distinguishable from the tone–was presented on an independent VI-2-min schedule during both the safe period and the shock periods. No attempt was made to prevent accidental contingencies with any of the various events in the situation. This final setup was continued for approximately 1 month before testing was instituted.

During testing sessions, Ss received 4 h of training immediately preceding actual testing. This was followed by a period of leverpress extinction lasting approximately 1 h, during which the lever was ineffective in producing the tone. Since the tone did not turn on, the nose-press response was not effective, but this was quite consistent with training and presumably did not extinguish the tendency for the latter response to occur in the presence of the tone. When the extinction period was completed, the lever response was again made effective, producing an auditory signal on a VR-5 schedule. Using a tone, clicker, clicker, tone schedule, either the tone used as a S^D or the irrelevant clicker (S^n) was the auditory stimulus produced by the lever response for the given test day. In either event, the nose press terminated the auditory stimulus, but the light and irregularly presented shocks continued throughout the test. The dependent variable then involved a within-S comparison of the reacquisition of the leverpress when the consequence was the presentation of a secondary reinforcing tone on a VR-5 schedule vs the response tendency on a separate day when the leverpress produced the "neutral" but familiar clicker on the same schedule. Since the response under either condition did not eventuate in the termination of the light or

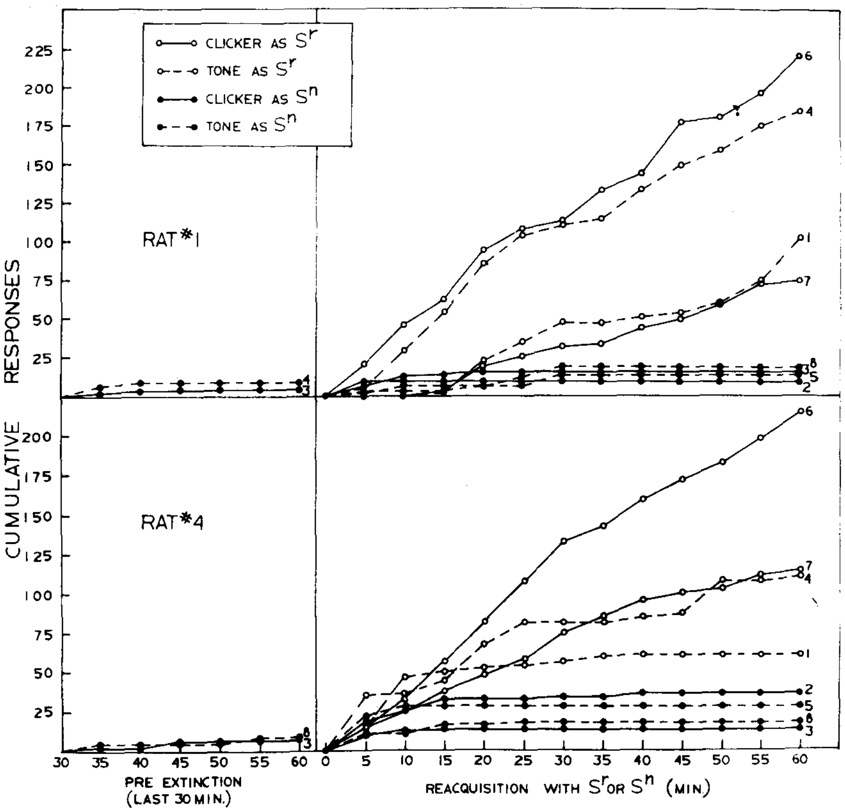

Fig. 1. Cumulative records for preextinction and reacquisition under neutral (S^N) and secondary reinforcement (S^r) conditions. (The order of testing is indicated by the number at the end of each individual record.)

its paired shocks, primary reinforcement was not present during the test.

After the 1-h test period, the S was again retrained for 1 h on the original training schedule, in preparation for another test 2 days later.

Following the completion of this first phase, where tone was the relevant stimulus (S^D) and the clicker the irrelevant (S^n), 2 weeks of retraining was completed in which the previously irrelevant clicker was the mediating S^D in the two response chains and the previously relevant tone was programmed independently of other events in the training. Testing was completed as before, except that during the training preceding each test, the relevance of the clicker and tone was reversed as just described. Thus training, extinction, testing, and then retraining occurred on each test day with the same tone, clicker, clicker, tone order of test. But now the clicker which was the S^D in training was expected to provide secondary reinforcement during the test.

In summary, there were eight 1-h tests for each S, four with a neutral stimulus (S^n) and four with an S^D, which presumably had become a secondary reinforcer, each test separated by at least 5 h of retraining, with the clicker and tone used as both a "reinforcing" and "neutral" stimulus.

RESULTS AND DISCUSSION

The data for both the last 30 min of "preextinction" and for the 60 min of the "reacquisition" test are presented in Fig. 1. There was very little responding during the final phase of the preextinction period. To indicate this, the data for the test days on which the greatest amount of responding occurred during the last 30 min of preextinction are presented separately for when the tone and when the clicker were to be used during the test. The single greatest number of responses was nine in the last 30 min of preextinction.

In addition, all eight of the cumulative records for the two Ss are plotted for the reacquisition period, with the order of testing indicated by the number at the end of the individual record. There appears to be a slight tendency for Ss to increase responding when conditions change from "preextinction" to "reacquisition," whether or not the auditory stimulus was an S^D or S^n. But, by the end of the first 20 min, there was no overlap among the 16 tests for the two Ss. Regardless of whether a tone or clicker was used, the S^D, now functioning as an S^r, clearly increased responding more than the S^n when each followed the lever response. When the auditory stimulus was a discriminative stimulus (S^D) mediating the two-response chain and indicating when the second response was likely to be successful in escaping the light and associated shocks, then the same stimulus functioned also as a secondary reinforcer during reaquisition to reestablish the leverpress which produced it. The average total responding during the testing when the lever response produced the S^r was 136.6 per hour, compared to 16.9 when the response produced the same physical stimuli, but functionally irrelevant and neutral.

There was no evidence of order of testing effects or any dramatic evidence for the superiority of either the clicker or tone in its capacity to function as an S^r. In addition, the use of the extended and repeated training, involving intermittent reinforcement, produced rather stable responding throughout the test period with little evidence of extinction of the S^r effect except perhaps for the first test of Animal 4. Apparently, the extended intermittent schedules in the present type of training design countered any tendency for a reduction in secondary reinforcement effect with replications as reported by Hughes & Adams (1967) and Wagman & Allen (1959). What appears to be the crucial factor is whether the stimulus functions as a discriminative stimulus for indicating when escape is possible. The present result extends the findings of Davenport & Lerner (1968) to the automated Skinner box situation of Dinsmor & Clayton (1963). In the present case the possibility of delayed primary reinforcement of shock escape is eliminated.

Two recent reviews of the evidence for positive secondary reinforcers established in aversive situations have been published since the data of the present study were collected (LoLordo, 1969; Siegel & Milby, 1969) and were critical of the designs evaluated. It would appear that the design of the present study and that of Davenport & Lerner (1968), which was not included in either review, correct some of the control problems suggested and provide less ambiguous evidence for the establishment of positive secondary reinforcement in discriminated escape training.

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Double-intermittent reward scheduling and secondary-reinforcer strength: Discriminated escape*

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A discriminated escape procedure was employed to train two groups of rats to activate a nose press in the presence of a tone to escape a 1-mA shock. Escape was allowed on a continuous or an intermittent schedule. Each group was then divided into three subgroups, two of which were required to learn a leverpress response where the only reward was the tone, presented on a continuous or an intermittent reinforcement schedule. The third subgroup served as a no-tone control. A durable secondary reinforcer was established which was a function of the secondary reinforcement schedule during testing.

Recent reviews (LoLordo, 1969; Siegel & Milby, 1969) conclude that the existence of a durable and effective secondary reinforcer in aversive drive situations was still largely a matter of conjecture. They felt that no completely adequate demonstration of the phenomenon in question had, as of that time, been tendered. However, recent results from our own laboratory, not included in these reviews and apparently not suffering from the problems of early studies (Davenport & Lerner, 1968; Davenport, 1970), have indicated that a neutral stimulus paired with escape from an aversive situation can acquire reinforcing properties when it functions as a discriminative stimulus for escape. It was felt, as a consequence, that current research should concentrate on the investigation of parameters that influence the establishment and strength of secondary reinforcers in situations in which the motivation for behavior is aversive. Schedule of reinforcement, one of the parameters that affects the establishment and strength of secondary reinforcers in appetitive drive situations, furnished the necessary point of departure. The early work of Zimmerman (1959) provided some rudimentary evidence for the efficacy of a two-phase or double-intermittent schedule of reinforcement. Fox & King (1961), in an effort to avoid the criticisms leveled at Zimmerman, added some appropriate controls and found evidence for the superiority of the double-intermittent procedure. Davenport & Sardello (1966), in a partial replication of Fox & King, introduced other methodological changes to insure mobility of the Ss and minimize stimulus redundancy. They were able to secure additional evidence for the superiority of the double-intermittent schedule over procedures involving continuous reinforcement.

The present experiment was designed to seek a verification of the superiority of employing a double-intermittent schedule, as opposed to a single-phase intermittent schedule, in establishing a stable and effective positive secondary reinforcer in an aversive-drive situation involving discriminated escape.

METHOD

The Ss were 36 naive male albino rats of the Sprague-Dawley strain, approximately 80 days old on the first day of the experiment.

The apparatus consisted of two standard single-lever Gerbrands-Skinner boxes in sound-attenuating chambers. Each box was equipped with a Lehigh Valley pigeon key, used to record nose presses, mounted on the back wall of the box, 10 cm from the lever and 5 cm above the grid floor. All programming and recording was automatically controlled, and escape from a 1-mA shock, provided by a Lehigh Valley constant-current scrambled shocker, was used as a reinforcer during the training period.

A procedure quite similar to Davenport & 'Sardello (1966) was used. Each S was given two 60-min training sessions in which every nose press resulted in a 60-sec escape from shock and the termination of two stimulus lights. All Ss were then placed on a schedule in which a tone was presented on a VI 4-sec schedule, and a nose press in the presence of the tone resulted in a 30-sec escape from shock and termination of the tone. All responses in the absence of the tone produced an additional 10-sec delay in the tone presentation while the shock continued. Each S was given three 60-min training sessions under these conditions. The variable interval presentation was subsequently extended to a VI 15-sec schedule subject to the above 10-sec nonresponse restriction for a total of 2 more hours before partial reinforcement training began. The 18 Ss receiving partial reinforcement continued to receive 50 tones on a VI 15-sec schedule throughout the remaining training sessions. However, the proportion of nose-press responses made in the presence of the tone resulting in reward was decreased to 60% for 2 h of training, 40% for 2 h, and 10% for 3 h, with the number of reinforcements given reducing from 50 to 5. The 18 Ss on continuous reinforcement were placed on a VI 45-sec schedule for 2 h, a VI 83-sec schedule for 2 h, and finally, a VI 420-sec schedule for tone presentations for 3 h. This latter procedure had the effect of presenting the tones at the same rate as those actually reinforced in the partial reinforcement group so that equal reinforcements over equal training times was maintained. There was no more reliable cue than the tone indicating when escape was possible in this discriminated escape procedure.

For testing the strength of the tone as a secondary reinforcer, a lever was added, and each response resulted in a tone on a continuous schedule for one-third of the group receiving partial pairing during training and a tone on a VR-4 schedule for another third. The other third of the groups received no tones during testing. A nose press in the presence of the tone terminated the tone, but not the shock. The group receiving continuous pairing of

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