THE FUNCTIONAL PROPERTIES OF A TIME OUT FROM AN AVOIDANCE SCHEDULE¹

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Investigations are reported of some of the discriminative (cue) and reinforcing properties of stimuli (TO_{av}) correlated with the discontinuation of a free-operant avoidance schedule. After several unsuccessful initial attempts to demonstrate the positively reinforcing effect of TO_{av} , a special technique was developed. The subjects were trained by means of a free-operant avoidance procedure to press a lever and postpone electric shock; by pressing a second lever, they could produce a cue correlated with the TO_{av} period. The importance of a distinct cue correlated with TO_{av} was demonstrated in experiments in which this signal was eliminated from the procedure. The reinforcing function of the TO_{av} period was explored by showing its effectiveness under various schedules of reinforcement.

Other observations were made concerning the course of extinction of both TO_{av} -producing responses and avoidance behavior.

In further experiments in which TO_{av} was used as a reinforcer, the TO_{av} behavior was also brought under separate stimulus control. The development of the various discriminations involved in the resulting performance were described.

I. INTRODUCTION

There are four possible ways for an experimenter to arrange a contingency between the behavior of an organism and reinforcement. When a specific act occurs, he can (1) present a positive reinforcer, (2) present a negative reinforcer, (3) remove a negative reinforcer, or, (4) remove a positive reinforcer (Skinner, 1938, 1953).

The actual *presentation* of certain reinforcers, *e.g.*, food, is an occurrence of only brief duration. Studying the consequences of the *removal* of such reinforcement always involves the removal of stimuli that have been correlated with the reinforcing event. In other words, these studies involve the manipulation of secondary or conditioned reinforcers.

Ferster's (1958) monograph is the most extensive investigation of stimuli associated with the discontinuation of positive reinforcement. Ferster studied the effects of withdrawing a stimulus correlated with positive reinforcement by using a stimulus in whose presence the animals could no longer obtain reinforcement.

He called this stimulus the time-out stimulus (TO) (Ferster, 1957), and demonstrated that the removal of such a conditioned positive reinforcer had many properties in common with the effects of conventional aversive events, such as electric shock.

In terms of the fourfold classification of reinforcement contingencies, Ferster's experiments raise the question of whether a stimulus correlated with a time out from shock avoidance (TO_{av}) will be a conditioned, positive reinforcer.

In the first series of experiments to be reported here, a discrimination procedure was used in which free-operant avoidance behavior was maintained in the presence of one set of stimuli; in the presence of other stimuli, the animals (rats) were never shocked (TO_{av}). These initial experiments failed to produce any evidence that TO_{av} acquired positive reinforcing functions.

In subsequent experiments, the animals had a second lever that they could press and so produced TO_{av} (Verhave, 1959). This procedure yielded positive results and opened the way for a continuing series of experiments with TO_{av} . The purpose of this report is to present initial data concerning several characteristics of behavior controlled by such a stimulus. Sidman (1960, 1962) has inde-

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pendently investigated a similar situation with monkeys, confirming the basic findings of the present research. More recently, Granda and Hammack (1961) have used a similar procedure with sleeping human subjects.

II. ESTABLISHMENT OF A MULT AVOID TO PERFORMANCE WITHOUT PREVIOUS CONDITION- ING OF THE AVOIDANCE BEHAVIOR

Method

Subjects. The subjects were male rats, 4 to 6 months old at the start of experimentation. They were maintained on free food and water in individual living cages.

Apparatus. The experimental cages were 10½ in. long, 5¼ in. wide, and 8½ in. high. Each cage was enclosed in a lightproof and sound-resistant box (attenuation, 10 db), and several such boxes were placed in a sound-resistant cubicle (attenuation, 10 db). A sound mask of white noise (75 db) was fed continuously into the cubicle. The automatic programming and recording equipment was outside the cubicle. The sides and top of the experimental cages were ⅛-in. Plexiglas; the front and rear walls, ¼-in. aluminum alloy; and the grid flooring, transverse stainless steel rods, ⅛ in. in diameter, spaced 1 in. apart. Stainless steel plates ⅛ in. thick covered the entire inside of the plastic side-walls. The plates were insulated from the aluminum end-walls and the grid flooring. Each wall and floor rod was successively opposed in polarity by a "grid scrambler," consisting of a series of microswitches operated by cams rotating at a high speed. A constant-current stimulator passing half-wave, 60-cycle DC at 350 v and 1.5 ma provided electric shock. Dinsmoor and Hughes (1956) have described the current-stabilizing circuit. The lever (Verhave, 1958) was center-mounted 2¼ in. above the grid floor in one end-wall of the experimental cage. A small pilot light was also center-mounted in the same end-wall 6 in. above the grid floor. This light was recessed into the aluminum alloy end-wall and covered with a flush-mounted piece of transparent plastic, 1 in. in diameter. Another light was mounted on the outside of the cage behind the end wall opposite to the lever.

Procedure. Sidman (1953) has described the free-operant avoidance procedure. Briefly, a 0.2-sec shock occurred every 2 sec, unless the animal pressed the lever; in Sidman's terminology, the SS (shock-shock) interval was 2 sec. Every time the animal pressed the lever, it postponed the shock an additional 20 sec; that is the RS (response-shock) interval was 20 sec. The animal received a shock each time 20 sec elapsed without a response, and from then on every 2 sec until it pressed again. Holding the lever down following a press did not prevent the shock.

The avoidance contingencies were in effect during 15-min intervals alternating with 10-min periods during which no shock was administered, even if the animal did not press the lever. During the 15-min avoidance-conditioning periods, only the light above the lever was on. During the 10-min time-out periods, only the light mounted outside the cage was on. The TO_{av} started immediately after the 15-min avoidance period had ended; the animal did not have to respond to produce the time-out.

Each session consisted of nine avoidance and nine TO_{av} periods, and started with an avoidance period. At least 1 day intervened between sessions.

Results and Discussion

Figure 1 presents the cumulative records of one animal and illustrates the results obtained with 14 other rats. The data of all the animals in which the discrimination was established in the present manner show a characteristic course of events. Initially, a very low rate of responding in TO_{av} is correlated with a pattern of responding during the avoidance periods that still results in a high shock frequency. Subsequently, as the avoidance performance improves, as shown by a reduction in the shock frequency, the response rate in TO_{av} increases simultaneously. This response rate then decreases again, while the avoidance responding improves still further.

The initial difference in the rates during the avoidance and the TO_{av} periods can be obtained without the presence of the exteroceptive avoidance and TO_{av} stimuli. The discrimination, if it may be called this, is at first based on the nonoccurrence of shock during TO_{av} . In many animals, the initially frequent shocks during the avoidance periods may gen-

Fig. 1. Development of avoidance behavior under external stimulus control without previous establishment of the avoidance behavior.

erate enough responding to account for the initial difference in the response rates. Observations on animals run under the present conditions, but with the TO_{av} stimulus omitted, bear out this interpretation.

As the shock frequency decreases, the first discrimination breaks down, and a "true" discrimination is formed based on the presence and absence of the tone. The temporary in-

crease in the TO_{av} responding can be interpreted as due to a generalization effect.

Figure 2 shows the record of Rat 53 after 15 sessions. This animal differed from the other 14 rats in that its rate in TO_{av} still had not dropped to zero after 15 sessions, and it persisted for another 50 sessions. Another feature is that the highest rate of responding in TO_{av} usually occurred just before the onset

RAT 53 Session 16

Fig. 2. Performance of an atypical animal on a multAvoid TO procedure.

of the avoidance period. The reasons for this particular aspect of the performance are not yet clarified (Herrnstein & Brady, 1959).

The last two phases in the development of the mult Avoid TO performance are not unique to procedures in which one component of the multiple schedule is controlled by aversive contingencies. Skinner has previously described similar data in which an operant was maintained by continuous positive reinforcement during S^D (Skinner, 1938). The present illustrations of "induction" differ from Skinner's only in the magnitude of the effect.

The behavior of Rat 51 (Fig. 1) leaves no doubt that proper stimulus control does develop under the present conditions. Session 7 shows that (1) responding in the avoidance stimulus may start promptly without being primed by a shock; and (2) it ceases immediately after the onset of TO_{av} . All 15 animals formed the tone-controlled discrimination within 10 sessions. There was considerable variability among animals with respect to the length of the stages in the development of the final performance.

III. ESTABLISHMENT OF A MULT AVOID TO PERFORMANCE WITH PREVIOUS CONDITIONING OF THE AVOIDANCE BEHAVIOR AND RESPONSE-CONTINGENT TO_{av}

Method

The subjects and apparatus were as described previously except that a 4-in. loudspeaker was mounted inside the sound-resistant shell. The basic avoidance procedure was described in Section II. In this experiment, the SS interval was 5 sec, and the RS interval was 20 sec.

During the discrimination training phase, the avoidance and TO_{av} intervals were both at least 15 min. Variations in the length of the avoidance period were possible because the onset of TO_{av} was response-correlated. The first time the animal pressed the lever after the avoidance period had been on for 15 min, it produced TO_{av} . Correlated with TO_{av} was a 433-cps tone, just audible to the experimenter when he stood inside the cubicle with the masking noise turned off but the sound-resistant outer shell closed. The tone was off

during avoidance periods. During each experimental session, the light above the lever was on continuously; at the end of the session, this lever light was switched off and the light outside the cage turned on. Between 12 and 15 avoid TO_{av} cycles were programmed during a session. A session always started with an avoidance period. At least 1 day intervened between successive sessions.

Results

Figures 3, 4, 5, and 6 present the data of two animals, Rats 100 and 101. The top frame of Fig. 3 shows the performance of Rat 100 during the last regular avoidance-conditioning session (Session 8). During Session 9 (same frame), the tone was introduced at regular 15-min intervals. The down position of the baseline pen indicates the tone-on periods. During this entire session, however, the avoidance contingency was still in effect when the tone was on. Starting with Session 10, the avoidance contingency was cancelled during the tone-on periods (TO_{av}). Rat 101 was treated similarly. In this case, Session 9 (Fig. 5, top frame) was the last regular avoidance-conditioning session. During Session 10, the tone was introduced without an actual TO_{av} condition being in effect. Session 11 was the first session on the mult Avoid TO procedure.

Introduction of the tone-on periods produced a change in performance of only Rat 101 (Fig. 5, Session 10). During Session 10, this animal's rate of responding was lower, and the shock rate had increased greatly. The effect was temporary and already disappearing toward the end of Session 10.

Four of the six animals rapidly developed a discriminative performance. As early as its second session on the discrimination procedure, Rat 100 (Fig. 3) responded much more rapidly in the avoidance than in the TO periods. Rat 101 showed the smallest difference in its avoidance and TO_{av} rates. As late as Session 17, however, both rats still occasionally "ran through" the TO_{av} periods (Fig. 4 and 6).

Discussion

These data are relevant to a point discussed in the previous section: is the discrimination in the early sessions based on tone or shock? Figures 3 and 5 seem to indicate that even for animals pretrained on avoidance, this is so.

Fig. 3. Development of avoidance behavior under external stimulus control with prior establishment of the avoidance behavior.

This is not necessarily the case, however. Both Rats 100 and 101 were still relatively poor avoiders at the time that discrimination training was started. When the avoidance performance is well established (as indicated by a low-shock density *e.g.*, less than 10 shocks per hr for SS-3 sec, RS-30 sec) before discrimination training is started, the problem of a discrimination based on shock during the initial phase of discrimination training does not arise.

The present data are similar to Appel's findings (1960) that if a mult Avoid TO procedure is introduced after pretraining the animals on avoidance, the discrimination usually develops during the first few sessions.

Appel also noted that the animals decreased their response rate in the avoidance component of the mult Avoid TO procedure during 30 successive 4-hr sessions (Appel, 1960, p. 46). Rat 51 (Fig. 1), like many other animals trained on the mult Avoid TO procedure in my laboratory, also decreased its rate of responding during the avoidance periods within seven $3\frac{1}{4}$ -hr sessions.

This decrease is not unique to the mult Avoid TO procedure, but is probably common to free-operant avoidance schedules which generate temporal discriminations. In Fig. 7, for example, Rat 18 shows a progressive decrease in its rate of avoidance responding during a period of 30 sessions (180 hr). (The

Fig. 4. Development of avoidance behavior under external stimulus control with prior establishment of the avoidance behavior.

Fig. 5. Development of avoidance behavior under external stimulus control with prior establishment of the avoidance behavior.

Fig. 6. Development of avoidance behavior under external stimulus control with prior establishment of the avoidance behavior.

data of the first five sessions are omitted from the figure.) No TO was involved in this procedure. The phenomenon represents the gradual development of a temporal discrimination (Sidman, 1954), which may proceed long after the shock rate has become stable.

On the assumption that removal of a stimulus associated with an aversive schedule

might be positively reinforcing, one might expect the development of positively accelerated rate changes (scallop) superimposed on the constant rate generated by the avoidance schedule. Procedurally, the responding during the avoidance periods is reinforced by the TO on a fixed-interval schedule. However, no scallops appeared during Session 17 for either Rat 100 or Rat 101; and none was observed after an additional 180 hr of experimental time under the same conditions, even though there was an explicit FI contingency. Figure 1 shows a similar absence of positively accelerated rate changes during avoidance periods.

The first attempt to obtain the effect was to increase the duration of the TO_{av} period. Then TO durations of 30 and 60 min were tried unsuccessfully for 12 sessions each. The experimenter was not reinforced, and the data will not be presented.

IV. A PRELIMINARY DEMONSTRATION OF THE POSITIVE REINFORCING FUNCTION OF TO_{av}

The above-described failures to observe any evidence of a positively reinforcing effect of

Fig. 7. Progressive decrease in rate of avoidance responding during 30 successive 6-hr sessions in a free-operant avoidance situation. The three data points per session indicate the average rates obtained during three successive 2-hr periods.

the TO_{av} prompted a more direct investigation of its possible reinforcing properties (Verhave, 1959a, 1959b). Instead of having the animal both postpone shock and produce the TO_{av} with the same response, a second lever was made accessible to the animal for obtaining the TO_{av} . The question to be answered was whether the animal's behavior could be generated and maintained when its only reinforcement was a time-out period from an avoidance schedule. (See also Sidman, 1960, 1962.)

Method

Subjects. The subjects were four male rats, 6 months old at the start of experimentation. They were maintained on free food and water in individual living cages.

Apparatus. The apparatus consisted of an experimental cage, $10\frac{1}{2}$ in. long, 10 in. wide,

$8\frac{1}{2}$ in. high. Two levers (Verhave, 1958) were mounted $2\frac{1}{4}$ in. above the grid floor in one end-wall of the cage. A distance of 6 in. separated the centers of the $1\frac{1}{2}$ -in.-long T bars of the levers. A pilot light was mounted 3 in. above each lever. An aluminum plate could be inserted between the two levers across the entire length of the cage. This divided the cage into two 5-in.-wide compartments, each with its own lever. All other features of the apparatus were identical to those described in Section II.

Procedure. The animals were given preliminary training on the avoidance procedure as described previously. Throughout the entire experiment, the SS interval was 3 sec, and the RS interval was 30 sec. The shock level was 1.5 ma and the shock duration 0.15 sec. During this initial training, the aluminum insert was in place, and only one lever was

Fig. 8. The early development of TO_{av} behavior. The presence of TO_{av} is indicated by a depression of the base line. During Session 4, the shocks seem to come after the start of the TO, because the pens were slightly out of line.

Fig. 9. Continued development (Sessions 6 and 7) and extinction (Session 8) of TO_{av} behavior. The presence of TO_{av} is indicated by a depression of the base line.

available to the rat. Once avoidance responding was well established, a 433-cps tone came on at irregular intervals during only one session. The avoidance schedule stayed in effect throughout this session. During the next session the second lever was made available to the animal. This lever will be referred to as the TO lever and the other as the Av lever. By pressing the TO lever, the animal could produce a 10-min TO from the avoidance schedule. The 433-cps tone was correlated with the TO_{av} periods.

During the initial avoidance-training phase, only the light above the Av lever was on during an experimental session. Once the TO lever was added, the lights above both levers were turned on during a session. Termination of each session was signaled by switching off the lever lights (s) and turning on a light mounted on the outside of the cage behind

the end wall opposite to the lever. An experimental session lasted from 6 to 10 hr. Each animal was used every other day, excluding weekends.

Results

Because the general features of the data are similar for all four rats, only the performance of Rat 12 will be presented. The two top panels of Fig. 8 show the avoidance performance of Rat 12 during the third session on the initial avoidance-training phase. During this session, the tone came on at irregular intervals, with the avoidance schedule in effect at all times. No consistent effect of the tone is observable. The next two panels (Session 4) show the animal's responses on the avoidance lever during the first session in which the TO_{av} lever was also available. By pressing the TO lever almost immediately after the start of the

experiment, the animal produced the first TO_{av} at the beginning of the session. The depression of the base line indicates TO_{av} periods, and the oblique marks on the cumulative record itself represent shocks. The 4th and 5th time-out periods produced by the animal followed each other very closely and showed the beginning of extinction of the avoidance responding during TO. During much of the remainder of Session 4, avoidance responding during TO progressively decreased, while the frequency of TO periods increased.

The cumulative record of responding on the avoidance lever during the next session (Session 5) appears in the lower two panels of Fig. 8. The avoidance behavior recovered in rate during the first half of this session, but by the end of Session 5 the animal was pressing

the avoidance lever even less frequently than at the end of Session 4, and the TO_{av} frequency had almost reached its maximum possible value.

Sessions 6 and 7 (four top panels of Fig. 9) demonstrate the continued decline in the rat's avoidance responding. During the last half of Session 7, the animal spent almost all of the experimental time in TO_{av} .

As an initial check on the reality of the TO_{av} period as the reinforcing event that maintained responding on the TO lever, an extinction session on only the TO lever was programmed during Session 8. In the first 8 min of this session, the animal took a few shocks, after which the avoidance rate abruptly changed to a higher value (two bottom panels of Fig. 9). During these first 8 min, the

Fig. 10. Reconditioning and continued development of TO_{av} behavior. The presence of TO_{av} is indicated by a depression of the base line.

Fig. 11. Maintenance of TO_{av} behavior on FR schedules. Session 26: FR 5; Session 27: FR 10; Session 28: FR 15. The presence of TO_{av} is indicated by a depression of the base line.

animal pressed the TO lever approximately 100 times;³ but simultaneously with the abrupt change in its rate of avoidance behavior, it stopped pressing the TO lever. For the remainder of the session, the animal only occasionally emitted a few bursts of responding on the TO lever. These bursts were usually correlated with the occurrence of shock and a temporary drop in the rate of responding on the avoidance lever.

During the next three sessions (9, 10, and 11), Rat 12's behavior on the TO lever was reconditioned (Fig. 10). The cumulative records of responding on the avoidance lever show the declining response rate and increasing TO frequency described earlier. The first

TO period of Session 11 was the last one during which any initial spontaneous recovery of the avoidance behavior was clearly observable. The animal's performance from Session 12 through Session 25 was identical to the one shown in the last half of Session 11.

During Sessions 26, 27, and 28, the behavior on the TO lever was maintained on fixed-ratio schedules (Fig. 11). During the first part of Session 26, the FR schedule on the TO lever was increased one step at a time with each successive time out. The animal was required to press the TO lever only once to obtain the first TO_{av} , twice to get the second and so on. Once it reached FR 5, the TO_{av} behavior was maintained at this value for the remainder of the session. During Session 27, FR 10 was programmed on the TO lever except for the first TO_{av} , which the rat obtained

³Cumulative recorder data of the TO lever responding of this animal are not available.

by pressing the TO lever five times. During Session 28, the first TO_{av} was obtained on FR 10; but for the remainder of the session, FR 15 was programmed. The high frequency of TO periods during these sessions (Fig. 11) shows clearly that small, fixed-ratio schedules can maintain the behavior on the TO lever. Just how large a fixed-ratio schedule can be programmed before the animal stops responding and returns to the avoidance lever is a question that will be discussed elsewhere. A more detailed account of the characteristics of the FR behavior on the TO lever will be given in a later section of this paper.

The data on the other rats were similar to those of Rat 12. The main difference among animals appeared when FR schedules were being programmed on the TO levers. At FR values above 10, two of the other three rats (Rats 9 and 10) stopped responding and returned to the avoidance lever. Their behavior on the TO lever could be re-established by lowering the FR requirement. Usually, the animal first had to be put back on CRF.

Although Rats 10 and 11 developed the behavior on the TO lever at much the same rate as Rat 12, Rat 9 ran for many sessions without pressing the TO lever. The animal began to show TO-producing behavior like the other rats only after it was given a special discrimination-training period during which the TO_{av} periods occurred at irregular intervals.

All four animals rarely pressed the TO lever during TO periods. Three of them did so fewer than 20 times per session during Sessions 9 through 29, and one (Rat 10) did not respond even once during this time. Since the animals obtained most of the time outs on CRF, with only one response approximately every 10 min, cumulative records of responses on the TO lever are not presented. Confirmatory data will be shown later in this report.

V. THE DESCRIPTIVE PROPERTIES OF BEHAVIOR REINFORCED BY TO_{av} WHEN PROGRAMMED ON A FIXED-RATIO SCHEDULE

Figure 12 shows sample cumulative records of responses on both levers during Session 40, when FR 35 was programmed on the TO lever. The TO_{av} periods are indicated by the numbered depressions in the cumulative curves. Shocks are recorded as oblique marks on the base line and are also numbered.

These sample records bring out the following features: (1) Discriminations on the Av lever and TO lever are very good. The animal responds almost continuously on both levers only during TO Period 2. (2) Although the animal has two levers to press, one to postpone shock and one to produce the TO, the performance is so well integrated that even on FR

Fig. 12. Performance on avoidance and TO_{av} levers. The TO_{av} is scheduled on FR 35. The TO_{av} periods are indicated by depressions in the cumulative records and numbered consecutively.

Fig. 13. Enlarged record of TO_{av} behavior of Fig. 14. The TO_{av} periods are left out.

35, the animal can obtain TO_{av} without getting a single shock. (See the avoidance period between TO_{av} Numbers 5 and 6.)

Figure 13 shows the same performance on the TO lever as Fig. 14, but in more detail. This record was obtained with a third recorder whose motor stopped during TO_{av} . The TO's are indicated by the oblique marks and numbered as in Fig. 12. This record reveals the following features of the FR performance (*cf.* Sidman, 1962):

- 1) The animal responds in rapid bursts which are separated by distinct pauses.
- 2) The number of responses in the bursts

tends to increase toward the end of the avoidance period.

3) Almost each avoidance period starts with a long pause before the animal presses the TO lever.

4) Pauses between bursts tend to become shorter toward the end of an FR run.

Phenomena 2 and 4 give a scalloped appearance to the cumulative records of responding on the TO lever.

There are outstanding similarities between the FR performance generated under our experimental conditions and those reported when food is the reinforcement (Ferster & Skinner, 1957; Owen, 1960; Stebbins & Sidman, 1954). The rate has a dual value; the animals respond in bursts alternating with pauses. A long pause like the typical FR postreinforcement pause occurs after the end of each TO. However, there is the very important difference that pauses occur frequently. Two possible causes for this, which may act synergistically, are the following: 1) The rat has to stop responding on the TO lever at least every 30 sec in order to press the avoidance lever if it is to prevent occurrence of the shock. 2) If the TO_{av} period is a relatively weak reinforcer, such a performance is not unusual, even with food reinforcement (*e.g.*, Owen, 1960).

Fig. 14. Performance of a rat in a free-operant avoidance situation with two levers. Each lever is equally effective in resetting the RS timer. The levers are already labelled with respect to their future functions. During the first 12 min of the session, the reinforcement marker was depressed because of circuit trouble, which also partially accounts for the high initial shock frequency.

VI. TO_{av} PROGRAMMED ON A "HEFFERLINE" SCHEDULE

Since TO_{av} was an effective, although apparently weak, positive reinforcer, the performance characteristics of the TO_{av} behavior were examined by using various other schedules of reinforcement. The first schedule to be used was a modification of the Hefferline schedule, in which reinforcement is secured by holding the lever down (Hefferline, 1950).

Method

Subjects. The subjects were two male rats, 6 months old at the start of experimentation. They were maintained on free food and water in individual living cages.

Apparatus. The apparatus was identical with that described for Section 4.

Procedure. The animals had preliminary training on the free-operant avoidance procedure. Throughout the entire experiment, the SS interval was 3 sec and the RS interval was 30 sec. The shock level was maintained at 1.0 ma and the shock duration at 0.3 sec. During the initial avoidance-training period, two levers were always available to the rats; and both levers were equally effective in postponing shock. During the next phase, the animals were trained to produce a 10-min TO_{av} . A 433-cps tone was used as the TO_{av} cue.

During the Hefferline schedule phase, the animal produced the TO_{av} condition (tone) only when it held the TO lever down. As soon as it released the lever, the tone went off and

the free-operant avoidance schedule (the 30-sec RS timer) took effect. Other experimental conditions were similar to those described in Section V.

Results

Figure 14 depicts the avoidance responses on the two levers during the last session of the initial avoidance-training phase. The records show some of the "spontaneous" switching from one lever to the other which has been described in detail elsewhere (Verhave, 1961d). The TO_{av} contingency on the TO lever went into effect at the start of Session 10. Figure 15 shows the finished development of the discriminations concerning the functions of the tone, the avoidance lever, and the time-out lever. These data confirm information reported in Section IV.

The Hefferline schedule was initiated at the start of Session 17 (Fig. 16). The first long "holds" appear during the second half of the session. (See arrows.) Whenever the time-out lever was held in the downward position, the reinforcement-marker pen of both cumulative recorders was also held in the down position. The first arrow on the left side of the bottom panel of Fig. 16 indicates the occurrence of the first hold of any significant duration. Notice that when the reinforcement-marker pen of the time-out lever recorder is in the up position for any significant length of time, the animal usually shows a sufficiently high rate of responding on the avoidance lever to keep the shock away. Figures 16, 17, 18, and

Fig. 15. Final stage of development of TO_{av} behavior.

Fig. 16. Development of holding behavior when TO_{AV} is put on a Hefferline schedule. Depressions of the TO lever are indicated by downward deflections of the reinforcement markers of both cumulative recorders.

19 give a record of the development of the performance on the schedule. The following features can be noted: (1) a gradual decrease in the avoidance rate, and (2) a gradual increase in the frequency and duration of "holds."⁴ At no time within the period of

seven sessions (42 hr), however, did the animal depress the lever for more than a few minutes. The greater part of a session was characterized by frequent lever release-press sequences. (3) An immediate increase in the rate of responding on the time-out lever. This effect can be explained by the fact that from the start of Session 17, each down-press produced the onset of the tone as a conditioned reinforcer.

⁴There were nine clearly visible "holds" of any significant duration during Session 17.

Fig. 17. Continued development of holding behavior when TO_{AV} is put on a Hefferline schedule.

Fig. 18. Continued development of holding behavior when TO_{av} is put on a Hefferline schedule.

Furthermore, the TO lever now served the same function as the avoidance lever. Each time the rat pressed the TO lever, it postponed shock for 30 sec.

The data for the second animal were practically identical. This rat was maintained on the Hefferline schedule for 24 sessions (144 hr) without showing holds of any greater length than those by Rat 113 during Session 23 (Fig. 20). Holds of 10 min and longer, as reported by Hefferline, were never obtained.

One reason for this difference might be that conditioned aversive stimulus in the present experiment may be less effective than

Hefferline's bright light. Unlike Hefferline's animals, the subjects here could release the lever for as long as 30 sec without producing the aversive stimulus.

There is one other feature of the course of the performance during a single session that is worth noting. Harrison and Abelson (1959) reported that the rate of escape responding (bar presses) tended to remain fairly constant throughout a session, whereas the rate of bar releases showed a progressive decrease during the first 15 to 20 min of a session. Similar phenomena appear in the TO lever record obtained during Session 23, except that the

Fig. 19. Continued development of holding behavior when TO_{av} is put on a Hefferline schedule.

warm-up takes considerably longer than 20 min. The frequency of holds does not increase noticeably until after the first 90 min.

In Session 24 (Fig. 20), Rat 113 could again produce a 10-min TO by pressing the TO lever. The animal almost immediately regained its performance of Session 16, although it pressed the TO_{av} lever considerably more often than was necessary during the latter half of the session.

VII. TO_{av} PROGRAMMED ON A FIXED-INTERVAL SCHEDULE

Because the properties of the FI performance are well-known, it is of interest to compare results obtained with TO_{av} with the data obtained by means of other reinforcers. The results might also clarify the initial failure to show the reinforcing effect of TO_{av} with the single-lever mult Avoid TO procedure.

Method

One subject, Rat 113 had been returned to a TO_{av} procedure (Session 24, Fig. 20) with continuous reinforcement (CRF) for pressing the TO lever. The conditions were then maintained unchanged for three sessions (25, 26, 27). During the next phase of this experiment, the TO_{av} was programmed on an FI schedule, which was gradually lengthened during several successive sessions. In Sessions 28 and 29, the animal could produce the 10-min TO whenever the avoidance procedure had been in effect for a fixed interval of 20 sec; in Session 30, the FI was 30 sec; from Session 31 through 34, the FI was 2 min; thereafter, FI 5, 10, and 15 min were programmed in succession with each value maintained for six sessions. The schedule was then returned to CRF for another six sessions (53 through 58).

RAT 113 SESSION 23

RAT 113 SESSION 24

Fig. 20. Continued development of holding behavior when TO_{av} is put on a Hefferline schedule and there is a return to normal CRF TO_{av} conditions.

A second animal was trained on the free-operant avoidance procedure as described in Section VI. The TO_{av} was then programmed on an FI schedule, and the rat moved through the series of FI schedules in the same manner as Rat 113.

Results

Figure 21 shows the cumulative records obtained during the last session that Rat 113 spent on FI 5 (Session 40), FI 10 (Session 46), FI 15 (Session 52), and CRF (Session 58). Each of these FI schedules clearly maintained the TO-producing behavior. Even with FI 15, the animal only occasionally spent unnecessary time on avoidance. But there was no evidence of the positively accelerated responding commonly associated with FI schedules of food reinforcement. The animal pressed the TO lever at an extremely low rate.

Again, the weakness of TO_{av} as a reinforcer, as well as the fact that the TO-producing behavior had to be emitted concurrently with the regular avoidance behavior, may account for the absence of a typical FI response pattern. Because of these findings, it is not surprising that no scallops were superimposed on the avoidance rates in the single-lever mult TO_{av} experiments of Sections II and III.

The second animal's data were identical with those of Rat 113, and will not be presented here.

VIII. SOME EXPERIMENTS CONCERNING THE SIGNALLING FUNCTION OF THE TO_{av} STIMULUS

A question arises about the function of the stimulus (tone) correlated with the TO from the avoidance periods. Without the tone as a "start and stop" signal, animals might not have been able to develop the complex performances that have been described. The next experiments were designed to study the discriminative function of the tone in contrast to its reinforcing function.

Method

Subjects. The subjects were eight male rats, 6 months old at the start of experimentation. They were maintained on free food and water in individual living cages.

Apparatus. The apparatus consisted of three experimental cages similar to the one de-

scribed for the preceding series of experiments. All other features of the apparatus were identical to those described for the experiments of Section IV.

Procedure 1. Four animals (Rats 1, 2, 3, and 4) had preliminary training on the free-operant avoidance procedure (Sidman, 1953). Throughout the experiment, the SS interval was 3 sec and the RS interval was 30 sec. The shock level was maintained at 1.5 ma, with a duration of 0.15 sec. From the very first session on, two levers were available to the subject in the experimental cage. Throughout the avoidance-pretraining phase, each lever was equally effective in postponing shock. The animal started a new 30-sec RS interval each time it pressed either lever. The four animals received different periods of pretraining on the avoidance schedule, ranging from 9 to 12 sessions.

During the next phase of the experiment, the rat could produce TO_{av} by pressing the TO lever once (CRF). This procedure is analogous to the situations described in Sections V, VII, and VIII. The only difference is that in the present experiment, no tone was correlated with TO_{av} .

During a third phase, the tone was introduced as an exteroceptive stimulus correlated with TO_{av} . It was subsequently taken out and replaced several times more.

Procedure 2. Four animals (Rats 51, 52, 53, and 55)⁵ had different periods of preliminary training on the free-operant avoidance schedule. As with Rats 1, 2, 3, and 4, two levers were available from the start. Both levers were functional.

Subsequent to the avoidance-pretraining phase, all four animals were trained to produce TO_{av} by pressing one of the two levers. A 433-cps tone was the TO_{av} signal.

After the TO_{av} -producing behavior was well established and responding on the two levers during the TO_{av} periods had been extinguished, the tone signal was taken out for the first time. It was subsequently reintroduced and removed several times more for each of the animals.

Results with Procedure 1

Figure 22 illustrates the performance of Rat 1 during Session 9, the last session of the free-

⁵These animals are not the same rats as those of Section II.

Fig. 21. Performance when various FI schedules are scheduled with respect to TO_{av} .

Fig. 22. Performance of a rat in a free-operant avoidance situation with two levers. The levers are already labelled with respect to their future functions.

operant avoidance procedure before introduction of the TO_{av} periods without a cue. The animal rarely pressed the TO lever. Figures 23, 24, and 25 present the progressive changes in performance on both levers during Sessions 10, 11, and 12, when the animal could produce unsignalled 5-min TO periods. The animal obtained its first three TO periods near the

end of Session 10. (See arrows.) A brief but complete change in prepotency from the avoidance lever to the TO lever occurred during the second TO period. A more lasting shift in prepotency from the avoidance lever to the TO lever occurred at the start of Session 11, with a second reversal at Arrows A and B (Fig. 24). During Session 12, responding on

Fig. 23. Progressive changes in performance after introduction of TO_{av} without an external cue.

Fig. 24. Progressive changes in performance after introduction of TO_{av} without an external cue.

Fig. 25. Progressive changes in performance after introduction of TO_{IV} without an external cue.

Fig. 26. Development of cued TO_{av} performance after a period during which TO_{av} was available without being correlated with an external cue.

the avoidance lever remained prepotent, with one exception. (See arrows, Fig. 25). During Sessions 13, 14, and 15, the performance of Session 12 was maintained, with no increase in the number of TO periods.

From Session 16 on, the tone was introduced. During Sessions 16, 17, and 18, the TO_{av} duration was 5 min. Because the number of TO_{av} 's

increased only slightly, the TO_{av} duration was increased to 15 min during Session 18, and to 30 min beginning with Session 20. Figure 26 shows the degree to which the discriminations had progressed by Session 25. The animal seldom pressed the avoidance lever. Except at the beginning of the session, "outbreaks" of prolonged bursts of responding still occurred occasionally on the TO lever. (See arrows, Panel 3, Fig. 26.)

The data of Rat 4 tell a different story. Like Rat 1, this animal confined most of its responses to one lever; but this time, it was the TO lever. Figure 27 shows the output on both levers during the last session of the free-operant-avoidance procedure before the animal could produce the unsignalled TO_{av} . During the next eight sessions, Rat 4 continued to press the TO lever almost exclusively.

Because of Rat 4's pattern of behavior, the schedule in effect was similar to the percentage-shock schedule described by Boren and Sidman (1957); when the animal failed to respond within 30 sec of a previous response, the pause was only occasionally followed by shock. Shocks could occur only when the animal was not in TO_{av} .

Because the animal was rarely shocked after it paused longer than 30 sec, its response rate

Fig. 27. Performance of a rat in a free-operant avoidance situation with two levers. The levers are already labelled with respect to their future functions.

RAT 4 SESSION 11
TIME OUT WITHOUT TONE

Fig. 28. Progressive changes in performance after introduction of TO_{av} without an external cue.

RAT 4 SESSION 17
TIME OUT WITHOUT TONE

Fig. 29. Progressive changes in performance after introduction of TO_{av} without an external cue.

Fig. 30. Cued TO_{av} performance after a period during which TO_{av} was available without being correlated with an external cue.

on the TO lever eventually declined. Figures 28 and 29 show the performance during the first and last sessions on the unsignalled TO_{av} procedure. There is evidence that at the same time, the animal formed a discrimination with respect to "getting a shock and making one or several presses on the lever." This can be seen during Session 17 (Fig. 29). On several occasions (Arrows A, B, C, and D), the rat was shocked, emitted a burst of responses on the TO lever, and then paused for several minutes. Occasionally, the animal pressed the avoidance lever in a similar pattern. (See Fig. 29, Arrows E and F.)

The tone was introduced at the start of Session 18. By Session 30 (Fig. 30), the performance came close to the pattern typical of the final stage under regular TO_{av} conditions.

Results with Procedure 2

Figures 31 to 34 show the effects of removing the tone on the performance of animals pretrained on the TO_{av} schedule with the tone as a cue.

Session 15 (Fig. 31) was Rat 53's last regular session on the two-lever time-out avoidance procedure before the removal of the tone as

the discriminative TO_{av} cue. The next two figures, 32 and 33, show the results of removing the tone during Sessions 16 and 17. The outstanding effect was a gradual, but eventually quite large, increase in the response output on the TO lever. Figure 34 (Session 18) shows the rapid return to the previous performance after the tone was re-introduced as a cue. The experiment was repeated several times with the same results. Identical results were also obtained with the three other animals used in this series, and will not be presented.

These experiments clearly show that the tone has an important signalling function, controlling the amount of responding during TO_{av} . The results of removing the tone, however, depend on the animal's training history. The reasons for the various aspects of performance of animals on Procedure 1 have already been outlined and need not be repeated. The increase in rate after removal of the cue in animals of Procedure 2 may be partially explained by an increase in shock frequency. With sufficient experience, the rats on Procedure 2 might eventually behave like the rats on Procedure 1 without tone.

Fig. 31. Final stage of TO_{av} behavior before removal of external cue correlated with TO_{av} .

Fig. 32. Effect of removing external cue correlated with TO_{av} .

IX. SOME OBSERVATIONS ON THE EXTINCTION OF THE TO_{av} BEHAVIOR

The TO_{av} behavior can be extinguished in two ways. First, TO_{av} can be withheld as the reinforcement for pressing the TO lever. This leads to extinction of only the TO-producing response. Second, extinction can be produced by eliminating the shock that the animal would otherwise receive for not pressing the avoidance lever. Removal of the shock should result in extinction of both responses.

If an animal successfully and consistently produced TO_{av} and consequently received a shock only rarely, extinction of its behavior by eliminating the shock may take a long time. The behavior of the poor avoider, that is, of the animal that received many shocks, therefore extinguishes more rapidly.

Both extinction techniques were tried out on almost every animal used in the TO_{av} experiments. Representative data on an animal whose shock frequency was intermediate between "very good" and "very poor" will suffice.

Method

Subject. The subject was a male hooded rat (Rat 31), 60 days old at the start of experimentation. It was maintained on free food and water in its own living cage.

Apparatus. The apparatus was identical with that described for Section V.

Procedure. The animal was first trained on the free-operant avoidance procedure for 24 sessions. The SS interval was maintained at 3 sec, the RS at 30 sec, the shock level at 1.5 ma, and the shock duration at 0.15 sec. During this phase, only one lever was available to the animal. In Session 24, the TO lever was in-

Fig. 33. Continued effect of removing external cue correlated with TO_{av} .

Fig. 34. Return to normal cued TO_{av} performance after a period during which the external cue correlated with TO_{av} had been removed.

troduced; by pressing it, the rat produced a 10-min TO_{av} (correlated with a 433-cps tone as cue) on CRF.

Results

The TO_{av} behavior was first extinguished during Session 34 by not presenting TO_{av} when the animal pressed the TO lever. Figure 35 presents the cumulative records. Extinc-

tion began at Arrow 1. The nature of the pre-extinction performance can be judged by the portion of the records before this arrow.

The immediate effect of withholding TO_{av} was a burst of activity on the TO lever during which the animal received several shocks (SS was 2 sec). After this initial burst, the rate switched back at once to the avoidance lever, only occasionally pressing the TO lever,

Fig. 35. Extinction of TO_{av} behavior by removal of the availability of TO_{av} .

Fig. 36. Extinction of TO_{av} behavior by removal of the shock. Pips on the shockline indicate where the animal would have been shocked if the avoidance contingencies had still been in effect.

usually in small bursts. The TO_{av} was again made available at Arrow 2, but the animal did not obtain the first TO_{av} until the end of the record. The performance on both levers then returned to its pre-extinction pattern. This phenomenon clearly demonstrated the functional independence of the responses on the two levers.

Figure 36 demonstrates extinction by removal of the shock (indicated by the labeled arrow). The first extended periods in which the animal did not press either lever appeared

near the end of Session 38. In the last half of Session 39, the periods of no responding had lengthened considerably. By the beginning of Session 40, the avoidance behavior had extinguished, and spontaneous recovery did not occur. The TO -producing behavior also appeared to be extinguished at first, but the animal then (at the arrow) produced a long series of TO periods before it eventually ceased pressing the TO lever.

A fairly advanced stage of extinction was reached during Session 41 (Fig. 37). The be-

Fig. 37. Advanced stage of extinction of both Av and TO_{av} behavior after removal of the shock and reconditioning of the behaviors on both the TO_{av} and Av levers.

havior was then reconditioned by re-institution of the shock. (See labeled arrow.)

X. REVERSAL OF THE FUNCTION OF THE LEVERS

If an animal presses the avoidance lever, and almost instantly thereafter presses the TO lever, a superstitious chain may develop. In an experimental situation similar to the one used here, Sidman (1962) has demonstrated superstitious chaining of the two responses in monkeys. Sidman's monkeys apparently were more susceptible to such spurious contingencies than the rats of my experiments, and he found it necessary to introduce additional contingencies to prevent the occurrence of superstitious chains. In the many rats I have used, I have not discovered a single instance of such superstitions. However there is always the possibility that they occur unnoticed. The preceding section illustrated one method (extinction) of showing the functional independence of the two concurrent operants. Another method is to reverse the functions of the two levers. If the animal switches its output to the preferred time-out lever whenever a reversal of function occurs, independence of the behavior on the two levers is again demonstrated. This experiment is not so definitive a test of independence as is extinction, since the superstitions may reverse, too.

Method

Subjects. The subjects were two male rats, 6 months old at the start of training. They were maintained on free food and water in individual living cages.

Apparatus. The apparatus was identical with that described for Sections VII and VIII.

Procedure. The preliminary training was identical with that described for the animals of Section VII. The values of the temporal and shock parameters were also the same as in Section VII.

After the TO_{av} -producing behavior had been established and the behavior in TO_{av} was almost entirely extinguished, the functions of the levers were switched. After several sessions, the initial functions of the levers were re-established. The same procedure was repeated several more times.

Results

Figure 38 shows the data obtained when the functions of the levers were switched for the third time. Session 31 shows the usual performance under normal conditions. The functions of the levers were reversed during Session 32 and re-established during Session 33. Session 35 illustrates the complete return to the initial performance of Session 31. Because the changes were significant only during the first part of the sessions, only the records obtained during this period are reproduced.

Fig. 38. Switching of the functions of the Av and TO_{av} levers.

The major effect of the reversal of the function of the levers was to increase the rate of responses on the TO lever (previously the avoidance lever). Immediately after the reversal during Session 33, the response output on the regular avoidance lever was increased. Both increases were temporary. The animal quickly adapted to the new arrangements. Similar findings were obtained with the other rat used for this experiment.

XI. THE DEVELOPMENT OF STIMULUS CONTROL OVER THE TO_{av}-PRODUCING BEHAVIOR

As part of a projected series of experiments (Verhave, 1959a, b); (1961, a, b, c), it was considered useful to bring the responses on the TO lever under the explicit control of a discriminative stimulus. In this manner, avoidance behavior could be evoked without the

Fig. 39. Development of discriminative control over the TO_{av} behavior by a separate external cue.

simultaneous occurrence of the TO_{av} response. In addition, the animal could be forced to spend a definite minimum amount of time on the regular avoidance procedure.

Method

Subjects. The subjects were eight male rats, 6 months old at the start of training. They were maintained on free food and water in individual living cages.

Apparatus. The apparatus was identical to that described for Section IV.

Procedure. The preliminary training of the animals proceeded as described for Section VI. After an animal consistently produced TO_{av} and the inappropriate responding during the time-out periods had been almost extinguished on both levers, the next phase of the procedure was initiated. After each TO_{av} period, the animal could not produce the next TO_{av} period for 5 min. During these 5 min, which is, in effect, a TO period for the TO lever, a light above the TO lever was extinguished. Both lever lights were on during TO_{av} , however. Responding on the TO lever was thus only reinforced when the light above this lever was on, outside TO_{av} periods. In Fig. 39 and 40, the periods in which the TO lever was ineffective are indicated by a depression in the top line above the cumulative records. The line is labeled T. O. D. (time-out discrimination) procedure. The length of the TO periods was 10 min. All other conditions were as described for Sections V and VII.

Results and Discussion

Session 13 (Fig. 39) shows the final performance on both the time-out and avoidance levers during the last session before introduction of the T.O.D. procedure. The initial result of the 5-min TO lever extinction periods (Session 14) was a series of extinction curves of the TO lever behavior during the T.O.D. periods. The shock frequently also increased. Both effects were temporary and disappeared gradually during Sessions 14, 15, 16, and several other successive sessions. During the latter part of Session 16 (Fig. 40), the number of TO lever responses emitted during the T.O.D. periods has greatly diminished. Similar results were obtained with the other seven animals. The present data illustrate once again the functional independence of the two operants.

XII. GENERAL DISCUSSION

The series of experiments in Sections V through XI has demonstrated that "a stimulus associated with a period of time-out from a stimulus associated with an avoidance schedule" (TO_{av}) can function effectively as a positive reinforcer.

Various reinforcement schedules generated performances on the TO lever which had many features of the performance patterns produced by the same schedules with conventional positive reinforcers. The main differences can be explained by two factors.

(1) Behavior by which the subject produces TO_{av} is always in competition with the behavior on the avoidance lever. The animal must stop pressing the TO lever frequently, and, instead, press the avoidance lever if it is to keep the shock from occurring.

(2) The TO_{av} period is a relatively weak reinforcer. The performance it maintains shows many similarities to performances maintained by food under low deprivation. For example, behavior reinforced by TO_{av} can be maintained only at low-valued ratio schedules (100); the FR straining is relatively excessive for the low FR values involved. With FI schedules, there are no scallops, and the response output is just about minimal. Extinction proceeds rapidly, and the "holding-the-lever-down" behavior with the Hefferline schedule is of relatively short duration.

XIII. THE SIGNIFICANCE OF THE DEMONSTRATION OF TO_{av} AS A REINFORCING EVENT FOR THE THEORETICAL INTERPRETATION OF AVOIDANCE CONDITIONING

A rather simple interpretation of avoidance behavior has become widely accepted in one form or another (Schoenfeld, 1950; Solomon & Wynne, 1953; Mowrer, 1960). The reinforcing events responsible for the acquisition and maintenance of avoidance behavior are held to come from two sources: the termination of the warning signal and its proprioceptive concomitants (Schoenfeld, 1950), or the fear or anxiety induced by these events (Mowrer, 1960). In another presumably competing formulation, it has been suggested that the very absence of the shock strengthens the operant

avoidance behavior (Hilgard & Marquis, 1940; Kamin, 1957, 1959). The perennial question is: how can the absence of a stimulus (such as shock) be a reinforcing stimulus?

The present experiments, which are a continuation and further development of the avoidance schedules initiated by Sidman (1953), may help to answer this question. "The

absence of shock" is in fact always a *stimulus condition* associated with nonoccurrence of shock, in other words, TO_{av} . Earlier formulations overlooked the fact that the termination of one stimulus (condition) *ipso facto* produces another one. The intertrial interval of the traditional avoidance experiment may be considered as another TO_{av} .

Fig. 40. Continued development of discriminative control over the TO_{av} behavior by a separate external cue.

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