UNSIGNALLED AVOIDANCE IN A SHUTTLEBOX: A RAPID ACQUISITION, HIGH-EFFICIENCY PARADIGM¹

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Detailed descriptive data are provided on the free-operant avoidance behavior of rats in a shuttlebox during both acquisition and terminal performance. Initially, eighteen 21-min acquisition sessions were given. Each hurdle-cross postponed the next shock 20 sec (response-shock interval) and shocks were scheduled every 5 sec (shock-shock interval) in the absence of a response. All eight subjects avoided over 70% of the shocks due (12/min) in Session 1. Maximum response rates were reached by the third session and declined slowly while shock rates continued to drop slowly through Session 15. Three subjects were run an additional five months with a response-shock interval of 20 sec and their terminal response rates were all under five responses per minute and shock rates were 0.07 per minute. Interresponse time distributions for terminal performance showed that over 95% of all responding by all three subjects occurred in the last half of the response-shock interval.

Historically, the study of avoidance behavior evolved into two fairly distinct methodologies or "schools". The first (signalled escape-avoidance) involved an exteroceptive warning stimulus (CS), an escape contingency, some type of discrete trial procedure, and a shuttlebox or similar apparatus requiring a running response.

In the second approach (unsignalled avoidance), no exteroceptive stimulus was employed and the trials feature was dropped for the free response situation. In the original report (Sidman, 1953) of this paradigm (unsignalled avoidance), brief, fixed-duration, inescapable shocks were scheduled at regular intervals in the absence of a response (S-S interval) and another shock-free period of time was produced by a response (R-S interval). The apparatus required a lever-press response.

In both of these approaches, problems making experimentation difficult are commonplace. These may be unique to one approach, such as the lever-holding difficulties encountered in unsignalled bar-press avoidance (Hurwitz, 1967), or the long-term deterioration in performance ("decrements") often found in signalled shuttlebox escape-avoidance (Anderson and Nakamura, 1964). Other problems

frequently encountered are common to both approaches, such as inferior performance at the beginning of a session ("warm up effect"), as well as frequent failures to learn reported for both unsignalled bar-press avoidance (Weissman, 1962) and for signalled escape-avoidance (Brush, 1966).

About 10 yr ago, Black and Morse (1961) conducted what was apparently the first study combining the free-operant paradigm with the more traditional shuttlebox apparatus, and their results with dogs were apparently successful in overcoming some of the common avoidance problems found in rats. Scobie (1970) has since combined the shuttlebox apparatus and the free-operant paradigm in successful avoidance conditioning with goldfish. The free-operant shuttlebox combination has also been employed with rats with increasing frequency in recent years (Grossen and Bolles, 1968; Herendeen and Anderson, 1968; Johnson and Church, 1965; Martin and Riess, 1969; Riess, 1969, 1970 *b-d*; Riess, 1972; Riess and Bath, 1970; Riess and Farrar, *in press*; Riess and Martin, 1969; Scobie, 1969), but in all cases these experiments have not focused on avoidance itself. Consequently, no basic descriptive data on unsignalled avoidance with rats in the shuttlebox are available. The present study sought to provide these data for both acquisition and terminal performance with special emphasis on the experimental prob-

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lems normally associated with the two traditional approaches to avoidance behavior.

METHOD

Subjects

Eight naive female albino Wistar rats from the colony maintained by the Galesburg State Research Hospital Psychology Laboratory, were raised in an activity cage environment and were moved to individual cages when they reached 68 to 74 days of age.

Apparatus

An 18.25 by 8 by 8 in. (46 by 20.5 by 20.5 cm) modified prototype Lehigh-Valley plastic shuttlebox contained 2-mm rods aligned parallel to the hurdle. These 40 rods formed a stationary grid floor and were wired so that no single circuit supplied any two adjacent bars. A 1.75-in. (4.5-cm) high hurdle made of two stainless steel strips separated at the corners by nonconducting plastic plugs divided the box into two equal compartments. Both strips were connected below the grid to a separate circuit. A 34.5 by 17 by 21 in. (87 by 43 by 54 cm) wood chest housed the shuttlebox. A speaker mounted on the inside center rear of the chest provided masking noise from a Grason-Stadler Model No. 901B white noise generator. Transparent plastic doors allowed light to enter the chest and permitted observation of the subject. Air was circulated from outside the chest by an air blower. A Grason-Stadler Model No. E1064GS combination constant current shock generator and electromechanical scrambler provided the shocks.

Procedure

The subjects received 18 daily 21-min unsignalled avoidance sessions. Each hurdle cross (*i.e.*, when both forepaws were seen by the experimenter to have touched the floor of the new compartment) postponed the next shock 20 sec (R-S interval) and shocks were presented every 5 sec in the absence of a response (S-S interval). There was no response-produced exteroceptive feedback. The shocks were 0.2 sec and 2.0 mA. Placing the subject in the apparatus began an R-S interval. Interresponse times (IRTs) were recorded in the last session.

Since experiments with unsignalled lever press avoidance are generally conducted under conditions quite different from the above (*i.e.*,

longer sessions, lower shock intensities, and with more experienced subjects), additional data on long-term performance were also collected. Three of the original subjects were run an additional five months at R-S = 20 sec during two intervening experiments. These experiments involved the presentation of a Pavlovian conditioned stimulus on an avoidance baseline, a procedure that has been shown to increase rates during the stimulus, but leave the avoidance rates essentially unchanged (Riess, *in press*). Behavior during this conditioned stimulus was extinguished before the continuation of the present experiment. These three subjects were then run for four daily 1-hr sessions at R-S = 20 sec, S-S = 5 sec, and shock = 0.1 sec, 1.0 mA, and the data for the fourth session were taken as a representative index of terminal performance for the new values of shock and session length. The data from the first 7 min of this final session were unrecorded because the local rates at the beginning of a session differ systematically from those of the remainder of the session. No exteroceptive stimulus change signalled the start of recording.

RESULTS

The response rates for Sessions 1 to 10 are presented (Figure 1) with Sessions 11 to 17 excluded because no further changes occurred after Session 10. The rates of hurdle crossing in the first session were high enough to avoid 70% of all shocks, calculated in terms of S-S intervals (*i.e.*, 12 shocks due per minute). Maximum response rates were reached in 1 hr (Session 3) for the group as a whole and slowly declined from Session 6 on. Although some semblance of an "acquisition" curve was in evidence in Sessions 1 to 3, the most significant behavioral changes were in the continued reduction of shock rates (see Figure 4) well after the response rates had begun to decline (response spacing).

A clearer picture of the development of response spacing (Figure 2) shows the course of response rates in five subjects for the session of maximum rate (M) and for the four sessions subsequent to it. Two subjects are not shown because their maximum rate occurred twice and another was excluded because the peak session occurred too late to allow four subsequent sessions to be plotted.

Fig. 1. Response rates for the first 10 acquisition sessions. The horizontal line indicates the minimum rate necessary to avoid all shocks when responses are ideally distributed.

The corresponding data for these three subjects can be obtained in Figure 1. The mean rate for the five subjects shown dropped nearly two responses per minute in the hour following peak rates, indicating that response spacing was acquired more quickly than suggested in Figure 1, which scattered the peak performances across sessions.

The data on relative local rates at the start of a session (warm up) are presented (Figure 3) as percentages of total responding occurring in the first half of each session for Sessions 1 to 5 and 13 to 17. In contrast to the customary inferior performance at the start of the session found in most avoidance situations, a larger percentage of the total responses occurred in the first half of the session in the unsignalled shuttlebox arrangement. The lower level of responding in the first half of the session was confined to Sessions 1 to 3 and reflected within-

session improvements. Both the overall response rates and within-session increases stopped after Session 3, indicating that the lower percentages of first half responding in these sessions were indeed characteristic only of the period in which overall rates were still increasing. Sessions 6 to 12 (not shown) were transitional, with the first half of the session containing about 52% of the responding. The last five sessions produced an almost uniform tendency (excepting Subject 87) toward more responding in the first half of the session.

In contrast to the stabilization of the mean response rates after Session 3, the mean shock rate continued to decrease into Session 15. Probably the most instructive comparison of response and shock rates can be made in the transition period from Sessions 5 through 10. The shock rate dropped 50% through these sessions, while the response rates also de-

Fig. 2. The development of timing behavior in five subjects during four sessions following maximum (M) rate.

creased in the same period, an indication that response spacing was well under way as early as the second hour.

A more detailed picture of response distributions (IRTs) and particularly of local rate changes cyclicly related to the receipt of shocks was obtained in Session 18. The latter phenomenon ("intershock cycles") was obtained in the following manner: all instances of shock (in all subjects) that were both preceded and followed by eight consecutive responses uninterrupted by an IRT of 20 sec or longer were averaged and are presented as sequential means (Figure 5). The overall response pattern preceding receipt of a shock (left panel) was not characterized by particularly longer than normal IRTs except for the responses emitted from the compartment in which the shock later occurred. These shocks generally followed the

development of a "preference" for one of the two compartments (*i.e.*, the subject showed a tendency to spend more time in one compartment than the other) and normally occurred in the preferred side. The post-shock response pattern (right panel) showed the familiar response acceleration. The relationship between time since last shock and subsequent IRTs was positive and linear with the exception of the first response ($S + 1$), which required the subject to re-enter the compartment in which it was shocked, which produced a hesitation before the more rapid responding began. The remaining deviation from linearity (at $S + 7$) was apparently statistically random. Response rates returned to normal in about 80 sec or after about eight responses. Although this is obviously in the same family of relationships as the analogous phenomenon in the lever-

Fig. 3. The percentage of responses occurring in the first half of each avoidance session for the first and last five days of acquisition.

press apparatus (Sidman, 1958), it is questionable whether the term "bursting" strictly applies, since the lengthy sequences of IRTs in the 0 to 4 sec range were conspicuously absent in the shuttlebox because of the greater time that was required by the hurdle-cross topography.

In the IRT distributions (Figure 6), sharp temporal control was indicated by the direction of the skew and the peaks in the individual curves. In all subjects except 88, this peak occurred in the 2-sec block following the midpoint of the R-S interval and the bulk of the remaining IRTs occurred to the right.

The IRT distributions for three of the original eight subjects (Figure 7) during terminal performance resembled those in Session 18, in that the discontinuous rise in responding still occurred in the 10 to 11-sec IRT block but the additional training made this rise even more abrupt. The stability of this

terminal performance was indicated by a high degree of minute-to-minute consistency in IRT ($r_{tt} = 0.989$), according to the Spearman-Brown Prophecy formula (Guilford, 1954, Pp. 354 and 377-378). Responding in the 0 to 9-sec block was reduced even further and the percentage of responding in the 12 to 19-sec range showed a corollary increase. Over 95% of all responses occurred in the last half of the R-S interval. The pre-shock IRT pattern (not shown) contained more longer-than-normal IRTs in both compartments. The preferences apparently dropped out after more extended training. The post-shock pattern also showed some attenuation, although this was undoubtedly due as much to the reduced shock intensity as to the additional experience. The shock rates were 0.07 per minute for all three subjects. Thus, the major shift in IRT patterns from late acquisition to terminal performance involved an increase in the mean and median

Fig. 4. Shock rates for the first 17 acquisition sessions. The scale on the horizontal axis has been altered after Session 4 to accommodate the reduced shock rates.

IRTs while the mode remained just to the right of the R-S mid-point.

DISCUSSION

The present results suggest that the combination of the free-operant paradigm and the shuttlebox apparatus for general use in the study of avoidance behavior provides a nearly ideal solution to a wide variety of problems encountered in both unsignalled lever-press avoidance and signalled escape-avoidance in the shuttlebox. The advantages of the unsignalled shuttlebox arrangement include the following: (1) There are no "failures to learn" so frequently encountered in both shuttlebox signalled escape-avoidance (Brush, 1966) and unsignalled bar-press avoidance (Weissman, 1962); (2) No response shaping is required, as is frequently the case in unsignalled bar-press avoidance (Riess, 1970a); (3) Acquisition proceeds much more rapidly than is the case in either of the two traditional arrangements, and this is true of both response rates and shocks avoided; (4) There is no initial period

of higher shock rates, as is often the case in both signalled shuttlebox avoidance and unsignalled bar-press avoidance; (5) After acquisition, there is a minimum of "bursting" (Sidman, 1958) and other gross local response rate fluctuations found in lever-press avoidance which detract from within-session stability and add variability to the results; (6) There are no gross topographical problems analogous to the lever holding often found in bar-press avoidance; (7) Terminal performance is characterized by a higher percentage of shocks avoided than is customarily found in either traditional type of avoidance; and, lastly, (8) There are no "avoidance decrements" frequently reported for signalled escape-avoidance (Anderson and Nakamura 1964). In addition, unsignalled shuttlebox avoidance provides a highly sensitive baseline for studies where behavior other than avoidance itself is of primary importance and these include shock intensity effects (Johnson and Church, 1965; Martin and Riess, 1969; Riess and Martin, 1969; Scobie, 1969); self-punitive behavior (Riess, 1970b); aversive properties of

Fig. 5. "Intershock cycle" of IRTs for the eight consecutive responses preceding a shock (left) and the eight consecutive responses following a shock (right). Data were pooled from every instance of shock in all subjects unless the eight adjacent responses included another IRT greater than 20 sec.

stimuli other than shock (Riess, 1970 *c, d*); Pavlovian conditioning (Grossen and Bolles, 1968; Herendeen and Anderson, 1968; Riess, 1969; Riess and Martin, 1969; Riess and Farrar, *in press*; Scobie, 1969); response topography requirements (Riess, 1971); and observational learning (Riess, *in press*). It is suggested that most of the problems typically encountered by investigators confining their efforts to the study of signalled shuttlebox escape-avoidance or unsignalled lever-press avoidance can be eliminated by a combination of the free-operant paradigm and the shuttlebox apparatus.

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