BAR HOLDING DURING ESCAPE CONDITIONING

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To analyze bar-holding behavior during escape conditioning three rats were trained to escape from shock by pressing a bar, and three were trained to escape by releasing a bar. Bar holding behavior was stronger and more stable under the release condition. These effects were related to the relative shock duration of onbar versus offbar shocks.

INTRODUCTION

During escape training, in which a rat must press a lever to turn off a shock, bar-holding behavior usually develops (Dinsmoor, Matsuoka, and Winograd, 1958; Keller, 1942). That is, the rat holds on to the bar between shocks.

There are two possible explanations of bar holding during escape conditioning. First, the animal is on the lever and holding it down at the moment the shock goes off; therefore this topography might be strongly reinforced. A second, not necessarily mutually exclusive, explanation is in terms of shock durations. If the rat leaves the bar and moves to another part of the box it will take a longer time to move to the bar and turn off the shock than if the rat is near or on the bar. That is, bar holding may be maintained because it may be more efficient behavior than not bar holding (in terms of shock durations).

An attempt was made to separate these two possibilities by varying the nature of the response. This variation is described in detail in the Method section.

METHOD

Subjects

Six male albino rats, experimentally naive, weighing from 410-490 grams, and maintained on *ad libitum* feeding during the experiment, were used.

Apparatus

Training was carried out in an experimental space 10 in. by 11 in. by 8 in. deep with

a telegraph key lever mounted on one wall $3\frac{1}{2}$ in. above the grid floor. The experiment was programmed and recorded automatically.

Procedure

All six rats were given shock-escape training for 1 hr per session for 24 daily sessions. The conditions of the escape training were as follows: every 10 sec a shock was delivered to the rat (approximately 1 ma with lever, walls and grid floor carrying rapidly reversing polarities). If the rat did not turn off the shock within 10 sec the shock was turned off automatically, and the next shock was delivered 10 sec later. If the rat turned the shock off then, the next shock was delivered 10 sec later.

A main feature of the experiment was the manner in which the rats turned off the shock.

For three rats the conventional technique of the bar press was used and for the remaining three rats a modification of this technique was used. The description of these differences is facilitated by reference to Fig. 1. With the conventional technique the rat must always *press* the bar to turn off the shock. If he is on the bar when the shock comes on (Fig. 1, upper left part) then he must release the bar and then press it. If he is off the bar when the shock comes on (lower left part) he need only press the bar. In both cases the press turns off the shock. Rats P (for press) -1, P-2, P-3 were run with this method. With the modified technique the rat must always *release* the bar to turn off the shock. If he is on the bar when the shock comes on (upper right) he need only release the bar to turn the shock off. If he is off the bar when the shock comes on (lower right) then he must first press

the bar and then release it. In both cases the *release* terminates the shock. Rats R (for release) -4, R-5, R-6 were run with this method. If bar holding under the normal bar pressing conditions is the result of the reinforcement of the topography at the moment of shock termination then rats that must release the bar to turn off the shock should spend more time off the bar than rats that must press the bar.

Fig. 1. Escape response modes: the behavior required to escape shock when rat is on the bar or off the bar when the shock is delivered. See text.

RESULTS

The bar-holding behavior that developed in this experiment was measured in three ways. The first measure is the overall percentage of time spent holding the bar down in each session. The results for this measure are presented in the upper part (A) of Fig. 2. The first point derived from this figure is that bar-holding behavior under the bar release requirement is stronger than under the conventional bar press requirement. The bar-holding behavior also developed more rapidly under the release requirement and was maintained at higher percentage levels. (R-6 showed considerable decline in overall percentage of bar time and overlapped with the Press animals at some points. This is discussed below.) Another important result obtained from this set of curves is the gradual diminution of bar holding under the press requirement.

The second measure of bar-holding behavior is whether the rat was on or off the bar when the escape shock was delivered. This measure is a refinement of the overall percentage of bar time measure in that it concentrates on the behavior at the critical

moment only; the moment of shock delivery, Fig. 2B.

The difference between groups is now sharpened. The overlap in the upper part of the figure (due mainly to R-6) was practically eliminated, and, in addition, the overall dispersion between groups was increased. That is, for the Press animals the general trend is for the percentage of on-bar shocks to be *less* than the overall percentage of bar time; for the Release animals the trend is for the percentage of on-bar shocks to be *greater* than the overall percentage of bar time (except for R-5 where no marked difference appeared). Therefore the two escape response modes, Press *vs* Release, produced large differences, not only in overall bar-holding time but in particular in the behavior at the precise moment of shock delivery.

In general, the results suggested that the Press rats tend to get off the bar before the shock, while the Release rats tend to get on the bar before the shock (except R-5). The measure of percentage of on-bar shocks gave only a limited picture of the bar-holding behavior within the shock cycle—and the difference in results between this measure and the overall percentage of bar time measure suggested a closer look at the within cycle bar-holding behavior with still a third measure. This third measure was introduced during the last three sessions only. The 10 sec interval between shocks was divided up into five, 2 sec classes. This permitted the separate recording of bar holding in each successive fraction of the 10-sec shock cycle. (The first class interval of 2 sec actually recorded bar holding occurring .8-2 sec after shock termination instead of 0-2. This was done with the idea of excluding purely artifactual bar holding or not bar holding immediately after shock termination, due solely to the mechanical press or release requirement.) This provided a distribution of the total absolute times spent bar holding in each fraction of the shock cycle. The absolute time spent in each fraction was then transformed into a percentage by dividing the total time in all five fractions into the time in each fraction separately. There is some distortion of the shape of the curve of the original absolute values in the direction of greater compactness; however, the distortion was small for this data. The advantage of this treatment is that different sets of distributions from the

Fig. 2. Percentage time spent holding the bar down per session for 24 sessions for all subjects (upper graph). Percentage shocks delivered when rat was holding the bar down for 24 sessions for all rats (lower graph).

same rat over several sessions or from different rats may be readily compared. (Complete uniformity in bar holding throughout the cycle would appear as a straight line across the 20% level. The area under all curves will sum to 100%.)

Figure 3 presents this transformation of the original values as the percentage of total bar-holding time as a function of the successive fractions of the shock cycle.

Before relating this data to the preceding data some comment is in order on the properties of these curves. Each rat reproduced its own curve to a remarkable degree, in spite of differences in *absolute* bar-holding time. For example, the three curves for P-3 are almost

identical, while the percentage of bar-holding times varied over a range of 18 percentage points for those three sessions. The within cycle bar-holding measure thus revealed constancies in certain aspects of bar-holding behavior when the other measure, overall percentage of bar time, indicated variability. In addition, this measure can reveal quite different bar-holding behaviors where the overall percentage of bar time suggests uniformity, the reverse of the first case. For example, the overall percentage of bar time of P-1 is similar to that of P-2 and P-3 as seen in Fig. 2A and B, but there is a large difference in the bar-holding behavior immediately after the shock as revealed in Fig. 3.

Notice that the low bar-holding values for R-4 and R-6 above the first class interval are not artifacts of the release requirement, (*i.e.*, the bar was just released so the subject must be off the bar) since a) R-5 does not show this low level at .8-2; b) the recording of the bar holding did not start until .8 sec after the shock was terminated. Likewise, the high bar-holding values for P-2 and P-3 are not due to the artifact of the press requirement (*i.e.*, the rat just pressed the bar so he must be on the bar), since a) P-1 produced very low values and b) same as b above.

The main point of the figure relates the changes in strength of bar holding in the shock cycle to the response mode. In P-1 the behavior is weak immediately after shock (this will be related to other data) then gains strength and then shows a sharp *decline* just before the escape shock. P-2 and P-3 show an overall decline in strength of bar holding with the approaching escape shock. This result was anticipated by the greater percentage of bar times than percentage of on-bar shocks seen

in Fig. 2, which also indicated that these Press rats were getting off the bar at sometime before the shock (but did not show when). The Release rats R-4 and R-6 showed a gradual increase in strength of bar holding with the approaching shock, while R-5 showed uniform bar holding during the shock cycle. Again this was earlier suggested by Fig. 2 in which the percentage of on-bar shocks was consistently greater than the percentage of bar times for R-4 and 5, indicating that these Release rats were getting on the bar as the shock approached in time. For R-5 the absence of any clear dispersion between the two measures of percentage of bar time and percentage of on-bar shocks suggested uniform bar holding during the shock cycle and this was confirmed by the flat curves at 20% for R-6 in Fig. 3.

The next set of data relates the bar-holding behavior just presented to another variable, relative shock duration. If the rat was holding the lever down when the shock was delivered, the time required to turn the shock off was accumulated in one running time meter; and

Fig. 3. Relationship between strength of bar holding and time between shocks for sessions 22, 23, and 24.

if the rat was off the bar at shock onset the escape time accumulated in another running time meter. Dividing by the number of on-bar or off-bar shocks gave the mean shock duration for on-bar and off-bar shocks. This data is presented in Fig. 4 for the Release rats and Fig. 5 for the Press rats.

Fig. 4. Mean shock duration for shocks delivered when rat was on the bar (on-bar shocks) or off the bar (off-bar shocks) for the Release rats.

For the Release rats the mean shock duration for on-bar shocks was far below that for off-bar shocks from the first session on. This generally accounts for the strong bar-holding behavior in these Release rats. R-6, in addition, showed considerable efficiency for off-bar shocks with stable, fairly low values prevailing over the last 16 or so sessions. This is the rat that showed a definite decline in overall percentage of bar time and a smaller, but also definite decline in percentage of on-bar shocks. (Refer to Fig. 2.) Staying off the bar seems to have had less punishing consequences for this rat than for R-4 and R-5 and hence accounts for the observed decline in bar-holding behavior.

The data was less clear for the Press rats. For P-1 and P-2 the mean shock duration

for off-bar shocks becomes reliably shorter than for on-bar shocks, presumably accounting for the declining strength of bar holding in these animals. Notice, however, that the off-bar shock duration is shorter than the on-bar shock duration as early as session four for P-1, but the bar-holding strength declines gradually over many sessions. This suggests that another variable, perhaps the variability of the shock durations, must be incorporated to account for these results. Similarly, since P-3 showed very similar mean shock durations for on-bar and off-bar shocks, the decline in bar holding must also be referred elsewhere, perhaps to the variability of shock durations. The method of recording shock duration permitted the calculation of means only, unfortunately.

Fig. 5. Mean shock duration for shocks delivered when rat was on the bar (on-bar shocks) or off the bar (off-bar shocks) for the Press rats.

The final set of data concerns spontaneous responding under the two response modes. Figure 6 presents the total number of responses per session for all subjects. With about 350 escape responses per session, the rest of the responses are intershock or spontaneous responses. There seems to be more

Fig. 6. Total responses per session for all rats for all sessions. Approximately 350 responses are escape responses in each session, the rest are "extra" or "spontaneous" responses.

Fig. 7. Frequency distribution of "spontaneous" responses (presses) for the Press rats as a function of time between shocks, for sessions 18, 19, and 20.

spontaneous responding in the Press rats initially but this disappears for P-2 and P-3 with further testing.

P-1, however, appeared to be a unique rat in that number of spontaneous responses increased considerably over training. In order to obtain a closer look at this spontaneous responding a frequency distribution of spontaneous responses as a function of time in the shock cycle ("or time after last shock") was introduced in sessions 18, 19, and 20. These distributions are shown for the Press rats in Fig. 7. The uniqueness of P-1 is attenuated by the finding that almost all of the increase in spontaneous responding was in the first second or two after the escape response. Therefore, in terms of the *shape of the frequency distribution* of spontaneous responding this rat was not unique, while in terms of amplitude he was. (No explanation for this is offered.) This finding can be used to account for some earlier bar-holding data. The curve for strength of bar holding for this rat P-1 (refer to Fig. 3) was low immediately after the escape response, in contrast to other Press rats. This was probably the result of the strength of spontaneous responding at this time.

Spontaneous responding (releasing) was also recorded for the Release rats and this is shown

in Fig. 8. The main point of these distributions concerns "bursts" after shock termination. This bursting after the shock has been seen by several investigators (Keller, 1942; Sidman, 1958; Boren, 1961) but has not been accounted for experimentally by some technique which manipulates the frequency distribution in time of spontaneous responding. Bursts after the shock are quite characteristic of all the Press animals (Fig. 9) and also of Release rat number 6, but the distributions for R-4, session 18, and R-5, sessions 18, 19, and 20 are clearly lacking in bursts. Whether this result was produced by recording releases for the release rats (whereas a distribution of presses for these rats might have shown a burst distribution) or whether there is a genuine absence of bursting in some animals under the release requirement might be of interest in further work.

DISCUSSION

Earlier work on the problem of bar holding during escape conditioning has been reported by Dinsmoor, Matsuoka and Winograd (1958) using the bar-release procedure. Their rats were trained to release the bar to escape from the shock in 200 trials in a one-session experi-

Fig. 8. Frequency distribution of "spontaneous" responses (releases) for the Release rats as a function of time between shocks, for sessions 18, 19, and 20.

ment. After 200 trials these rats (as a group) were spending about 50% of the time on the bar and taking about half their shocks on the bar. They concluded from their experiments that bar holding was a preparatory response.

The present experiment extends the analysis to the behavior of individual animals in terms of percentage of bar time *vs* percentage of on-bar shocks, within cycle bar-holding strength, on-bar and off-bar shock durations, and the changes in behavior with continued training. In particular, the recording of on-bar *vs* off-bar shock durations in the present experiment permitted the isolation of a reasonable variable to account for much of the bar-holding behavior that was observed.

The main point of this experiment was the demonstration that the topography at the moment of the shock termination does not control bar holding in escape conditioning. The variable which does control bar holding is most likely the relative shock duration of on-bar *vs* off-bar shocks. "Relative shock duration", however, is a vague term. The mean shock duration accounted for a good part of the data, but not enough. A refinement of the relative shock duration idea might also include the variability in shock duration, or

more specifically, the relative frequency of long and short shocks. For example, in a hypothetical case, the mean duration of on-bar shocks may be shorter than the mean duration of off-bar shocks and one would therefore expect strong bar holding to prevail. However, if there are occasional long on-bar shocks, but no, or rare, long off-bar shocks, then bar holding might be weak. The possibility that occasional long shocks exert special control over bar-holding behavior deserves separate investigation.

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Received January 8, 1962