EFFECTS OF A PRE-SHOCK STIMULUS ON TEMPORAL CONTROL OF BEHAVIOR¹

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Rats were exposed to a situation in which a response on lever B was followed by reinforcement if a preceding response on lever A had been made at least 5, 10, or 15 sec before. The effects of signalled unavoidable shock were studied on the behavior maintained by this procedure. All rats made fewer A-to-B sequences during the periods of pre-shock stimulus. In addition, when the A-to-B delay was 10 or 15 sec, the distribution of A-to-B times changed, there being more shorter intervals. However, for animals where the A-to-B delay was 5 sec, the distribution of A-to-B times was not changed during the pre-shock stimulus. In all cases, there was an increased proportion of inappropriate B responses (*i.e.*, with no preceding A response) during the pre-shock stimulus; this was most marked with animals exposed to a 15-sec A-to-B delay.

A number of experimenters have studied the effects on behavior of signalling a slight unavoidable shock. Estes and Skinner (1941) found that lever pressing maintained by an intermittent schedule of food reinforcement occurred less frequently during a pre-shock stimulus than in the absence of that signal. This finding has been replicated using many different schedules of food or water reinforcement (Lyon, 1968), and the behavioral phenomenon has come to be known as conditioned suppression. However, the unqualified generalization that positively reinforced behavior is suppressed during a pre-shock stimulus is not justified, because there are apparently anomalous reports when the schedule of reinforcement used is defined as a DRL, *i.e.*, when a low rate of responding is differentially reinforced by the schedule. Although Leaf and Muller (1964) found that such DRL behavior was suppressed during a pre-shock stimulus, Finocchio (1963) reported an acceleration of DRL responding during a pre-shock stimulus in certain conditions. Blackman (1968) also reported acceleration of DRL responding when a shock of low intensity was used, even though the same shock level produced suppression of behavior during the pre-shock stimulus when it was superimposed on other schedules of reinforcement.

Migler and Brady (1964) suggested that multiple response situations may provide more comprehensive data than single-lever experiments that specify a minimum inter-response

time if a response is to be followed by reinforcement, as is the case with conventional DRL schedules. They conducted an experiment in which a response on one manipulandum (B) was followed by reinforcement only if the subject had previously emitted a response on manipulandum A and allowed a minimum specified interval to elapse. Migler and Brady found that the distribution of A-to-B response times did not change during a pre-shock stimulus, although their subjects made fewer A-to-B response sequences.

The present experiment was designed to investigate these apparent discrepancies further. In a two-lever situation similar to that employed by Migler and Brady (1964), the interval required to elapse between responses on the two levers was set at either 5, 10, or 15 sec. These longer intervals are similar to those used in single-lever DRL situations previously studied by Leaf and Muller (1964) and by Blackman (1968), while the shorter interval is identical to Migler and Brady's.

METHOD

Subjects

Six naive male rats (Wistar albino) were maintained at 80% of their pre-experimental

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weights. They were approximately 120 days old at the start of the experiment. At the time of each experimental session, they had been deprived of food for approximately 21 hr. Water was continuously available in the individual living cages, but was not available in the experimental test chamber.

Apparatus

One commercially manufactured test chamber was used (Grason-Stadler model E3125B). This contained two levers; each required a force of approximately 20 g (0.196 N) to depress it. The chamber was illuminated by a 10-w houselight during experimental sessions. Two small speakers were mounted near the pellet dispenser. One was connected at a Grason-Stadler E901B white noise generator, the other to an audiofrequency generator and an associated amplifier. A Grason-Stadler E1064 shock generator was connected to the grid floor of the chamber.

The experiment was automated from an adjacent room by means of relays, timers, and uniselectors. Responses and reinforcements were totalled by means of digital impulse counters and a three-channel print-out counter. A cumulative recorder was used to provide a continuous display of presses on the left lever.

Procedure

The rats were accustomed to the deprivation conditions, until the daily intake of food needed to maintain their 80% weights was almost constant. They were then adapted to the test chamber by being placed in it for two 1-hr sessions in which food pellets were delivered at irregular intervals averaging 30 sec. Next, the delivery of a food pellet was made dependent upon a press on the left lever (lever B). No shaping procedure was necessary. Two of these bar-training sessions, each with 100 reinforcements, were given. During these bar-training sessions, white noise was continuously delivered to one of the speakers. During the next three experimental sessions, each of which was terminated by the one hundredth reinforcement, the onset of white noise was dependent upon depression of the lever to the right of the food hopper (lever A). A response to lever B was now followed by food only in the presence of white noise, and each depression of lever B also terminated the white noise.

This was therefore a two-lever chain situation with an added stimulus.

After these preliminary sessions, an A-to-B delay dependency was introduced. For each animal, a response on lever B was now followed by reinforcement only if the white noise had been present for at least one second. All responses on lever B terminated the white noise if it was present. As before, a response on lever A switched on the noise. If a second response was emitted on lever A (*i.e.*, when the noise was already present) this response reset the delay requirement to 1 sec. There was one such experimental session, which lasted 56 min. This session duration was retained for the rest of the experiment.

The delay requirement between response A and response B was then gradually lengthened, until Rats 1 and 2 were exposed to a 5-sec delay, Rats 3 and 4 to a 10-sec delay, and Rats 5 and 6 to a 15-sec delay. This gradual lengthening of the interval required 10 experimental sessions for Rats 5 and 6.

Each rat was then exposed to 35 daily experimental sessions of its appropriate schedule. To summarise these final schedules:

Lever A: 1. A response in the absence of noise produced the noise and started the appropriate delay requirement.

2. A response in the presence of noise reset the delay requirement to its maximum, leaving the noise present.

Lever B: 1. A response was followed by reinforcement only if the white noise had been present for at least the required time.

2. All responses in the presence of noise, whether followed by reinforcement or not, terminated the noise.

3. Any response emitted in the absence of white noise had no scheduled consequence.

After schedule control had been developed, a further five experimental sessions were given in which periods of a 1000-Hz tone were delivered to the second speaker. This tone was presented for 1-min periods once every 8 min, the first occurring after 4 min of the experimental session. There were therefore seven tone periods in each session. The addition of these periods of tone was the only change in procedure from the previous 35 sessions, the schedules of reinforcement being in operation continuously as before.

During the next 30 experimental sessions, each period of tone ended simultaneously with the delivery of a brief, unavoidable electric shock (0.5 ma, 0.2 sec), all other experimental dependencies being unchanged.

In the final phase of the experiment (20 sessions), the tone periods were extended to 2 min, presented once every 8 min as before. The shock intensity and duration were unaltered, and the schedules of reinforcement remained in operation continuously, exactly as before.

RESULTS

The schedules used generated behavior on lever B which resembled that produced by conventional DRL schedules on one lever; that is to say, responses were spaced evenly in time. It appeared that the schedules maintained behavior essentially similar to normal DRL behavior, the only difference being that each delay period was initiated by an overt response to lever A, rather than by the previous response on the one manipulandum present in the single-lever situation. Before the tone and shock were introduced to the experiment, inappropriate responses on both levers were rare, although they did occur occasionally (*i.e.*, responses on lever A when the noise was already present, and responses on lever B when the noise was not present). Visual inspection of the animals revealed that each was exhibiting a consistent pattern of non-lever pressing behavior in the intervals between a response on lever A and the subsequent response on lever B. In all cases, this pattern of collateral behavior consisted of simple, repetitive and rhythmic sequences of behavior (for example, gnawing the grid floor, scrabbling in the food hopper).

Presentation of the periods of tone alone, before shock was introduced, produced a little disruption of behavior at first, but by the third such session any disruption had disappeared. This claim is supported by inspection of cumulative records taken of responses on lever B only, and suggests that any confusional factors between the white noise and the 1000-Hz tone were merely temporary.

The main results are represented by the frequency distributions displayed in Fig. 1 to 3. These present the total data obtained from the last 10 experimental sessions with

1-min periods of pre-shock tone, and from the last 10 sessions with 2-min periods of tone. In the absence of the tone, each response on lever B was classified within intervals timed from the preceding response on lever A. For Rats 1 and 2, each B response was classified into the appropriate time interval of 10 successive 1-sec intervals, for Rats 3 and 4 into the appropriate interval of 10 successive 2-sec intervals, and for Rats 5 and 6 into the appropriate interval of 10 successive 3-sec intervals. The number of B responses classified into each time interval was totalled, and these totals were then expressed as percentages of the overall number of B responses thus classified. These percentages are displayed in histogram form to the left of each figure. In addition, a count was made of the number of inappropriate B responses, that is, those emitted when the white noise was absent. This number is expressed as a percentage of the total B responses (*i.e.*, all B responses, whether white noise was present or absent). This percentage is also displayed in Fig. 1 to 3 to the left of the relevant histogram, labelled E (errors on lever B). Exactly the same data collection and analysis was performed for the behavior emitted during the tone pre-shock stimulus for these last 10 sessions of each tone length. These data are displayed on the right of Fig. 1 to 3. In all the histograms, white columns denote percentages of responses in intervals for which no reinforcement was delivered (*i.e.*, appropriate, but premature, B responses); black columns denote percentages in intervals where a B response was followed by reinforcement. It will be seen, then, that these figures compare the efficiency of timing attempts during seventy 1-min pre-shock stimuli with the efficiency of such attempts during 490 control minutes when the pre-shock stimulus was absent, and also the efficiency of timing during seventy 2-min pre-shock stimuli with timing during 420 min when the pre-shock stimulus was absent. In addition, the figures display the proportion of inappropriate B responses in these periods.

Figure 1 shows the experimental results obtained from both animals exposed to the 5-sec delay requirement between A and B responses. It can be seen that the A-to-B response times did not change noticeably during the pre-shock tone. There was, however, a slight increase in the proportion of inappropriate B responses

Fig. 1. Distributions of A-to-B response times from rats exposed to 5-sec A-to-B delay. The percentages are of total appropriate B responses, except for columns labelled E, which denote the proportion of inappropriate B responses, expressed as a percentage of total B responses.

(*i.e.*, those emitted without a preceding A response).

Figure 2 displays the results for the two rats exposed to a 10-sec A-to-B delay requirement. With such a requirement, the A-to-B response times changed during the pre-shock tone. There was an increased proportion of premature but appropriate B responses (*i.e.*, recorded in the first five 2-sec intervals in the figure). In addition, it is clear that there was a greatly increased tendency during a pre-shock stimulus for these rats to emit inappropriate responses on lever B.

Figure 3 shows the results obtained from the two subjects required to delay at least 15 sec between an A response and the following response on lever B. It is apparent that there was a gross change in the distribution of A-to-B response times during the pre-shock stimulus, there being an increased tendency for lever B to be pressed prematurely. Thus, the mode of each distribution shifts to the left (shorter delays). In addition, the proportion of inappropriate B responses became appreciable during the pre-shock stimulus, although they did not form a large proportion of all B responses in the absence of the tone.

The major presentation of the results so far has concerned the temporal relationships between B responses and their preceding A responses. However, the effects displayed in Fig. 1 to 3 are only one feature of the effects of presenting a pre-shock stimulus. In addition to the above analysis, it was also possible to calculate the frequency of B responses in the presence and absence of the pre-shock stimulus. Thus, it was possible to produce suppression ratios as is done conventionally in experiments investigating the effects of a pre-shock stimulus on behavior maintained on a single lever. Table 1 presents such suppression ratios. They are presented in two forms for each duration of the pre-shock stimulus. The first represents the suppression of total responses on lever B, as would be calculated in a single-lever situation. The second takes into account in the calculations only those responses on lever B that were appropriate—*i.e.*, for which there was a preceding response on lever A which had switched on the white noise. In both cases, the frequency of responses during the pre-shock stimulus was divided by the frequency in the absence of the pre-shock tone. So, if the response frequencies were unaffected

Fig. 2. Distributions of A-to-B response times from rats exposed to 10-sec A-to-B delay. The percentages are of total appropriate B responses, except for columns labelled E, which denote the proportion of inappropriate B responses, expressed as a percentage of total B responses.

Fig. 3. Distributions of A-to-B response times from rats exposed to 15-sec A-to-B delay. The percentages are of total appropriate B responses, except for columns labelled E, which denote the proportion of inappropriate B responses, expressed as a percentage of total B responses.

Table 1
Suppression Ratios Obtained; See Results Section in Text

Rat	A-to-B Delay	1-Min Tone		2-Min Tone	
		Total B Responses	Appropriate B Responses	Total B Responses	Appropriate B Responses
1	5 sec	0.45	0.45	0.67	0.65
2	5 sec	0.35	0.34	0.77	0.76
3	10 sec	0.44	0.38	0.64	0.63
4	10 sec	0.59	0.56	0.82	0.70
5	15 sec	0.26	0.09	0.77	0.65
6	15 sec	0.60	0.54	1.10	0.91

during the pre-shock stimulus, this ratio would be 1.00; if the frequency was less during the tone than in the absence of the tone, the ratio would be less than 1.00; complete suppression during the tone would be represented by a ratio of 0. It will be seen from Table 1 that the suppression ratios for appropriate B responses are sometimes less than the comparable ratios for total B responses. This is clearly the result of the fact noted earlier that the proportion of inappropriate B responses rose during the pre-shock stimulus. So the two ratios hardly differ for Rats 1 and 2, neither of which made a large number of inappropriate responses at any time; on the other hand, the ratios differ noticeably for Rats 5 and 6, which made a much higher proportion of inappropriate B responses during the pre-shock stimulus than in its absence. Notice also that, in all cases, there is less suppression with both types of calculation during a 2-min tone than during a 1-min tone. Finally, attention is drawn to the ratio for total B responses for Rat 6 with a 2-min pre-shock stimulus. This figure of 1.10 denotes that the frequency of B responses (whether appropriate or inappropriate) was higher during that pre-shock stimulus than in its absence, this despite the fact that the comparable ratio for appropriate B responses only is 0.91, representing suppression.

DISCUSSION

Three general conclusions are prompted by the present results: (1) During the pre-shock stimulus, the frequency of A-to-B sequences decreased whether the delay was 5, 10, or 15 sec. This confirms and extends the finding of Migler and Brady (1964), who used only 5-sec delays and a slightly different experimental

situation where response A produced no change in stimulus conditions, and where only 50% of criterion B responses were followed by reinforcement. (2) With a 5-sec A-to-B response delay, there was no reliable change in the distribution of A-to-B response times during the pre-shock stimulus. Again, this confirms the previous observation of Migler and Brady (1964). However, it is important to note that with a 15-sec A-to-B delay there was a large change in the distribution, there being an increased tendency for shorter A-to-B times. At the intermediate delay requirement (10 sec), the change was smaller, but there is evidence for some change in the temporal patterning of behavior. (3) During the pre-shock stimulus there was an increase in the proportion of inappropriate B responses. This increase was more marked with longer A-to-B delay requirements. Perhaps this is because the A-to-B response times with longer delay requirements were themselves more disrupted during a pre-shock stimulus. This breakdown in discriminative control of the animals' behavior may be in accord with Hearst's (1965) report that aversive stimuli produce a deterioration in a discriminative performance. Hearst established a pattern of behavior where periods of responding for occasional reinforcement were mixed with periods of little responding because no reinforcements were available. Non-dependent shocks produced an increase in the latter behavior, especially when these shocks were preceded by a warning signal (as in the present experiment). This increase in responses in the absence of a discriminative stimulus associated with food availability is similar to the increase in inappropriate B responses in the present experiment. One difference, however, is that the discriminative breakdown in

Hearst's experiment was not confined only to a pre-shock stimulus.

In one case, the increase in inappropriate B responses in the present experiment contributed to an increase in the absolute frequency of response on lever B during a pre-shock stimulus (Rat 6, 2-min tone). The effect may be analogous to the acceleration of DRL responding with a single lever previously reported by Finocchio (1963) and by Blackman (1968).

In all cases there was more suppression of the number of A-to-B response sequences during a 1-min pre-shock stimulus than during a 2-min stimulus. As the present experiment was designed, it is possible that this is no more than a sequence effect. However, it seems more likely to be in agreement with a finding of Stein, Sidman, and Brady (1958). They used variable-interval schedules of reinforcement, and found that the relative duration of a pre-shock stimulus was one determinant of the amount of conditioned suppression it produced. The present report may provide correlative data from behavior maintained by a different type of reinforcement schedule. Stein *et al.* (1958) noticed that their animals would allow themselves to miss only a certain proportion of possible reinforcements as a result of suppression. Unfortunately, the present data do not make it possible to consider such a possibility in this experiment. However, with the present behavior it is at least true that a longer pre-shock stimulus is less favorable to the production of behavioral suppression. It is in this less favorable situation that overall acceleration of B responses was observed with one subject (Rat 6). This may support the previous observation by Blackman (1968) that

acceleration of single-lever DRL behavior is produced in conditions that are relatively unfavorable to the development of conditioned suppression.

The two-lever situation clearly offers advantages in assessing the effects of a pre-shock stimulus on behavior maintained by schedules of reinforcement that specify a minimum delay between responses. However, the exact relationships between behavior generated by these schedules and behavior generated by single-lever DRL schedules remains a problem for experimental analysis.

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