INSTRUMENTATION & TECHNIQUES

Effects of shock source and method of contact upon runway escape behavior¹

JOSEPH V. LAMBERT and L. J. HAMMOND,² TEMPLE UNIVERSITY, Philadelphia, Pennsylvania 19122

Rats performed better in a shock-escape apparatus with L-shaped metal strips as a runway when a constant-current (CC) shock source was used as compared to a matched impedance source. CC source superiority disappeared when the shock surface was wet (saline solution). Several additional demonstrations strongly suggest that the superiority of the CC source was not related to aversiveness per se but to responses peculiar to particular shock sources.

There are certain drawbacks to the use of electric shock as an aversive stimulus, especially in the case of instrumental escape. At least two classes of undesirable behavior occur during prolonged exposure. For one, as Bolles (1967) has pointed out, "the rat has a whole gamut of responses which are elicited, perhaps unconditionally, by shock (e.g., jumping, squealing, freezing and biting) [p. 180]." Since the E typically selects a different response, such as running or bar-pressing, to be reinforced, these elicited responses compete or interfere with learning. Secondly, there is a type of adjustive interfering response that apparently reduces shock aversiveness (such as the grasping of grid bars in a Skinner box, described by Campbell and Teghtsoonian, 1958). These adjustive responses, which are learned in contrast to elicited responses, also compete with the designated instrumental response.

Shock is typically delivered by either a constant-current (CC) or matched-impedance (MI) source. These two sources elicit different behaviors and permit different forms of adjustment (Cornsweet, 1963; Bolles, 1967; Campbell & Teghtsoonian, 1958). However, the research on shock type has not generally considered these response differences. It has focused, instead, upon the search for a single scale of aversiveness for electric shock, such as electric power. The logic influencing this search appears to be incompatible with the observation that different elicited and adjustive responses occur with different shock sources.

The experiment reported here was designed primarily to develop more

effective shock-escape behavior for rats running in an alley. Pilot animals were trained to run in an alley similar to that used by Campbell and Kraeling (1953) and subjected to stimulation from a MI shock source. The rats showed excessive competing behavior resembling the jumping and stepping lightly described by Bolles (1967) for the constant-voltage shock source. This competing behavior produced excessively long running times. We know that rats exposed to CC sources in the typical apparatus containing a shocking grid have a tendency to freeze and to grasp the grid bars tightly (Campbell & Teghtsoonian, 1958). The opposite might occur with CC shock delivered through the flat surface of an L-shaped shock runner used in some runways (Campbell & Kraeling, 1953). In addition, the use of wet, instead of dry, electrodes might reduce the overall impedance of the shock circuit somewhat and, thus, the variability between shock sources. Tursky and Watson (1964) have shown that variability in subjective estimates by humans of aversiveness of electric shock produced by different types of shock parameters is greatly reduced by a large-scale reduction of impedance in the shock circuit.

METHOD

Subjects

Forty-three male albino rats of the Sprague-Dawley strain were assigned to four groups of 10 Ss each in a 2 by 2 design. Type of shock source (MI vs CC) and electrodes (wet vs dry) were the two variables. Three Ss were discarded because of procedural error. All Ss were lightly anesthetized with sodium pentobarbital 24 h before running. Also, most of the hair was shaved to help reduce adjustive responses, e.g., by preventing the rat from using hair as an insulator when sitting between electrodes.

Apparatus

The apparatus consisted of a straight alley similar to that of Campbell and Kraeling (1953). The alley was 10 ft long and 2-5/8 in. wide inside, with interior walls 4 in. high. The top was of Plexiglas hinged in sections, and the floor was made of two aluminum runners 1 in. wide, with a 5/8-in. gap between them. Thin sheets of galvanized metal were bolted to each

interior side. These sheets, together with each runner, formed an L-shaped shock surface on each side of the alley. Strips of cellulose sponge, 1/2 in. thick and 1 in. wide, could be bolted to the runners. Application of saline solution to the sponges produced the wet-electrode condition. During the dry-electrode condition, the sponges were removed. In all cases, the sides of the alley were dry.

The alley was divided into three sections: a 1-ft startbox, an 8-ft alley, and a 1-ft goalbox. The boxes were separated from the alley by guillotine doors. Photocells were placed below the gap between the floor runners, 3 in. into the alley from the startbox and 3 in. into the goalbox. An overhead 150-W floodlight was suspended 6 1/2 ft above each photocell. The photocells controlled relay circuitry and a standard electric clock that recorded running times for the 8-ft distance between the two photocells to the nearest 1/100 sec.

Shock was produced by a constant-current source, consisting of a step-up transformer with an output of 1,200 V ac and a number of resistors in series with an output that totaled 1.3 megohms when the source was set to produce .85 mA (the CC condition in this experiment). This current intensity was measured as the voltage drop across a 110 K ohm resistor temporarily connected between the two sides of the alley. Shock was also produced by a matched impedance (MI) source consisting of a variable transformer with fixed series resistance of 86 K ohms. A setting of 185 V ac was used in the initial experiment; this setting produced .85 mA when measured in an identical manner as for the CC source.

Procedure

The Ss were run in squads of three to five from the same group. Each succeeding squad was from a different group. The Ss were given 14 trials of escape training in the alley, with an intertrial interval of 2-5 min. Each S was placed in the startbox for approximately 5-10 sec before the startbox door was raised, and then shock was turned on in the startbox and alley within the next second. Shock was never present in the goalbox. The S was removed immediately upon entry from the goalbox and placed in a holding cage filled with

shredded paper towels for the duration of its intertrial interval. Since the Ss were shaved and some were wet, the bedding helped to dry and warm the animals.

Data Analysis

All running times were transformed to speed (1/sec), but both time scores and speed scores were examined. The two-trial block means were calculated for each S, as well as the mean of the last six trials (Trials 9 through 14).

RESULTS

Running times for the four groups were quite variable except for the CC-dry group. These variances are shown in the upper left of Fig. 1. Individual F tests indicated that the CC-dry group was significantly less variable ($s^2 = .507$) than the CC-wet, MI-dry, or MI-wet groups ($F = 18.21$, $F = 12.06$, $F = 40.14$, respectively; $df = 9/9$, $p < .001$, in each case). These variance differences precluded the analysis of the mean time scores, shown in the lower left of Fig. 1. Therefore, as is typically the case in alley-running experiments, the times were transformed to speeds. There were no significant differences between speed variances (upper right of Fig. 1, $p > .05$ for all individual F tests). An analysis of variance (Shock Type by Electrode Condition) was performed on the speed scores, the means of which appear in the lower right of Fig. 1. The histograms for both mean times and mean speeds show that the CC-dry group was quite different from the other groups. An analysis of variance of speed scores showed a significant interaction effect ($F = 4.25$, $df = 1/36$, $p < .05$). No significant main effects were found.

DISCUSSION

With the dry condition, the CC shock source was more than twice as effective in producing terminal escape time scores as the MI source that is commonly used in this situation. Furthermore, and perhaps most important, the variability of running times was markedly attenuated—so much so that the common reciprocal transformation would appear to be unnecessary for Ss in experiments involving only CC shock.

Observation of the individual Ss in the two dry groups indicated that, although many MI Ss ran just as well as those receiving CC, 25% to 50% of the Ss in the MI group simply did not run. They walked, crawled, and writhed to the point that some were traveling at less than 1 ft/sec. The CC condition appears to eliminate this kind of performance entirely. As a further recommendation for constant-current sources, the Ss under this condition exhibited a clear acquisition function in contrast to Ss under the other three conditions (see Fig. 2).

In other shock-escape experiments utilizing MI sources (e.g., Bower, Fowler, & Trapold, 1959; Campbell & Kraeling, 1953; Fowler & Trapold, 1962; Trapold & Fowler, 1960), the functions show better evidence for acquisition than our MI curves. In three of the studies, it is stated that the rats had already been given instrumental training. In two of the experiments (Fowler & Trapold, 1962; Trapold & Fowler, 1960), the rats had been trained prior to being run in an alley for food reward. It is possible that the higher the initial probability of running in the alley, the less the likelihood that other responses of adjustment will interfere with

Fig. 1. Histograms of the time scores (left half) and speed scores (right half) for the last six trials of the main experiment. Group variances are shown in the top half, group means in the bottom half.

running. In our experiment, all Ss were naive and lacked this possible advantage.

Constant-current shock sources vary widely in voltage level, just as MI sources vary in the size of the fixed resistor. When the CC voltage is low (350 V ac in some cases), there is little difference between this and an MI source with a large fixed resistance. In our experiment, the voltage of the CC source was quite high (1,200 V ac), while the MI resistor was fairly low, 86 K ohms. The high voltage of the CC source is probably necessary for producing the efficient escape behavior noted here.

Finally, the wet electrode condition was a complete failure from a practical standpoint, and even destroyed the efficiency of the CC source. This is difficult to explain. One might surmise that the importance of changes in current density that fluctuate when the S picks up and sets down his feet under CC shock are responsible for elicitation and adjustment responses that are compatible with running, and that the wet electrode with its far better contact negates these changes in current density with varying paw pressure upon the shock runners.

Additional Demonstrations

The results of the experiment raised several questions: Was the shaving procedure necessary in order to produce efficient escape under the CC-dry condition? Was the difference between the CC-dry and MI-dry condition a function of different elicited and adjustive responses or simply the result of slight inequalities in the level of aversiveness of the particular settings of the two shock sources? In order to answer these questions, additional observations were made.

Fig. 2. Acquisition running speeds over two-trial blocks for the four groups of the main experiment.

Fig. 3. Acquisition running speeds over two-trial blocks for the three additional demonstrations. The curve for the MI-dry group of the main experiment (185 V ac) has been replotted from Fig. 2.

Fifteen rats were run with the same apparatus and procedure but all under dry, unshaven conditions. A group of five Ss received .85-mA CC shock in order to assess the role of shaving. Two more groups of five rats each were run under a higher (275 V ac) and a lower (150 V ac) MI condition to assess the role of aversiveness in the efficiency of escape behavior. The particular MI settings were estimated from

a graph of the scale of aversion for MI sources with different fixed impedances (Campbell & Masterson, 1969, Fig. 1-5, p. 15). This was done so that the 150-V ac setting was at approximately 65% of the scale range from detection to tetanization, the 185-V ac was at 75%, and the 275-V ac was at 85% of this range. The acquisition curves for these three groups appear in Fig. 3. As can be seen, the curve for the unshaven CC Ss is almost an exact replication of the CC curve in Fig. 2. Neither the higher nor the lower MI setting produced escape behavior comparable to CC shock. The declining slope at the higher MI setting was representative of all five rats and probably reflects greater competition from adjustive responses at this level.

REFERENCES

- BOLLES, R. C. *Theory of motivation*. New York: Harper & Row, 1967.
 BOWER, G. H., FOWLER, H., & TRAPOLD, M. A. Escape learning as a function of amount of shock reduction. *Journal of Experimental Psychology*, 1959, 58, 482-484.
 CAMPBELL, B. A., & KRAELING, D. Response strength as a function of drive level and amount of drive reduction. *Journal of Experimental Psychology*, 1953, 43, 97-101.
 CAMPBELL, B. A., & MASTERTON, F. A.

- Psychophysics of punishment. In B. A. Campbell and R. M. Church (Eds.), *Punishment and aversive behavior*. New York: Appleton-Century-Crofts, 1969. Pp. 3-42.
 CAMPBELL, B. A., & TEGHTSOONIAN, R. Electrical and behavioral effects of different types of shock stimuli on the rat. *Journal of Comparative & Physiological Psychology*, 1958, 51, 185-192.
 CORNSWEET, T. N. *The design of electric circuits in the behavioral sciences*. New York: Wiley, 1963.
 FOWLER, H., & TRAPOLD, M. A. Escape performance as a function of delay of reinforcement. *Journal of Experimental Psychology*, 1962, 63, 464-467.
 TRAPOLD, M. A., & FOWLER, H. Instrumental escape performance as a function of the intensity of noxious stimulation. *Journal of Experimental Psychology*, 1960, 60, 323-326.
 TURSKY, B., & WATSON, P. D. Controlled physical and subjective intensities of shock. *Psychophysiology*, 1964, 1, 151-162.

NOTES

1. This research was supported in part by a grant-in-aid from Temple University. The authors wish to thank James Lambert for his aid in the construction and design of the apparatus.
2. Reprints may be obtained from L. J. Hammond, Department of Psychology, Temple University, Philadelphia, Pennsylvania 19122.