SHOCK DENSITY AND EFFECTIVE SHOCK INTENSITY: A COMPARISON OF DIFFERENT SHOCK SCRAMBLERS¹

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The author had been unable to obtain bar press avoidance behavior at low shock intensities (< 0.5 ma) using a Lehigh Valley Electronics shock scrambler but had obtained good acquisition at these intensities using a Grason Stadler scrambler (Bolles and Warren, 1965). One difference between the two scramblers is that the Grason Stadler unit may activate a given pair of shock grids half of the time, or more, whereas the Lehigh Valley scrambler activates a given pair of grids only one-ninth of the time. These design features provide only a rough approximation to mean or effective shock intensity; the latter is also a function of the time lost in switching grid patterns, how many grids the animal stands on, and behavior during shock.

The present paper describes a method for measuring shock density, which is defined as the ratio of the time that current is actually flowing through the animal to the time that shock is nominally presented. The method is used here (1) to compare shock density characteristics of three commercially available scramblers, and (2) to show how the animal's momentary electrical resistance can be determined.

METHOD

Subjects

Six groups of five naive female Sprague-Dawley rats, about 100 days old, were used.

Apparatus

A 1 ma "constant current" shock was produced from a 880 v dc source and an 880,000 ohm limiting resistor. Shock was presented

through one of three commercial scramblers (Lehigh Valley Electronics, Foringer, or Grason Stadler) to the 12 floor grids and the walls and bar (connected together) of a standard Foringer rat box. Momentary current flow through the subject was monitored by a transistor circuit which sampled the current 1000 times per sec for 1 sec during a inescapable portion of each shock. The basic circuit is shown in Fig. 1.

R_1 is first adjusted to give a short-circuit current of 1 ma. R_2 is used to calibrate the sensitivity control. In operation, current flowing in the shock line generates a small voltage across R_3 which is sensed by the transistor Q. R_4 , the sensitivity control, permits the threshold of the transistor to be varied over the range .2 ma to 1 ma current in the shock line. C_1 is used to prevent detection of very brief switching transients.² $R_6 - C_2$ convert the square wave output of the pulse generator to a series of sharp spikes so that the shock current is sampled only at the beginning of each .001-sec period. Perhaps the least familiar circuit element is the And Gate. This device provides an output ground when and only when all of its inputs are grounded. When the "operate" input is grounded, and a suprathreshold current is sensed in the shock line, and a 1000 pps ground pulse arrives from the generator, then a pulse accumulates in the counter. The operate switch designated in Fig. 1 is a bistable device which can be grounded by a momentary manual command, stays grounded while it

²There is capacity in the order of 200 pf in the scrambler and in the leads going to the shock grids. As voltage is reversed on the shock grids, current will flow for a period of about 10 μ sec as these small "condensers" are discharged and recharged. The rat cannot sense shocks delivered by such small condensers, but the detector can. It would count such capacitive effects as shocks, even when there is no animal on the grid. C_1 does not eliminate the capacity effect shocks, but prevents their being counted.

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Fig. 1. Current monitoring circuit.

$R_1 = 1 \text{ meg}$
 $R_2 = 2 \text{ meg}$
 $R_3 = 12 \text{ K}$

$R_4 = 100 \text{ K}$
 $R_5 = 680$
 $R_6 = 5 \text{ K}$

$C_1 = .001$
 $C_2 = .001$
 $Q = 2N414$

counts 1000 pulses from the generator, and then becomes ungrounded. The points labeled 0 and -12 v dc are connections to the supply voltage of the And Gate and other transistorized equipment (Digi Bits).³ In brief, the shock sampling circuit determines on any trial how many times, up to a possible 1000, in 1 sec the current flowing through the rat exceeds a given pre-set threshold value. A number of such determinations provide a good estimate of the mean shock density at a given shock intensity, *i.e.*, the percentage of time that current flowing through the rat exceeds that value.

Procedure

The animals were tested in a discriminated avoidance situation. Shock was presented every

30 sec, and was preceded for 10 sec by an 80 db white noise warning stimulus. Although shock could be avoided by a response during this 10-sec interval, once shock came on it could be terminated only by responses coming after the first 2 sec. Thus on non-avoidance trials the subject received a minimum of 2 sec of shock.

Shock density was not measured during the first part of the shock interval, *i.e.*, the first fraction of a second shorter than the rat's latency to respond to shock was excluded. The 1-sec shock sampling interval was begun by the experimenter pushing a button (latency about .3 sec) when shock came on. Shock current was sampled at sensitivities of .9, .8, .7, .6, .5, .4, and .25 ma in order 10 times each. Each subject was run with one of the scramblers being compared in one session until it had accumulated the necessary 90 non-avoidances. In the case of both the Foringer and the Grason Stadler scramblers, shock density can be

³The present simple transistor amplifier follows better and gives a sharper threshold than BRS Electronics' own Schmitt trigger.

expected to vary from one pair of shock lines to another. To randomize the occurrence of differential shock patterns the shock lines were disconnected and reconnected in scrambled order after each subject.

RESULTS

Figure 2 gives the data for a typical animal tested with the Grason Stadler scrambler; each point represents the proportion of 1000 momentary shock samples in which current flowing in the rat exceeded an intensity shown on the setting of the sensitivity control. The smooth curve is a visual fit through the means

of the different sensitivity arrays. This curve is evidently close to an asymptote of about .63 at the lower current settings, which means that counting even the most attenuated shocks, the animal was being shocked only about 63% of the time. Different animals (and shock grid connection patterns) yielded asymptotic density figures ranging from .54 to .65 with a mean of .61, for the Grason Stadler scrambler. The corresponding range for the Foringer scrambler was .70 to .75, with a mean of .73, and for the Lehigh Valley scrambler .08 to .12, with a mean of .09.

The median relative shock intensity may be defined as that current at which the shock density is one half the asymptotic shock density. In the case of the data described in Fig. 2, the median relative shock intensity was .875 ma.

Fig. 2. Typical shock density vs. intensity function for a rat tested with the Grason Stadler shock scrambler.

The mean, obtained by numerical differentiation, was a little lower, .82 ma. Hence, the mean effective current would be $(.63)(.82) = .52$ ma, just about half of the nominal value of the constant current shocker. The importance of these current figures lies in their relationship to resistance. Momentary current flow is attenuated below 1 ma by the rat's resistance in series with the current limiting resistor. So whereas the asymptotic shock density is primarily a function of the apparatus, the shape of the function, and specifically, the drop in shock density at increasing current settings, depend wholly upon the animal's resistance. Hence, it is possible to determine from a given momentary current value the corresponding value of the subject's resistance. This animal's median resistance was 126 K, and its mean resistance, *i.e.*, the resistance corresponding to the mean current, was 193 K. The range cannot be established precisely, but only about 5% of shocks were received while resistance was above 880 K (*i.e.*, current less .5 ma) while there was evidently a sharp minimum resistance in the order of 50 K (*i.e.*, at a current of about .94 ma). Considering all animals with all scramblers, the range in median resistance was 90 K to 190 K, and the mean of these medians was 140 K.

To obviate the need to use a minimum shock duration, the following procedural modifications were made. Two current sensing circuits like that shown in Fig. 1 were connected in parallel. The first was adjusted to detect all shocks greater than .5 ma, *i.e.*, essentially all shocks, while the second was adjusted to detect all shocks greater than .85 ma, *i.e.*, shocks received while the animal's resistance was less than 150 K, the value found above to approximate the rat's median resistance. Counters were connected to the two detectors and a third counter was used to indicate response latency. With this procedure, the ratio of counts in the first and third counters gives shock density while the ratio in the first and second counters gives a measure of resistance. Three groups of animals were run for a single session, again, one group with each of the shock scramblers, but in contrast with the previous animals, with no minimum shock duration contingency. A response in the presence of shock always terminated it immediately. However, all counting stopped after .25 sec

unless the subject terminated the shock before that time. Therefore, the data represent the characteristics of current flow only during the first .25 sec or less of shock.

The shock density data were entirely consistent with those found in the previous study. The distributions of median shock densities had nearly the same ranges as before but they lay, in general, about 10% lower. The difference can probably be attributed to differences in response topography.

The animal's electrical resistance was determined from the ratio of the number of shocks received exceeding .85 ma to the number of those received exceeding .5 ma, which describes in effect the proportion of time during shock that resistance is less than 150 K. With the different scramblers the median proportions were Foringer, .56, Grason Stadler, .51, and Lehigh Valley, .27; the overall median was .45. The significantly higher resistance figures found with the Lehigh Valley scrambler suggest that under the present conditions that scrambler produces less emotional reaction in the rat than the other two. Such a difference might account for the difference in acquisition of avoidance behavior noted in the introduction. That no such difference in resistance was found in the first part of the study when a 2-sec minimum shock duration was in effect suggests that it is possible to compensate for low shock density by increasing shock duration.

The shock monitoring device described here makes it possible to determine an animal's resistance while shock is being presented, and permits the necessary correction for the brief intervals during which no shock is being received. That is, it measures momentary resistance. The present data do not permit an adequate answer to the question of whether individual differences in resistance, or changes in resistance, are related to avoidance performance, but the method could be applied to this question, and to a number of systematic investigations of the subject's resistance.

REFERENCES

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