INSTRUMENTATION & TECHNIQUES

A digital system for recording startle responses in small animals*

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An easily constructed isometric startle-recording system is described. The animal enclosure is attached to a plywood board which, in turn, is mounted in a "springboard" arrangement. Movement is detected by a phonocardiograph mounted beneath the chamber, and a digital record of this movement is obtained through the use of a voltage-to-frequency converter. A brief experiment in which the system was used to assess the rat's reaction to electric footshock is also presented.

The startle responses of animals to brief, intense stimuli have been studied both in their own right and as possible indicants of the energizing effects of primary and secondary motivational variables. Devices for recording such responses typically involve enclosures mounted on resilient supports coupled to movement transducers and graphic recording equipment. As an example, in one instance (Brown, Kalish, & Farber, 1951), a confinement cage was mounted on a postage scale and the movements due to the rat's startle reactions were transmitted to ink-writing muscle levers by mechanical linkages. The system was essentially isotonic and the unavoidably large excursions of the platform could have provided undesirable feedback stimuli to the Ss. Other, more nearly isometric, stabilimeters have been developed that employ a variety of transducers and recording devices. Thus, the slight movements of enclosures mounted on stiff highly damped suspensions have been converted into proportional electrical signals by magnets moving in coils of wire (Hoffman & Fleshler, 1964), by strain gauges (Kurtz & Siegal, 1966), by movements of a loudspeaker coil in its magnetic field (Davis & Wagner, 1969), and by various other systems. In at least two instances, startle-reaction movements have been converted into electrical signals by the use of a commercial crystal phonograph cartridge (Anderson, Johnson, & Kempton, 1969; Galvani, 1970). In these cases, the cartridge was fastened under the enclosure, and a metal rod,

substantially longer and heavier than the customary steel needle, was inserted in its place. Because of its inertia, the oversize "needle" lagged behind vertical displacements of the cartridge and thus generated a voltage that mirrored the acceleration and amplitude of the animal's response. The signal was amplified and recorded oscillographically.

Unfortunately, the graphic records produced by most systems are laborious to measure. In addition, highly compliant isotonic suspensions could serve, in principle at least, as possible sources of confounding stimulation. The system described here was essentially isometric, the minimal movements of the support being sensed by a crystal cartridge with a heavy "needle" in the ballistic configuration described above. The electrical signal from the cartridge was converted into a digital equivalent of the integrated area under the voltage curve through the use of a voltage-to-frequency (VTF) converter and a Schmitt trigger feeding an electronic counter. The device has the advantages of providing almost no feedback stimulation for the startled animal, and its sensitivity can be varied by changing the point at which the suspension platform is clamped, by varying the mass of the "needle," or by changing the gain of the VTF converter. Moreover, the digital output is compatible with paper-tape punches, magnetic-tape devices, digital computers, and high-speed printers.

APPARATUS

The rather rigid suspension system consisted of a birch plywood board (61 cm long x 16.5 cm wide x 1.27 cm thick) securely clamped to a heavy aluminum base so that only 22 cm of the board extended out beyond the base. On the free end of this springboard-like arrangement, a removable animal enclosure was mounted on a permanently fixed base containing stainless steel grid bars. These were 2.3 mm in diam, set into plastic side rails 1.2 cm apart and 3.4 cm above the board. The actual enclosure was made of 3.2-mm Plexiglas, 7.3 cm wide x 18.4 cm long x 6.5 cm high (inside).

An Astatic phonocardiograph (No. 24) was mounted on the plywood board beneath the center of the chamber. An 8.6-cm rod, weighing 5.5 g, replaced the usual needle and rested in a position parallel to the plywood board. The output of the cartridge was connected directly to a VTF converter (Dymec Corp., Model 2210). The VTF functioned to produce output pulses whose frequency was directly proportional to the voltage from the

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Fig. 1. Mean output of the voltage-to-frequency converter as a function of voltage applied to calibrating magnet.

cartridge, irrespective of polarity, up to a maximum of 10 KHz. These pulses were fed to a Schmitt trigger through an impedance-matching resistive load (82 K ohms) and a 10-mF input capacitor which isolated the trigger from a dc standing potential. The sum of these pulses corresponded to the integral of the input voltage curve. The output of the VTF was gated for a brief period of time, and the cumulative frequency of pulses during this interval defined the amplitude of the startle response. The pulses were recorded by a solid-state data acquisition system, but any high-speed counting device could have been used.

The physical properties of the plywood board resulted in a well-damped system. The rigidity of the mounting was enhanced by weighting the end of the board that was attached to the aluminum base with a 150-lb bag of sand. The entire sensing apparatus was enclosed in a sound-attenuating ventilated chamber.

During preliminary tests, "needles" of several different sizes were tried along with variations in the unsupported length of the plywood "spring-board." The particular values used were chosen for two reasons. First, the system returned to a steady state following a midrange response within 50-60 msec. Second, the system responded in a roughly linear fashion to a wide range of different magnitude startle responses.

Calibration was accomplished by momentarily applying different voltages to an electromagnet which had been spring-mounted over a small steel plate attached to the animal enclosure. The field produced by the magnet (as measured by a Hewlett-Packard 428B dc clip-on milliammeter with a 3529A magnetometer probe) was a linear function of the voltage applied. The "responses" produced by the magnet were generally comparable to those produced by rats. Figure 1 indicates the relation between voltage applied to the magnet and magnitude of the recorded response. The day-to-day

reliability of the system was quite good, with little changes noted over a period of several weeks.

It should be noted here that the "area under the curve" measure obtained with this apparatus is not necessarily the same as the peak amplitude measure typically reported. Adequate damping and sufficiently short scan times should serve to produce an acceptable degree of correlation between these two measures. Also, a voltage-sensitive circuit could be used between the cartridge and the VTF to allow for the determination of latency of some predetermined voltage output from the cartridge.

EXPERIMENT

In order to evaluate the effectiveness of the present device, a procedure previously reported by Hoffman, Fleshler, and Abplanalp (1964) was employed to investigate the rat's startle reaction to different intensities of electric shock.

Method

The Ss were 15 naive female albino rats approximately 130-140 days old and weighing approximately 240 g each.

The grid bars in the animal enclosure were wired in series with different resistors through a stepper switch to a Grason-Stadler shock source and scrambler (Model E1064GS). The nominal intensities (open circuit) were arranged in 10 0.1-mA steps from 0 to 0.9 mA.

On each of 2 consecutive days, each rat was placed into the startle chamber and, following a 5-min adaptation period, was presented with a series of 90 0.3-sec shocks. Each intensity was presented nine times, with the order of presentation determined randomly within each block of 10 trials. The intertrial interval was 20 sec.

The output of the VTF converter was recorded for a total period of 1 sec, beginning .27 sec prior to shock onset.

Results

Separate analyses of variance were applied to both the mean and median scores obtained at each intensity level

Fig. 2. Mean output of voltage-to-frequency converter as a function of shock intensity collapsed across test days.

on each day of testing. Both measures yielded essentially identical results. There was no effect of days, but a highly significant effect due to intensity level (mean: $F = 147.9$, $df = 9, 126$; median: $F = 93$, $df = 9, 126$). Figure 2 shows mean startle as a function of shock intensity collapsed across days. The relation closely approximates that reported by Hoffman et al (1964).

DISCUSSION

The system described here seems to offer advantages over previous devices for recording the startle response. It is easy to construct and adjust, it is isometric and provides a digital output compatible with various contemporary digital instruments. Although the cost of the VTF converter employed above may be prohibitive in the small laboratory, a functionally equivalent device may be obtained from Anadex for about \$275 (without power supply, Model 7000-5072-00). Many digital voltmeters also operate on the principle of voltage-to-frequency conversion and may be adapted for this purpose.

Finally, it is worth noting that the principles employed in this system can be readily adapted for use in recording general motor activity by increasing the sensitivity of the system and monitoring the VTF at appropriate intervals.

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ERRATUM

STARR, B. J. Automated problem solving for the behavioral sciences. *Behavior Research Methods and Instrumentation*, 1972, 4, 161-164—In Fig. 2, the minus sign indicating the direction of the flow for negative evaluation of the argument ITALY-NHI was omitted. The topmost decision box of the three sequential decisions at the bottom should read $K > N$ (not $K \geq N$). The subsequent decision box has the Y and N reversed.