TECHNICAL NOTE

*AVERSIVE CONTROL BY AN ELECTROSTATIC SHOCK
SOURCE: AN UNMODIFIABLE, HUMANE PREPARATION¹*

Application of electric shock to certain species has been possible only through chronic electrode implantation. In animals such as the rabbit, thick fur covers the entire body, including the underside of the feet, affording complete protection from shock delivered through foot-grids. The disadvantages of chronic electrode implantation, such as reduced mobility, discomfort to the organism, and risk of infection increasing with the age of the preparation, necessitated the use of a new type of shock source in an experiment where rabbits were to be used in an operant escape context.

Commercially available shock sources in foot-grid delivery systems use moderate voltage levels (200 to 300 V) in the 1-mA range. Such voltage levels are ineffective in species described above, but static electric shock with very high voltage (over 5 kV) and very low average amperage (μ A range) produces an electrostatic discharge that readily penetrates natural insulation with no tissue damage whatever.

The most common laboratory source of electrostatic shock (*i.e.*, the Van de Graaf generator) is not a useful source, inasmuch as it tends to produce a variable discharge or none at all in conditions of high humidity, when the charge on the globe-type accumulator dissipates in moist air.

An induction-type electrostatic generator has been developed by Moore (1968). A version of this apparatus delivered a reliable static discharge that has been used to motivate operant escape responding by rabbits and rats in this laboratory.

This generator is capable of producing an electrostatic spark of 50 kV at less than 10 μ A, at a rate of approximately two discharges per second. The generator, which has been completely described by Moore (1968, apparatus, pp. 201-231) consists of a series of motor-driven rotating metal rods that sweep stationary brushes (constructed of several layers of Plymouth Rubber Co. No. 5360 semiconducting tape), causing a potential difference to occur between two metal collecting plates (a competent university workshop should be

able to construct the generator from Moore's (1968) drawing for less than \$75.00 for material). When this charge is sufficiently high, a discharge occurs between the points of a spark gap and is delivered to the animal via a foot-grid arrangement in the circuit, diagrammed in Figure 1. The intensity and frequency of the discharge may be controlled by varying the speed of the motor and the size of the spark gap (approximately 30 kV/cm). In the present version, which is shown in Figure 2, the rods rotated at 1700 rpm, with a spark gap of 1 cm. We have measured the discharge current of the Moore generator across a 10-ohm carbon resistor in series using a calibrated oscilloscope. We found the peak discharge occurs in the micro-second range, so that the duration of the discharge is very short (a few millionths of a second).

The properties of static electric shock sources are not described in literature familiar to behavioral workers, and a few comments about the salient features of these types of devices would seem in order.² Generators of the Van de Graaf type are highly susceptible to charge leakage in conditions of high humidity. Any charge accumulating on the globe may be immediately drained, when the moist air readily accepts the static charge. In this type of generator, a moving belt produces a charge by means of friction. In the present generator of the Moore type, a charge is induced (see Figures 1 and 2) as rotating rods sweep past Plexiglas plates of different charge; briefly, when a rod nears the region of a Plexiglas plate (*e.g.*, the positive plate) it assumes the opposite charge (negative), which is then captured by the brush (semi-conducting tape) and charge is built up on the negative collecting plate. An identical process, opposite in polarity, builds up charge on the positive collecting plate (see Moore, 1968, for a more complete explanation of induction of static discharge). This generator uses neither the large surface-area collecting globe nor the moving belt, which may also lose charge in conditions of high humidity. In the present induction-type generator, charge is directed through a wire that has a variable gap in it—the "spark gap"; the function of this gap is to force the accumulation of

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Fig. 1. Wiring diagram of Moore's "Dirod" electrostatic generator. In this circuit, remote switching is possible using a high-voltage switch or a solenoid-type device with an excursion about five times the width of the spark gap.

electrons on one side of the gap (terminated in a screw and nut fitting in the present apparatus for adjustment of the size of the gap). No electrons will flow between the points of the gap until the charge on the plates of the Moore generator is great enough to overcome the resistance offered by the air. This high-voltage flow, which is not susceptible to problems of humidity because of the use of the induction-type generator, serves as a potentially aversive pressure-stimulus.

The static charge transmitted to the organism acts somewhat like water from a "squirt-gun", which is a directed and concentrated stream aimed at a specific locus, splashing harmlessly over the surface of the target after contact. The pressure of the stream at the point of contact is certainly aversive but with no accompanying tissue damage. The lack of habituation shown by organisms in this preparation probably is due to the variability of this locus at the point of least electrical resistance, which changes as the animal moves. Animals have produced reliable escape responding in over 50 hr of shock using a 15-sec intershock interval.

In conventional shock, which passes through the organism at higher amperages, the current has the potential of causing heating and tissue damage; this does not occur in the surface-shock effect associated with static discharge. In shock from commercially available shock generators normally employed with rats, respondent behavior such as squealing and grid hopping may be readily seen, even at moderate intensity levels. In rabbits, when, for example, fixed electrodes are used with normal current, penetrating vocalization can occur. Such respondent behavior is absent in the present application, although reliable escape responding readily occurs.

Some other advantages of static shock include the

relative safety of this preparation, which produces virtually no current, and the elimination of the need to scramble the polarity of the shock so that organisms cannot modify the shock by postural means. In the present application, if an animal is not present in the chamber sparking will occur between grids. When an animal is placed in the chamber, despite a position in which grids of the same polarity are grasped, shock is not avoided or modified, inasmuch as the animal will inevitably be in the path of least electrical resistance from a pole of opposite polarity. That is, the distance between grids of the same polarity is always greater than the distance between a grid of opposite polarity and some point on the animal's body. In the usual situation where low voltage prevents discharge between grids, polarity randomization is essential.

An unusual precaution is required in connection with the present shock source. Coronal discharge is a problem always associated with static discharge. After assembly, the generator should be operated in a darkened room to allow the detection of leakage, which shows up as a region of blue glow. Steps should be taken to increase dielectric shielding and to smooth out sharp edges and corners to obviate leakage.

In the present preparation, rabbits and rats responded to terminate shock; escape initiated a 15-sec intershock interval. A wall-mounted circular plastic response lever (10 cm in diameter) served as manipulum for rabbits. Rats were also easily trained in the shock escape operant in a commercial (Grason-Stadler) one-bar chamber with ordinary foot-grids, in a similar circuit using the Moore generator. A summary of escape responding for rats and rabbits is given in Figure 3. Both species developed a reliable escape operant with no response-shaping difficulty. The escape response was

Fig. 2. Photographic view of Moore generator. Photograph courtesy of A. W. Masterton.

shaped for rats and rabbits by the method of reinforcing successive approximations to the operant, within 15 and 45 experimenter-terminated shocks, respectively.

In an alternate delivery system using the Moore generator, a wire loop connected to the negative collecting plate, via the spark gap, is tied around the rabbit's body; this is a useful preparation for the rab-

Fig. 3. Escape responses as a function of training session for three rats and three rabbits using static-electric shock. Rabbit No. 1 received shock via the wire-loop arrangement described in the text; all other animals received shock via foot grids. A maximum of 240 shocks could be delivered in 1 hr; mean escape response latency for each session may be calculated by inspecting the number of shocks escaped in 1 hr.

bit, which tends to be fairly immobile in the response chamber. The wire is first partially insulated by inserting it in a flexible plastic tube punctured with several pin holes, causing discharge from the wire loop to the animal through the holes. This discharge is an effective, although organically harmless noxious stimulus.

In summary, advantages over usual electric-shock delivery systems (in addition to eliminating the need for chronically implanted electrodes or total shaving of body hair in certain species) include less respondent behavior in response to shock, no tissue damage through burning, and no unauthorized modification of shock as sometimes occurs in even scrambled shock preparations where rats display a rolling-over behavior. This posture modifies or eliminates foot shock by using the back hair as an insulator. Grid-hopping behavior, an even more common method of unauthorized modification, is ineffective with static electric shock. In the

present preparation, the high-voltage discharge readily occurs despite such behaviors; in fact, any posture that increases the distance between the animal and the grid (up to the distance between adjacent rods in the grid) will actually increase the force of the discharge. If augmentation of the discharge is desired, a high-voltage capacitor can be arranged by connecting the discharge collector plate to one pole of the capacitor with a single wire, which, in effect, increases the collector plate area.

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