NOTE

A simple preparation for obtaining a reliable heart rate record in freely moving rats

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A technique for recording heart rate (HR) from freely moving rats using a specially developed harness and subdermal electrodes is described. Electrodes are implanted via a hypodermic needle. Animals prepared in this way are unrestricted in their behavior and show no signs of distress. EKG signals are of high fidelity and are relatively free of electromyographic interference. These characteristics enable reliable phasic HR responses to be recorded during periods of high skeletal muscle activity such as those exhibited during aversive conditioning. Since the procedure is relatively untraumatic, electrodes may be removed and reimplanted at a later date.

In most behavioral experiments in which heart rate (HR) has been recorded from the laboratory rat, EKG signals have been obtained by attaching pins or surface electrodes to the animal's skin or by implanting subdermal electrodes (e.g., Doerr, 1967). While the latter technique produces the most reliable and artifact-free EKG signal, the typical chronic preparations utilize a connector mounted on the animal's skull and are somewhat obtrusive (e.g., Vanderwolf & Vanderwart, 1970). Furthermore, sterile conditions for surgery are paramount to these techniques, and failure to meet these conditions can result in subject loss. With regard to the general condition of the animal, surface electrodes are preferable and, coupled with a telemetry system, probably represent the least obtrusive method of recording HR (Meinrath, Collins, & D'Amato, 1977). However, in our experience, the EKG signal so obtained is particularly susceptible to electromyographic interference and to artifacts associated with electrode movement, and it has proved to be inadequate for recording HR during aversive conditioning experiments. For these reasons, a chronic preparation was developed whereby subcutaneous electrodes are implanted by a very simple surgical technique and the electrical connector is mounted on a specially designed harness.

METHOD

Harness

Figure 1a illustrates the harness design with dimensions suitable for animals weighing 375-450 g. A soft glove leather is used in constructing the harness.

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Figure 1. (a) Harness design showing location of the Amphe-nol connector and electrode wires taped along the inside of the harness, emerging at Point O. (b) Illustration of harness as it should fit around the animal. The electrode leads C (lower right), F (lower left), and R (upper right) should enter the animal's ventral surface.

Multistrand, stainless steel, Teflon-coated wire is used for electrode leads (7 x .002-in. diam strands) sealed in Teflon coat (total diam = .009 in.) (Clark Electromedical Instruments, Reading, England). Three .3-m lengths are cut and .2 cm of the insulating layer is removed from one end of each. Amphe-nol connecting pins (220-PO6) are crimped onto the bared ends of each wire, which are then located in an appropriate length of plastic sleeving (Amphe-nol 221-1-5-60). This assembly is cemented to a strip of leather (3 x 2 cm) and, after threading the electrode leads through a hole cut in the harness, is firmly secured to the harness by means of a double-sided adhesive strip (RS Components No. 554-844) (see Figure 1b). The harness is completed by using surgical tape to secure the leads along the inside of the harness so that all three emerge at a point midway between the two large apertures that fit around the animal's front legs.

Surgery

Each electrode lead is first sterilized with an appropriate solution (e.g., Roccal Antiseptic, Winthrop Laboratories). After the animal is anesthetized [sodium pentobarbital (Sagatal), 30 mg/kg, high intraperitoneal], the fur is removed as illustrated in Figure 2, as well as across the back of the shoulders where the harness fits. The harness is provisionally fitted to the animal and a mark is made on the animal's ventral surface in the region where the electrode leads are to be inserted.

In order to locate the reference electrode, a hypodermic needle (Gillette 23Gx1 in., K 11924) is inserted subdermally at Point C and run under the skin to emerge at Point O. The reference lead is then threaded through and out of the hypodermic from Point O to Point C, and the hypodermic is removed. The procedure is repeated for the lower left electrode (F) and the upper right electrode (R) such that the three electrodes enter the skin in the region of Point O and emerge at Points C, F, and R (Figure 2). The harness is then fitted around the animal's shoulders and fastened in place by cutting a slot in the overlapping flap to permit the Amphe-nol connector to be fed

Figure 2. Diagram of ventral view of rat showing the electrode locations. The area encompassed by dotted lines should be shaved.

through and the two ends of the harness to be fastened together on either side of the connector using double-sided adhesive strip. The electrode leads are then tightened by carefully pulling at their exposed ends until they enter the animal in Region O, close to where they leave the harness. Finally, the leads are cut approximately 1 cm from where they emerge at Points C, F, and R, and the insulating layer over this length is removed to form the electrodes, which are then allowed to slip back under the animal's skin.

The electrodes are located in a Limb Lead II configuration, and the potential of the lower left minus the upper right electrode (VF - VR) is amplified and recorded (using the lower right electrode as a common) to produce the characteristic electrocardiographic complex.

DISCUSSION

The EKG signal recorded from an animal prepared according to the preceding description is shown in Figure 3 and in Figure 4, together with corresponding HR, oxygen consumption (OC), and activity data. In contrast to other methods of recording the EKG, this preparation is markedly free of muscle noise, and the high-amplitude R wave facilitates the recording of a clean and reliable HR record. These typical characteristics prove to be most beneficial when a good-quality HR record is required during experiments in which the animal is engaged in a wide range of high-energy activities.

A study of the relationship between HR and the animal's specific activity conducted in our laboratory has produced data comparable to those reported by Vanderwolf and Vanderwart (1970). High-energy activities and behaviors associated with an erect posture are characterized by elevations in HR. The wide range of spontaneously occurring behavior patterns observed in animals indicates that the harness and electrodes

Figure 3. Typical EKG recorded from an implanted rat.

Figure 4. Polygraph record of EKG, OC, HR, and activity level (ultrasonic movement detector) from a freely moving rat in a running wheel.

present minimal hindrance to the animal's normal behavioral repertoire. The low resting HRs recorded following several hours in the experimental environment (305 bpm average in 12 Lister hooded rats; average age = 262 days), together with the general unaggressive temperament of these animals, suggest that animals prepared by this procedure are not in a state of discomfort.

The method of recording HR described in this paper requires inexpensive materials, and the harness can be discarded when the experiment is complete. The preparation can be expected to remain intact for approximately 20 days, after which the harness and electrodes can be removed under anesthetic at no detriment to the animal.

At this time, HR has been recorded and displayed using a Grass Model 7D polygraph connected to the animal via a specially designed servo-assisted electrocannular swivel. This arrangement means that, although

the animal is connected to the recording apparatus by a three-core wire, its movement is minimally impaired, as the motor-driven swivel is triggered to take the load of the adjustment of the connecting lead contingent upon the animal's slightest movement. Finally, if required, the preparation could easily be adapted for signal transmission by means of telemetry.

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