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Inexpensive Motion Detectors for Quantification of Animal Activity

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Measurement of locomotor activity of captive animals is important in such fields as chronobiology, physiology, animal behavior and ecology. Because running wheels are convenient and can be made inexpensively, they are the most commonly used device to quantify activity, particularly in studies of rodents (2). However, wheel running is unnatural behavior, and activity measurements do not necessarily correlate with activity in large enclosures or in natural environments (5,10). Tilt floors and treadles also can be used to quantify activity, but these too provide sensory feedback to the subjects and may alter behavior. It is questionable whether activity of animals in small cages is relevant to behavior in the field regardless of the device used to measure activity. It is clearly preferable to monitor behavior in the field if ecological implications are of importance; however, researchers often are limited by the objectives of the experiment or other constraints and must conduct laboratory studies. Under these circumstances, it is best to minimize error resulting from measurement methods such as running wheels. Activity measurements are expected to be more closely correlated with the behavior of free-living animals if obtained using devices that do not provide sensory feedback. For those conducting ecological research, a method of collecting data under these circumstances is desirable.

Radiotelemetry and video recording can be used to measure activity directly without affecting behavior, but each can be impractical because of time or money required. For example, radiotelemetry requires expensive equipment, and transmitters must be worn by the animals or implanted in them. Use of video cameras requires a large amount of time to evaluate and score the recorded behaviors. Vorhees et al. (9) solved this problem by using video equipment in conjunction with contrast-sensitive trackers to quantify movement over

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large areas. Activity measurements obtained in this way are more reflective of natural behavior, but the equipment required can be prohibitively expensive.

When the objective is to measure activity patterns without quantification of specific behaviors, photo-cells and infrared sensors offer many advantages and have been used successfully in research of rhythms (1,8). Time and equipment requirements are minimal, and the data obtained are useful for studies of circadian rhythms and are more likely to be relevant to activity under natural conditions. These devices offer flexibility in experimental design because they can be used to quantify locomotor activity of large or small animals in standard cages and over large areas. Examples of electronic activity monitors used include Opto-Varimex and Stoelting monitors (6,7). These do not interfere with the behavior of the subjects and provide valuable data; however, neither monitor can be modified easily to collect data under seminatural conditions. Additionally, commercial electronic activity monitors can be quite expensive (beginning at \$2000 or more), especially for monitoring large numbers of animals simultaneously. Other companies such as TrailMaster and Radio Shack sell battery-powered infrared motion sensors that may be useful in the field or under seminatural conditions. However, even these are relatively expensive, beginning at \$180.00 and \$60.00, respectively.

Here I describe the wiring and settings that enabled me to use inexpensive infrared motion detectors to quantify activity. I used the described system to record spontaneous activity of caged Patagonian leaf-eared mice (*Phyllotis xanthopygus*) under a variety of experimental conditions for approximately 7 months (4).

The infrared motion detectors used (Reflex® Replacement Motion Sensors, Model SL-5407; Heath Company) were purchased for approximately \$19.00 each at a local hardware store. Sensors were wired in circuit with a lamp and a power source. In addition, 120-V, 50/60-Hz relay coils (Catalog No. 275217; Radio Shack) (approximately \$6.99) were wired in parallel with the lamp. Electrical wire, lamp cords to connect to the power source and lamp bases were

purchased locally. The cost of one apparatus was approximately \$30.

Figure 1 illustrates the circuit. When motion was detected, a switch in the sensor closed, and the circuit to the light and the relay switch was completed. When the switch in the motion sensor closed, 110V AC was applied between pins A and B (Figure 1b), turning on the electromagnet. Contact was broken from pin 1 to pin 3 and made between pin 3 and pin 5. The relay switch was wired to a computer that counted the number of times contact was made between pins 3 and 5. Continuous data collection was accomplished using the DataQuest III software package (Data Sciences International, St. Paul, MN, USA); however, similar systems could be constructed to record data on an event recorder or on a computer using, for example, the inexpensive system described by Horton et al. (3).

Because these sensors are made to turn on a light when motion is sensed, a

relay switch placed in the circuit will not trigger an event recorder unless a lamp is included in the circuit. Although it might be possible to find a resistor to replicate the time-dependent resistance of a lamp, a simpler solution is to include the lamp in the circuit. The lamp should be checked periodically and replaced if burned out. If the animals under study are not to be kept under constant light conditions, the lamps can be covered (I used clay gardening pots), or the connecting wires can be cut long enough to allow placement of the lights outside of the room where the animals are maintained.

According to the manufacturer, the motion sensors have a maximum range of 21 m and a maximum coverage angle of 150°. The motion detector is most sensitive across its field of view as opposed to objects moving towards it, therefore I positioned a detector 40 cm over each mouse cage (24 × 48 × 20-cm polycarbonate cage) rather than along

Figure 1. Wiring of motion sensor to detect activity of mice. (a) The motion sensor is wired to a power source (black wire), ground (white wire), lamp (red wire) and coil (pins A and B) of a relay switch (red wire) using wires attached to the sensor at time of purchase. (b) The normally open switch of the relay switch is wired to a channel and ground line of either an event recorder or to a switchboard wired to a computer for data collection (pins 3 and 5). When the sensor detects movement, the lamp is turned on and the relay switch closes simultaneously. When the relay switch closes, the event recorder or computer records the event.

Benchmarks

the side. Sensitivity of the motion sensor can be adjusted and was set to maximum in my experiments. The position of each sensor was adjusted to ensure that movement in any area of the cage would be detected. The motion sensor was set to the test setting, in which case the sensor functioned regardless of ambient light and reset after 5 s, allowing a maximum count of 12 movements per min.

Figure 2 shows a typical activity pattern for an individual maintained under a 24-h light cycle of 16 h light, followed by 8 h dark. A consistent circadian rhythm of activity was evident ($P < 0.001$). These nocturnal mice typically became active immediately after lights were out, and two peaks in nocturnal activity were clear.

Figure 2. Activity data of an individual mouse. Activity measurements were made over a duration of 9 days, and data were averaged into one 24-h period. The activity over 24 h is double-plotted to show the pattern more clearly. The 8-h dark span of the light cycle is indicated by a black bar on the X-axis.

In summary, the design described here avoids the disadvantages of running wheels and tilt floors by using a motion sensor that allows direct and continuous measurement of activity without altering the behavior of the subject. Other studies have used motion sensors in similar ways, but this design allows the use of inexpensive and readily available equipment. Minimal money and time are required to establish this system, and once established, data can be collected continuously.

Limitations of this system include the requirement of a lamp in the circuit, which limits its applicability to field situations. Motion detectors have been used successfully to monitor activity in large outdoor enclosures (1), and it might be possible to replace the lamp in the circuit with a resistor to allow outdoor use. The device certainly could be used in a large indoor enclosure. Because the system described here makes use of infrared detectors, it might be limited to activity measurements of endothermic animals. Despite these limitations, the apparatus will prove useful in many laboratory situations and may even be used as a control in studies of activity that use running wheels. In addition, it will be possible to modify the system to suit specialized applications.

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