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A simple and effective method for building inexpensive infrared equipment used to monitor animal locomotion

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HIGHLIGHTS

- We designed and constructed a flexible, inexpensive infrared rat monitoring system.
- We recorded and analysed drug-induced rat behaviour using our monitoring system.
- Our system reveals selective significant drug-induced differences in rat behaviour.
- L-DOPA significantly increases selective rat behaviours recorded by our system.
- Total cost of our system is substantially less than that of commercial suppliers.

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ABSTRACT

Background: Infrared (IR) technology is a flexible and effective way of measuring animal locomotion. However, the cost of most commercial IR equipment can limit their availability. We have designed an inexpensive and effective replacement for commercial IR sensors that can be attached to enclosures to monitor animal locomotion.
New method: IR components were soldered to circuits connected to a single microcontroller. These IR components were housed inexpensively using plastic tubing and cork discs to further focus and extend detection of the IR beam. A standard personal computer recorded data from circuit boards connected to an inexpensive interface. This system may be used in a range of lighting conditions without requiring readjustment or recalibration.
Results: Validation of our equipment design was done with male Sprague Dawley rats treated with reserpine 22 h prior to administration of saline or L-DOPA (125 mg/kg). Data was collected in eight different measures: horizontal activity, immobile time, elevated activity, centre elevated activity, elevation time, elevation bout, and repeated and non-repeated movement while elevated. L-DOPA increased horizontal movement and all elevated activity excepting elevated movement and centre elevated movement, demonstrating selective drug effects.
Comparison with existing methods: The total cost of our complete IR system (US$517.45) was substantially less than the least expensive quote (US$19,666.90) obtained for a commercial IR system.
Conclusions: We have successfully designed and constructed a flexible and inexpensive IR system to monitor at least eight measures of rodent locomotion at a significantly lesser cost than quoted by commercial suppliers.

1. Introduction

The first infrared (IR) detector was made in 1800 by the discoverer of Pluto and IR light; William Herschel (Rogalski, 2012); and has been used to measure motor activity in rodents and other animals at least since 1970 (Fibiger et al., 1971). Despite the rapid rate of technological improvements; IR photocells remain a major method of measuring motor activity in rodents. The only real competitor to assess locomotion and rearing are camera based systems that are expensive and require equally expensive software. Camera systems do provide additional information in terms of path analysis compared to infrared technology; but these measurements are less often used in pharmacological research than quantified locomotion as this additional information may not be worth the

Abbreviations: L-DOPA, L-3,4-dihydroxyphenyl-alanine; IR, infrared.

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enormous increase in both expense and time needed for data analysis.

A substantial component of animal research is composed of locomotion and behaviour analysis. These measures are the basis of many animal models and tests such as the elevated plus maze and open field tests of anxiety, the reserpine-treated rat or 6-hydroxydopamine-lesion rat or MPTP-treated primate models of Parkinson's disease, the conditioned place preference test of reward, and exploratory/investigatory behaviour. The behaviours and locomotion recorded in these tests and models include total distance travelled (Zakharova et al., 2009), spatial patterns of locomotion (Geyer et al., 1987), immobility/freezing (Gresack et al., 2010), hole pokes (Riley et al., 1979), time spent in specific areas/compartments of the apparatus (Dietz et al., 2007), drinking and eating behaviour (Jahng and Houpt, 2001) and rearing (Gresack et al., 2010), all of which can be recorded using IR technology. Analysis of these behaviours and patterns of locomotion have been used to understand basis of many human behaviours such as drug use (McLelland et al., 2014), anxiety disorders (Pellow et al., 1985), neurological diseases (Johnston et al., 2005), and learning and memory (Cassel et al., 1998). Thus, access to inexpensive and effective IR devices is extremely valuable in animal research to develop insight into animal and human behaviour and allows many laboratories a wider selection of tests and models to study in a more affordable manner.

One of the greatest advantages to using IR technology is that, unlike mechanical switches, the activation of IR sensors is undetectable to the animal and therefore has minimal influence over its behaviour. Additionally, IR devices are compact, lightweight, and can be used in almost all laboratory light conditions. No newer technology has been able to compete with IR in both usefulness and price, especially as IR emitters and detectors have become extremely inexpensive, as compared to 30–40 years ago. Furthermore, the equipment needed to interface between the photobeam detectors and a computer or other data-logging device has improved considerably and become inexpensive and easily available online. However, costs of pre-made equipment from research equipment companies remains relatively high, often prohibitively so, especially considering how inexpensive the component parts have become, and how simple software is to write at present.

Some of the least expensive IR devices can range between US$50 and US$100 from research equipment supply companies (for example, one pair of IR emitters and detectors from a research equipment company that is widely used have a median price of around US$75 at the time of writing, so that IR emitters and detectors 10 per box and 5 boxes would cost US$3750), just for the IR devices, and excluding delivery. However, one IR emitter and detector pair can be bought online for US$0.33, at the time of writing, so that 40 can be bought from electronic supply stores for US$13.21, substantially less than from even the least expensive research equipment supply company. This expense does not include an interface to transmit IR beam break data to a computer for further processing (four channel IR controller from one company at the time of writing is approximately US$230, or another US$2875), and does not include the cost of software, cable, or circuit boards that are generally required to accurately measure animal locomotion. Therefore, our goal was to construct a set of five enclosures as an inexpensive alternative to commercial IR devices and a computer interface that was compatible with most modern computers to measure the activity of five rats simultaneously.

2. Methods

Although employing IR technology can vary in complexity, our purposes required measures of both horizontal motor activity (locomotion) and elevated activity (elevated posture and behaviour). Thus, similar to commercial equipment, we created unidirectional IR beams. Our microcontroller detects the break in IR beams when an animal enters the beam and prevents the IR light from reaching the sensor. For these enclosures, the voltage in the IR sensor circuit changes when the beam is broken or unbroken. This voltage is converted to a digital signal, transmitted to a connected computer and recorded. We can thus measure number of beam breaks as well as the duration at which a beam remains broken.

2.1. Construction

2.1.1. IR emitter/sensor pairs

The IR emitters purchased were required to reliably transmit 300 mm in a low voltage situation. The IR emitters operate at 5 V and allow up to 100 mA forward current. These specifications enabled the emitters to safely transmit over the required distance (approximately 30 cm) without operating at maximum capacity. In order to create a detectable IR beam, IR emitters were paired with IR sensors, creating a unidirectional IR beam that was sensitive to interruption.

Though only a 30 cm distance was required, the IR emitters were able to transmit up to 80 cm by supplying 100 mA forward current and increasing the resistance in the IR receiver circuit up to 600,000 ohms. However, transmission over this distance created a substantially larger beam width which was likely to interfere with nearby IR sensors.

We built a network of IR beams to measure horizontal and elevated activity of rats in 20 cm × 30 cm × 25 cm ($w \times l \times h$) Poly(methyl methacrylate)[1] (PMMA) enclosures (US$17.81 each). We purchased IR emitters (Model TSAL 7200) from element14 (au.element14.com, US$0.08 each) and sensors (Model Lite-On LTR-301) from Mouser Electronics (au.mouser.com, US$0.25 each), classified as IR LEDs and NPN phototransistors, respectively. A 5 V DC power supply rated at 4 A ($22.16) was used; however this circuit could be constructed to accommodate a range of power supplies. Accessories for this circuit to monitor five enclosures included resistors (US$4.68), 8 core cable (US$56.13), circuit boards (US$18.71), enclosing boxes (US$5.61), and connector wires (US$18.71). Extras such as glue, power connector plugs, ferrules, solder, and croc clips totalled US$80.52.

In order to calculate the requirements of the power supply, it was necessary to verify how much power the IR emitters needed to form a reliable IR beam. The circuit voltage output of the IR sensor determined the strength of the IR beam: the stronger the beam, the lower the voltage is. As the microcontroller discerns a voltage below 1.2 V as a digital zero (0), it was decided that a voltage change of roughly 0.5 V would be considered reliable in order to rule out any false beam breaks. As we were using 10 IR emitters per enclosure and 5 enclosures, we used the equation:

$$75\,\text{mW} \times 50\,\text{IR emitters} = 3.75\,\text{A}; \quad (1)$$

2.1.2. Housing

Shielding is another factor to consider when constructing IR LEDs and sensors. Although the IR light emitted from an IR LED is invisible to humans (and many other animals), it emits light over a wide field. Therefore, distances larger than 2–5 cm between the LED and sensor require shielding and housing of the LED (and sometimes the sensor to avoid LED emission overlap, see Fig. 1A and B) to focus the light towards the sensor more effectively. One solution is to add a lens to the housing unit of the LED to further focus the IR light towards the sensor (Batson and Turner, 1986). However, this

[1] Commonly known by the trade name Plexiglas®, Perspex®, or Lucite®.