Development and Validation of a Universal Measurement System for Measuring the Performance of Mammals

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ABSTRACT

Exercise wheels for mammals are commonly used as test systems in many medical research areas. Studies may be related to many different areas such as vitamins, hormones (as dopamine), and physical endurance. As research develops the scope and size of the studies increase and the requirements of the test system might change. In order to conduct the experiments effectively, there is a need to increase the number of test stations, and the test station may also be required to handle physically larger mammals. This study presents and validates a wireless system for endurance tests. The system was validated on mice and humans. It is scalable, and can be expandable up to 254 test stations. In the case of the exercise wheel with mice, the ADEA system was used as a reference. The initial validation was done by comparing the activity measured by both systems in mice with different hormone dopamine levels. The correlation coefficients between the systems estimated activity levels were in the range from 0.916 to 0.967. The new system enables quantitative measurements of the activity level using standard SI units (meters and seconds, respectively). In the validation with humans, runners were clocked by the system and manually. The lowest correlation coefficient obtained during these measurements was 0.864. Thus, both applications showed a high correlation with conventional methods.

Keywords: Dopamine, Endurance Tests, Motor Activity, Rodent, Running Wheel, Sport Measurements, Time Measurement, Wireless System

1. INTRODUCTION

When a medical drug discovery is made, it usually requires in vivo testing of various species of living mammals. These tests often require measurements of vital parameters such as blood pressure, body temperature, endurance, and hormone levels such as dopamine, vitamin content, and endurance, among other parameters.

DOI: 10.4018/ijsda.2014040102
There is a need for systems that enable these kind of tests, and often a large number of experiments are required during the test phase. In order to conduct these experiments more effectively, a system enabling a scalable number of test stations would be desirable. The tests often need to be performed on animals (often mammals) of various physical size.

Further, systems that enable objective quantification of the parameter under test are preferable. Examples of such systems are mechanical running wheels and systems for time measurements on an athletic track. These systems, based on simple measurement principles as revolutions of the wheel or manual time measurements, have since long been used to perform measurements of locomotion and motor activity.

It is preferable to have a system that enables the experiments to be performed at any place, e.g. inside a laboratory or outdoors. The access to the laboratory can be further enhanced by using the technology Internet of Things (IoT). In such a system, each sensor node can be connected (wired or wireless) to the internet. This gives the possibilities to transmit the measurement data in real time. Many systems use wireless nodes (sensors), which can be accessed by Internet. A wireless node can for example use a radio band such as the Industrial, Scientific and Medical (ISM) band. One advantage of making use of the ISM band is that it contains license-free frequencies.

The aim of this study was to develop and validate a system for wireless measurements to be used in endurance tests of mammals. The system should be able to handle different sizes of mammals and be scalable (expandable) in terms of up to hundred test stations. Concepts for two various applications should be developed and validated: An exercise wheel for small mammals and a time measurement system for endurance applications of humans. The system should enable quantitative measurements of the activity level, using standard SI units (meters and seconds, respectively). In the present study, the small mammal is represented by a rodent, mouse, and the large mammal is represented by a human being, an athlete.

This paper is organized as follows: In Section 2, the related work is described. Section 3 describes the system and how the experiments are performed. Section 4 presents the results, and Section 5 relates the findings to previous research. Section 6 is the conclusion.

2. RELATED WORK

The running wheel has been used in several experimental setups. Allen et al. (2001) studied cardiac and skeletal muscle adaptations in mice running in rotational wheel. They demonstrated that voluntary exercise results in cardiac and skeletal muscle adaptations that are compatible with endurance training. Pellegrino et al. (2005) studied the effects of voluntary wheel running and its association with amino acid supplementation on skeletal muscle in mice.

Most tests with running wheels use the principle to measure the number of revolutions the wheel has performed during a certain period of time. One construction of a running wheel with a tachometer that measures the number of revolutions was presented by (Bheem et al., 1966). Murphee and Johnson (1974) made a change in this design and introduced the electric component infrared diode (IR) as a sensor. An IR diode is an optical component that reacts when a light beam is broken. With the infrared diode sensor instead of a mechanical counter, the design has been greatly improved and the measurement process has been automated and integrated with microprocessors and other digital components. The topology of the design is based on infrared sensors, integrated with a microprocessor. This system represents a much higher degree of automation. By using a microprocessor, the electronics are minimized and the system is equipped with additional opportunities to conduct more advanced measurements. Another way to measure the number of revolutions of a wheel is described by Jung and Luthin (2010). In their experiment,
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