PRIMATE BEHAVIORAL INSTRUMENTATION

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Abstract - Circadian rhythms provide a biological "program" that controls daily changes in physiology and behavior. We have developed a rhesus monkey model that enables us to investigate physiological rhythms and circadian effects on performance in an integrated framework. Body temperature and animal activity are of great importance in the study of circadian rhythms. To monitor a free-ranging monkey's temperature we utilize a telemetry system. Monkey activity is measured using strain-gage transducers mounted under the animal's home cage. Non-human primates are not always the most cooperative experimental subjects; therefore some unique solutions are necessary to overcome these constraints.

Introduction

Circadian rhythms influence performance. These influences have been described for a variety of tasks in humans [2] and in animals [3]. A familiar example, and one which our lab has explored, is the phenomenom of jet lag [5]. Travelling across time zones produces alterations in sleep-wake cycles, temperature and activity rythyms. In addition, there are decriments in performance. We have examined the coupling of these rhythms and there relationship to performance. Experimentally, the measurement of temperature is a very important because: a) body temperature is hard to influence by external stimuli, and b) it is continuously available. For example, we can distort the observable sleep-wake cycle of a person by simply waking them in the middle of the night. However, this does not raise the person's temperature to normal daytime levels. In our example then, we have uncoupled the temperature and activity ryhthms. It is when these rythyms are uncoupled that errors and accidents most frequently occur.

In our research, the rhesus monkey model is employed to provide us with greter experimental control over subject and environmental variables. However, the monkeys are not always as cooperative and respectful of equipment as human subjects. We then use a telemetry system to monitor temperature and strain gages mounted under the cage supports to measure activity. In this manner, these two important rythyms can be monitored with a reduced risk of damage to equipment.

II. Discussion of Temperature

Our primate temperature recovery system uses a transmitter (Mini-Mitter, Sun River, OR) implanted in the retroperitoneal space of each monkey. This transmitter transmits a pulse at a rate that is linearly proportional to the body temperature of the monkey. This signal is transmitted on a carrier frequency in the AM band of 27MHz. The signal is demodulated using a Sony ICF-2010 receiver. Once it is filtered, amplified and tested the signal is sent to a Digital PDP11 data collection system.

The transmitters have a very limited transmitting range so that battery life can be extended. This poses several problems in the recovery of the signal. Using a telemetry recovery antenna in the configuration of a trapeze (Figure #1), which was developed at our facility, we have overcome many of the problems of signal recovery [1]. In the past the antenna was outside of the cage necessitating passage of the telemetry signal through the cage walls. Four of the sides are solid, only the top and front are a grill. The antenna is now optimally close to the transmitter inside the animal.

Despite these improvements in transmission, RF noise and signal strength still had room for improvement. An interface to a Sony receiver accomplished this by increasing the signal to noise ratio (SNR). In addition, the output pulse of the transmitter is an audio tone burst that needs to be transformed to be sent to the computer for counting. The signal passes through a variable low pass filter and a high pass filter. Each of the eight transmitters that we use are slightly different in its audio frequency characteristics. The variable filters allow us to adjust the filters for the best band pass response. The next stage for the signal is an amplification stage and then the signel is rectified. The peaks of the audio pulse are detected using a peak detector. This signal is then compaired against an adjustable threshold. The output of the comparitor is now a square pulse that has a width equal to the width of the original audio pulse. The width of this pulse is compaired against a test pulse produced at the same time as the real pulse. Only if the signal pulse is longer than the test pulse will a one-shot generate a pulse to the computer for counting. The reason for this test pulse is to eliminate noise being counted as a temperature pulse. For example, the

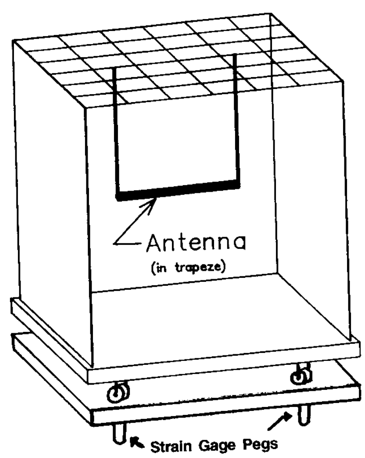

Figure 1

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animals pellet dispencer sometimes produces a spike of noise at a very short duration. This system reduces pulse selection errors.

Ultimately, the PDP11 counts the pulses which have passed these tests for 2 minutes and then calculates the animals body temperature based on the particular transmitter pulse to temperature characteristics. Temperature is recorded every 10 minutes, 24 hours a day.

III. Discussion of Activity

To measure activity we use strain gages mounted at the maximum force transfer points of the cage to convert weight into an electronic signal. 350Ω gages are mounted on cylindrical plastic pegs under a false floor in which the cage (figure 1) is supported. Strain is the ratio of the change in length to the initial unstressed reference length. A strain gage is the element that senses this change and converts it into an electrical signal. When a strain gage is under tension or compression its resistance changes. Two gages are mounted on each of the four pegs and are opposite legs of a Wheatstone Bridge. As the weight of the animal produces compression on the pegs the output of the bridge changes. This change is then amplified using a high gain differential amplifier. The amplified signal now passes through a differentiator circuit. This transforms the weight change in the cage per unit time into a force. When the force signal is greater than a preset threshold, a pulse of 15 mSec duration is sent to the computer. This process is done for each of the four legs of the cage. Either one can produce a force pulse to the computer. Like temperature, activity is recorded every 10 minutes, 24 hours a day.

CONCLUSIONS

Looking at figure 2 we see the difference between old temperature data using an antenna outside of the cage and new temperature data using the trapeze as an antenna and new electronics. The plots are from similar 24-hour periods. It can be seen from the top plot that there are many missing points. This is due do the signal from the transmitter not being dectected. This causes a miss calculation of temperature. Each missed pulse causes a 0.5% error in the calculation. An animal's body temperature varies approximately 4°C over a 24-hour period which would make the error 0.11 degrees per missed pulse. This error is unacceptable for the research that is being performed in our lab. We now have fewer missed time points, thus higher reliability with the system.

In the past activity only gave us a gross measure of the animals activity. Old activity methods used the home cage of the animal mounted on a pivot where the cage could tilt from front to back and open and close switches. The obvious problem is that the animal could be very active simply by staying in one half of the cage and never produce a count. With the new strain gage method of detecting activity we can look at very fine patterns of the animals activity. Figure 3 is a density plot of an animals activity of a 2 month period. The ordinate is 48 hours and the absissa is 2 months. The data each day is double plotted so as to show any patterns that cross the midnight line. The density of each point is proportional to the amount of activity. The use of these plots coupled with the improved method of activity data collection allows us to discern fine activity patterns within larger ones.

The new designs for collecting temperature and activity have improved the accuracy and the reliability of data collection.

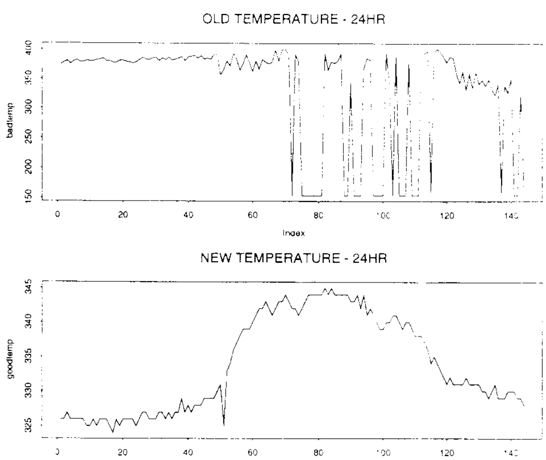
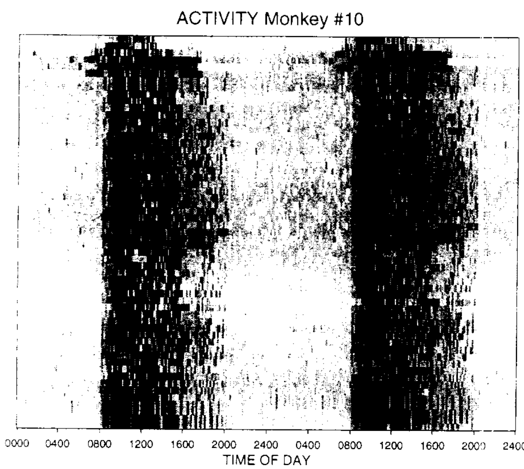


Figure 2



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