

Combined use of the PhenoTyper and accelerometer for activity and sleep pattern categorisation



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Background

Aims

- The categorization of sleep stages in sleep pattern analysis requires the recording of both EEG and motor activity via EMG
- EMG recordings have technical problems due to anatomical and physiological limits
- The PhenoTyper system provides useful information of gross locomotor activity in a freely moving animal in its home cage (1). However, the software only detects robust changes of the body centre of gravity, neglecting fine movements during the stationary phase
- The detection of subtle movements is fundamental for categorisation of sleep stages
- The use of an accelerometer as part of an EEG recording device provides information on subtle movements (2), however limitations would occur if an animal moves with a constant velocity, and it does not provide information on the animal's spatial location
- In terms of translational studies from animals to humans, the use of an accelerometer as compared to neck muscle electrodes, is more appropriate

- To combine and compare the use of the PhenoTyper and an accelerometer to provide a more robust reading of locomotor activity in mice
- This would allow the collection of information of both x:y position of the animal as well as its micro-movements
- A more reliable interpretation of EEG recordings during circadian rhythms is expected
- Also, the combined use of PhenoTyper and accelerometer could be a good replacement for EMG electrodes

Methods

Apparatus

- Hardware: PhenoTyper cage (Noldus)
- Software: Ethovision 3.0 (Noldus)

Wireless EEG recordings (NewBehaviour)

- Specifications:
 - 512 MB memory storage
 - Weight: 3 g
 - 5 channels recording
 - Re-usable
 - Accelerometer (movement)
- The **accelerometer** sensor (SignalQuest SQ-SEN-200) acts like a normally closed switch which chatters open and closed as it is tilted or vibrated. It's an omnidirectional motion sensor and will produce continuous on-off contact closures when in motion. When at rest, it normally settles in a closed state. It is sensitive to both tilt (**static acceleration**) and vibration (**dynamic acceleration**). The sensor is fully passive, requires no signal conditioning.



Subjects

- 12 months old C57BL/6j female mice (n=4)

Surgery

- Epidural gold screw electrodes were placed over prefrontal cortex and left and right hippocampi of fully anaesthetised subjects (1.5% isoflurane in medical grade oxygen). Reference and ground screws were placed in neutral zones (parietal and occipital regions). Screw electrodes and assembly pins were anchored and fixed to the skull by means of dental cement.
- Experiments took place at least 7 days post surgery.

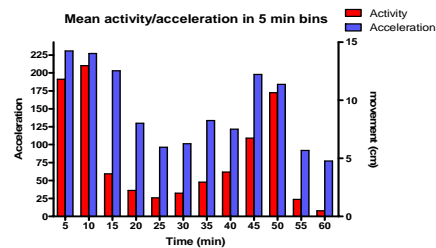
Experiment outline

- Mice were placed into the PhenoTyper box and tested for 1 hr (during the light phase).
- A wireless EEG recorder data logger (NewBehaviour, Zuerich, Switzerland) with a built-in accelerometer was connected to the animal and its activity was synchronised with the recording of locomotor activity in PhenoTyper® boxes (EthoVision 3.0, Noldus IT, Wageningen, The Netherlands) and the accelerometer.
- Data were analysed in time slots of 4 second epochs such that distance (cm) and acceleration (expressed in form of "on-off" digital signal) were plotted in a x:y graph for correlational analysis.
- Animals were also visually observed during the test to combine the software and the visually recorded data. "Active awake" and "quiet awake" were defined by the experimenter as high activity and little or no movements, respectively.

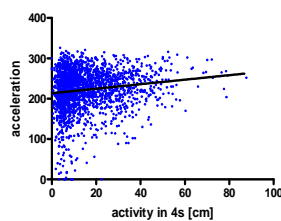
Statistics

- Linear regression analysis was used to test correlation between acceleration (recorded by the accelerometer) and movements (recorded by Ethovision).

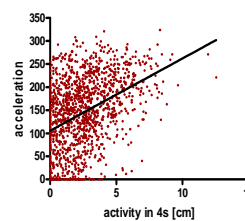
Results



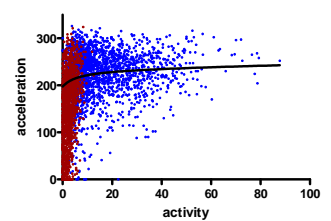
Accelerometer vs phenotyper activity: ACTIVE AWAKE



Accelerometer vs phenotyper activity: QUIET AWAKE



Accelerometer vs Activity



Linear regression analysis between activity and acceleration during the active awake phases. Data are expressed as mean of 4 s time bins of awake episodes

Linear regression analysis between activity and acceleration during the quiet awake phases. Data are expressed as mean of 4 s time bins of awake episodes

- During active awake phases, data recorded by the data logger (acceleration) and Ethovision (distance in cm) were statistically correlated ($r^2=0.01912$; $F(1, 1975)=38.49$; $p<0.0001$).
- The accelerometer reached the maximal measurable acceleration as it became saturated, whereas the Ethovision continually provided linear information about the activity.

- Gross movements recorded by Ethovision and fine movements recorded as acceleration were correlated during quiet awake phases ($r^2=0.1584$; $F(1, 1357)=255.5$; $p<0.0001$).
- During quiet wakefulness the animal stays still but sometimes grooms, moves the head or sleeps; in such cases the accelerometer provided useful information to discriminate between different stages of quiet activity also during the transition between sleep stages.

Conclusions

- The present experiment validated the importance of combined use of the PhenoTyper and the wireless data logger with the built-in accelerometer for sleep/awake phases categorization.
- In active phases, the accelerometer saturates rapidly, whereas the PhenoTyper provides complete information about the animal's activity.
- In quiet phases for a small range of movements the accelerometer gives a more detailed reading of small changes in activity typical of pre-sleep phases.
- The present findings are essential for the automatic scoring analysis of sleep stages.
- The PhenoTyper allowed a gross analysis of the locomotor activity, whereas the accelerometer provided an index of fine accelerations.
- Together, the two devices offered an enriched reading of the animal's activity allowing a more robust interpretation of the automatic recognition of the behavioural parameters and possibly sleep stages.

References

- (1) Visser, de, L.; Bos, van den, R.; Kuurman, W.; Kas, M.; Spruijt, B. (2006). Novel approach to the behavioural characteristics of inbred mice: automated home cage observations. *Genes, Brain and Behavior*, 5, 458-466
- (2) Sunderam S., Chernyy N., Peixoto N., Masona J.P., Weinstein S.L., Schiff S.J., Gluckman B.J., (2007). Improved sleep-wake and behavior discrimination using MEMS accelerometers. *Journal of Neuroscience Methods* 163, 373-383.