# EEG gamma power enables robust automated sleep-staging in rodents

John Huxter[1], Sandor Kantor[1], Michael Lanigan[1], Lauren Giggins[1], Leo Silenieks[2], Mark Duxon[1]
[1]Transpharmation Ltd. UK [2]InterVivo Solutions Inc. Canada

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## Introduction

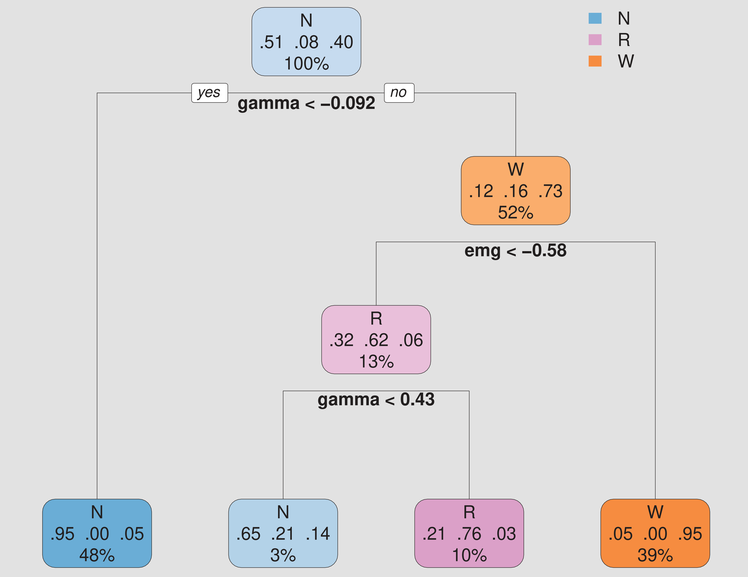
Sleep disturbances are common in neuropsychiatric and neurodegenerative diseases. Consequently, changes in sleep architecture and changes in EEG spectral power specific to different sleep-stages are valuable tools in translational preclinical research. Algorithms for rodent sleep-stage classification usually rely on changes in muscle-tone and EEG power in the delta, theta and/or sigma bands. However, these outputs typically require refinement by human visual scoring, making the process laborious and prone to human error. We aim to develop a simple but robust sleep-stage classification system which better correlates with the results of human visual scoring, and makes manual curation redundant.

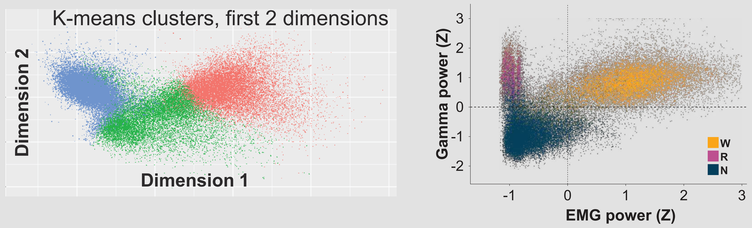
## Methods

We recorded fronto-occipital epidural EEG, EMG (nuchal muscle) and activity from 7 adult male Sprague Dawley rats for ~22 hours. An expert scorer defined 10s epochs (W)ake, (R)EM sleep and (N)on-REM sleep based on visual inspection of the EEG and EMG traces. FFT analysis of the data in 1s windows was then used to generate median EMG and qEEG values for each epoch. qEEG bands used for analysis included 1-4Hz delta, 4-10Hz theta, 12-30Hz beta, 30-100Hz gamma and theta / delta ratio.

## Gamma & EMG power predict sleep-stages

Using combined data from all rats, K-means clustering based on 7 EEG and EMG features revealed 3 clouds of points. Regression-tree analysis revealed that gamma and EMG power sufficiently predict manually-scored sleep stages. Surprisingly, theta and delta were relatively poor predictors.

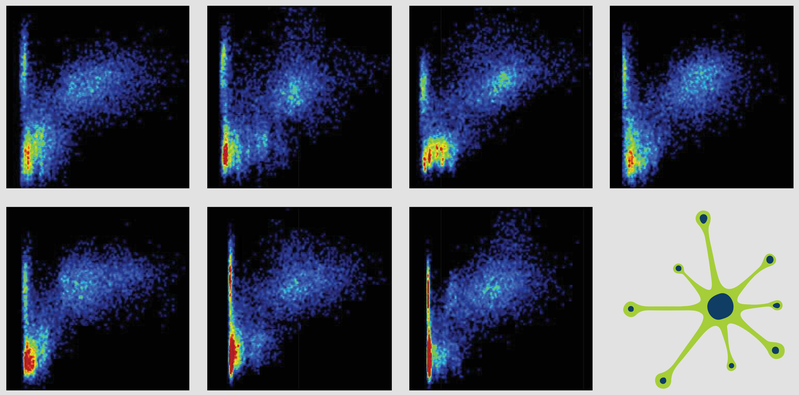




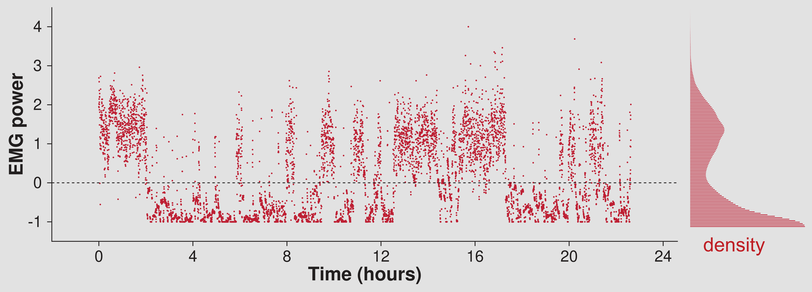


## Normalized EMG & gamma power revealed three clusters of points for every rat tested

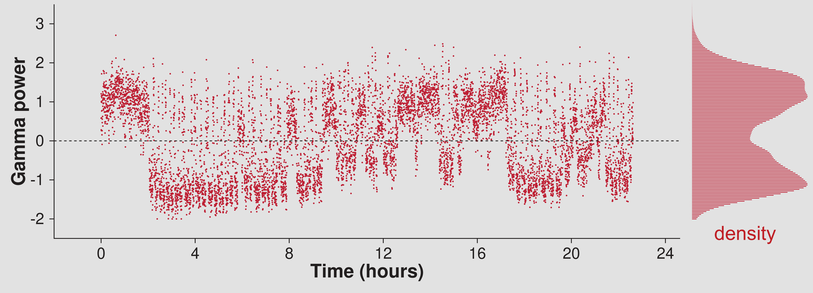


Density plots showing the distribution of normalized EMG power (x-axis) gamma-qEEG power (y-axis) for 7 animals across 22 hours recording

## Both EMG and gamma power show a clear bi-modal distribution, but are independent

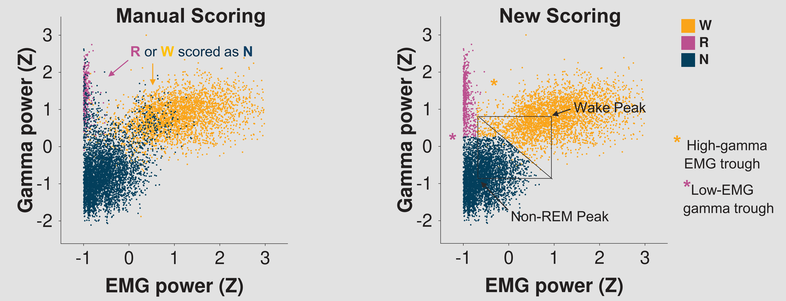



22-hour EMG power (Z-scored) shows shifts between two states, with high values associated with bouts of waking mobility. During REM sleep we expect EMG tone to reduce to near-zero.



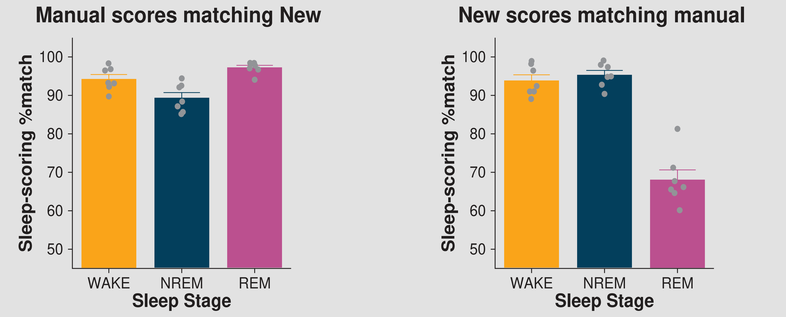

Corresponding gamma power (Z-scored) mirrors some aspects of the EMG and is also bimodal. Note however that there are many periods of high gamma-power which coincide with very low EMG. These periods are associated with REM-sleep.

## Subject-specific thresholds can be derived from the distribution peaks and troughs




EMG versus gamma power distribution for a single subject, with colours representing manual (left) and automated (right) sleep stage scoring

## The gamma/EMG-based algorithm produces sleep-stage scorings very similar to human scoring, with improved REM sleep detection




## Conclusions

- The new algorithm, based on normalized median estimates of EMG and gamma EEG power, provides fast, reliable unsupervised sleep stage scoring that closely matches manual scoring.
- High gamma power differentiates REM-and non-REM sleep, while low EMG separates REM-sleep and waking.
- REM sleep detection is improved, with better differentiation from non-REM sleep than obtained using theta & delta measures.

## References

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## Contact

john.huxter@transpharmation.com
linkedin.com/company/transpharmation
twitter.com/TranspharmLtd