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Decoding behavioral state from local field potential recordings in basal forebrain and visual cortex

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Introduction

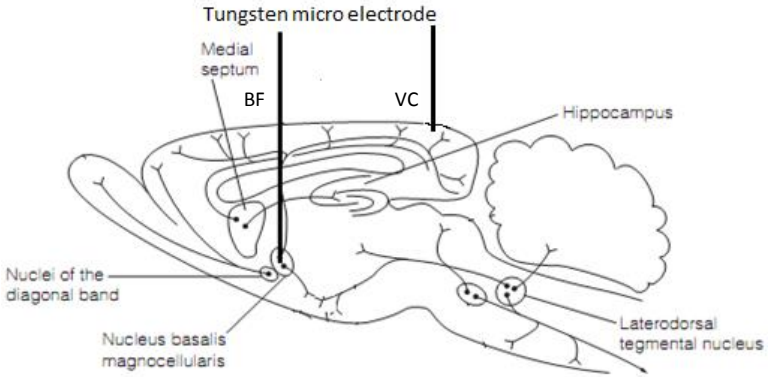
- The basal forebrain (BF) cholinergic system is a regulator of cerebral cortical function by providing the major source of cholinergic as well as non-cholinergic input to the neocortex.

- The BF projections play an important role in modulating neural network state, for example by enhancing cortical responsivity as well as contributing to wake/sleep regulation.

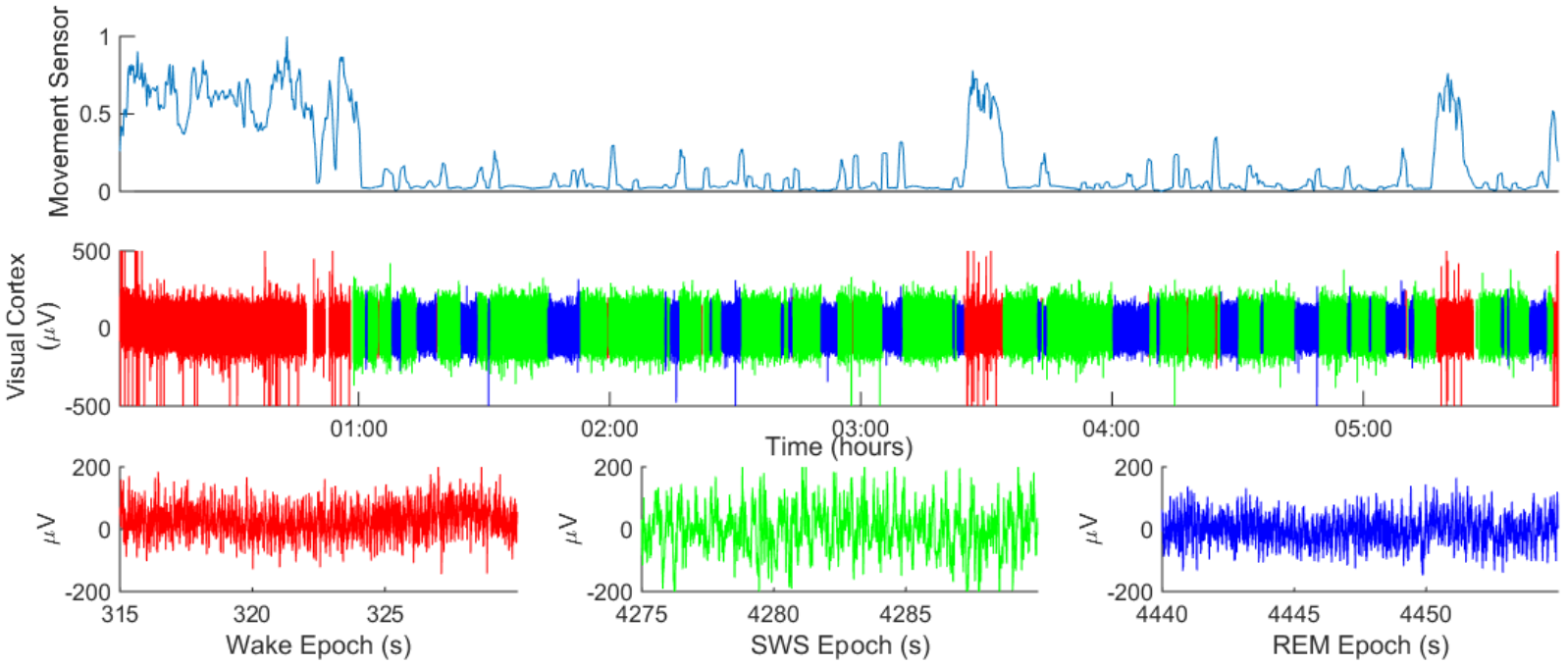
- Here, we study how electrical signals in BF and visual cortex (VC) vary with the behavioral state of rats (wake, slow-wave sleep, rapid eye movement sleep) using long-term recordings in animal's home cage with a miniature wireless recording device.

- We also examine how much information is present in these brain regions about behavioral state.

Methods

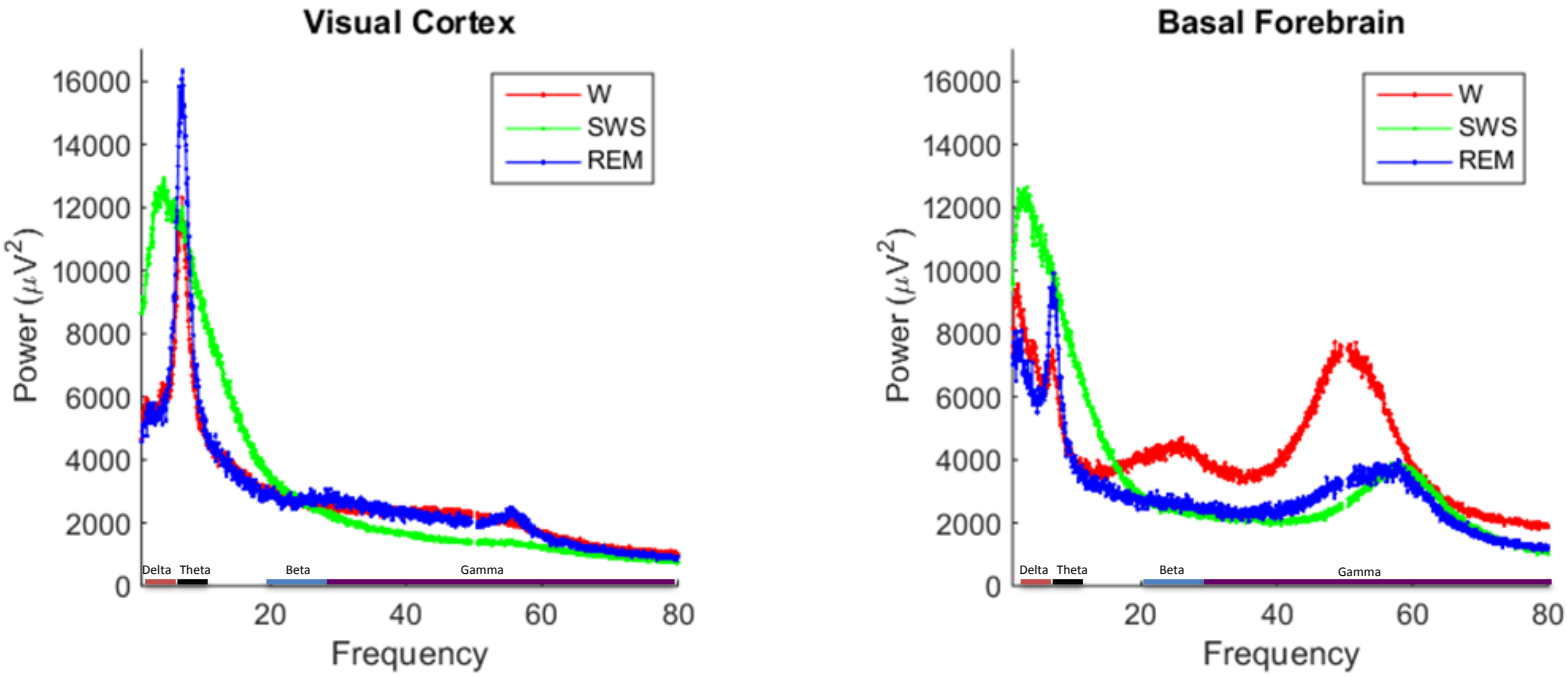

Tungsten micro electrode
Medial septum
BF
VC
Hippocampus
Nuclei of the diagonal band
Nucleus basalis magnocellularis
Laterodorsal tegmental nucleus

Intracranial local field potentials and behavioural states.



W - Wake
SWS - Slow Wave Sleep
REM - Rapid Eye Movement Sleep

Power Spectral distributions and behavioural states

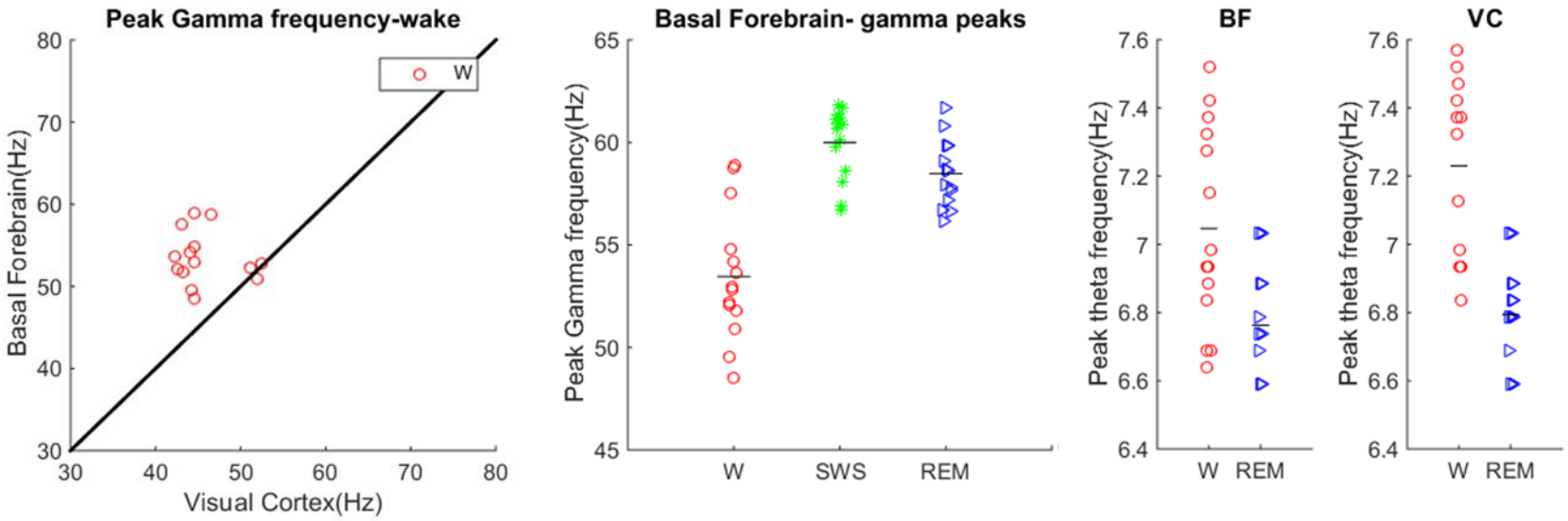


- In Visual Cortex, during wake and REM sleep high frequency gamma(30-80Hz) activity is maximal along with theta(5-10Hz) which is most prominent in the cortex. During slow wave sleep gamma is minimal and irregular slow waves of delta frequency are prominent.

- BF displays much stronger beta (20-30 Hz) and gamma oscillations during wakefulness than VC.

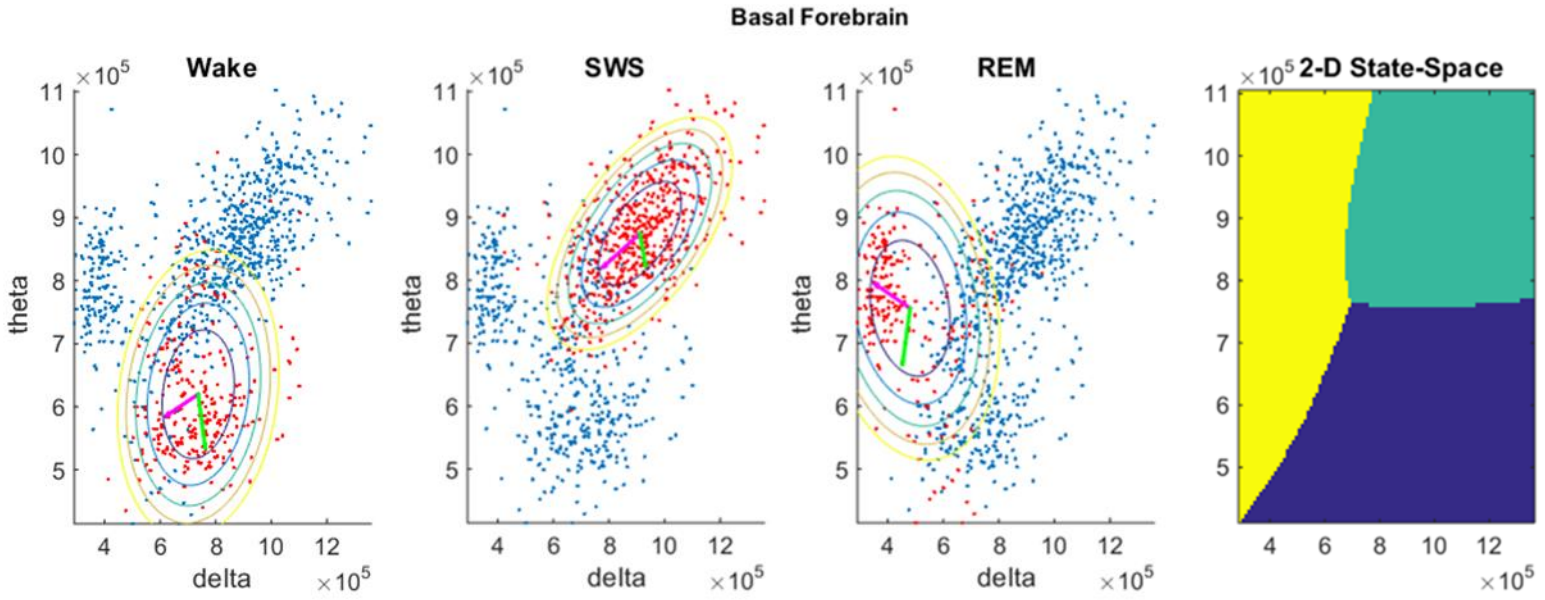
- In BF, the gamma is showing peaks in all the behavioral states which provides a signature for engagement of BF networks during all behavioural states.

Brain region specific modulation of gamma and theta peak oscillation frequencies



- ✓ Peak gamma frequency during wake was significantly higher in BF (53 Hz) than in VC (46 Hz), suggesting independent local gamma generating networks in the two brain areas.
- ✓ Within the BF, peak gamma frequency was significantly lower for in wake (53Hz) than both SWS and REM (60 and 58Hz respectively) , whereas gamma power showed the opposite relationship.
- ✓ Theta peak frequencies, while differing between REM and wake state, were similarly modulated in BF and VC, suggesting that theta is coordinated by long-range BF-VC interactions.

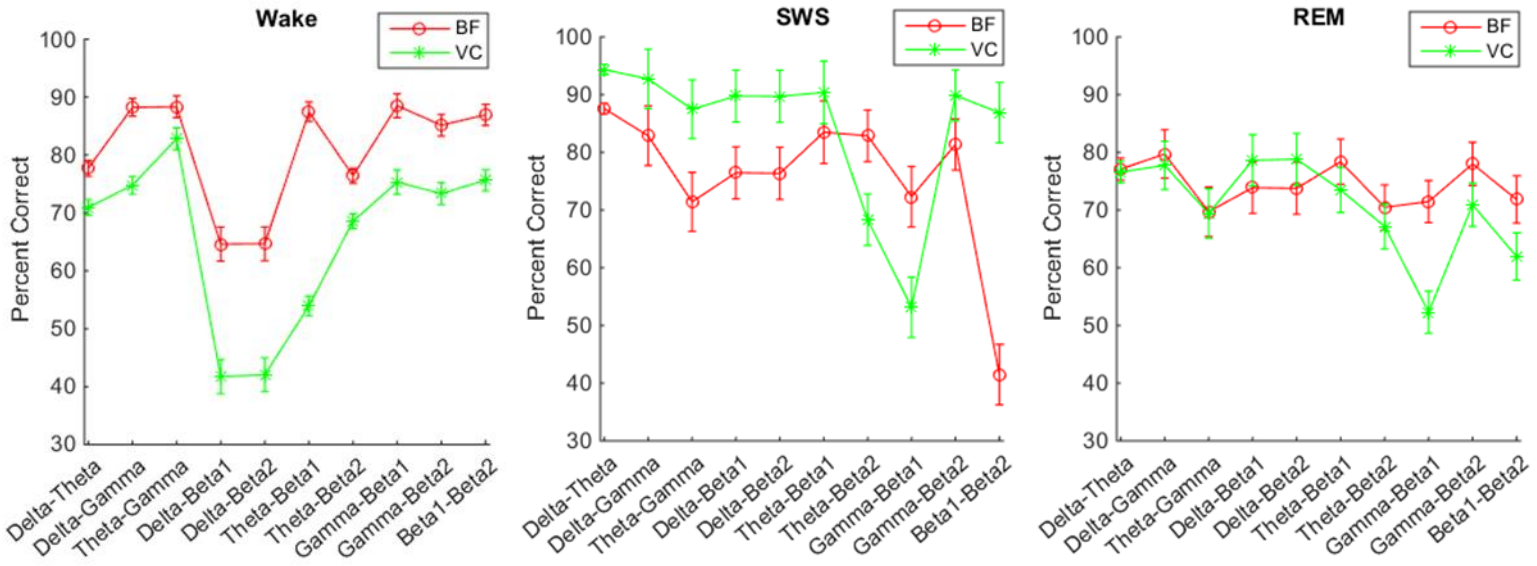
Behavioral state decoding based on Mahalanobis distance classifier using pairs of frequency bands



- We trained a classifier on a random 80% of neural data epochs (15s duration) from each behavioral state for pairs of frequency bands using mahalanobis distance measure, which generates a decision surface that allows classification of the remaining 20% of data epochs.

- The procedure is repeated 100 times with different training data selection, and classifier performance is assessed in terms of percent correct classification of the test data.

Behavioral state decoding based on Mahalanobis distance classifier using pairs of frequency bands



- ✓ The BF signals allow more accurate classification of the wake state than VC signals, particularly when gamma band activity is considered.
- ✓ SWS state classification is more accurate based on VC signals
- ✓ REM state classification is possible to a similar degree using BF and VC signals, except that classifications involving the beta band are more accurate for BF data.

Conclusion

- ✓ The variation of LFP signals in BF and VC display numerous characteristic differences, involving both low (delta, theta) and high (beta, gamma) frequency bands.
- ✓ Differences in peak oscillation frequencies are evident for gamma, but not theta bands, which can is suggestive of local generation and long-range oscillatory coordination respectively.
- ✓ These findings provide novel insights into frequency specific neural activations in basal forebrain and its cortical target region.

Thank You!