On the Comparison of Neural Activity During Sleep and Wakefulness in Basal Ganglia and Thalamic Regions

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Introduction

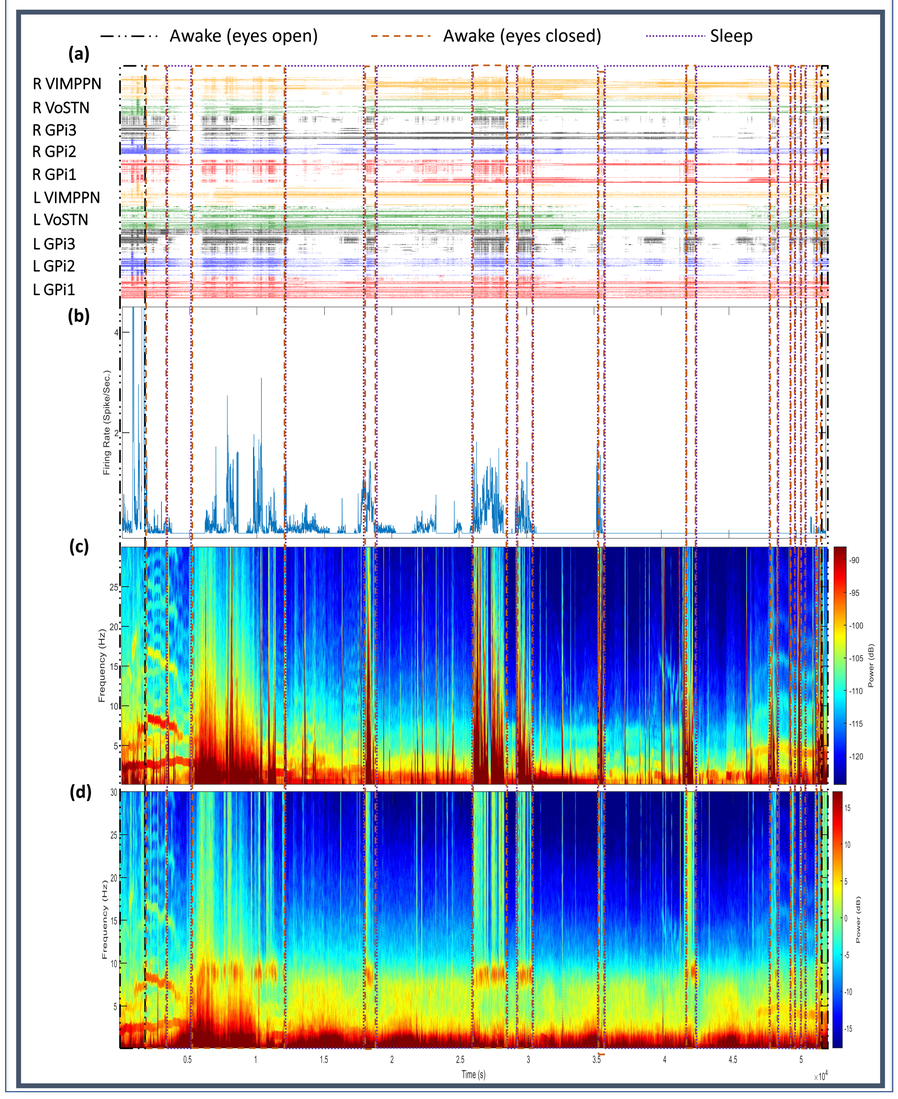
- Deep brain stimulation (DBS) is a neuromodulatory intervention that has profound impact on treatment of children with movement disorders such as dystonia and tremor [1].
- Researchers have long attempted to elucidate patterns of neural activity in basal ganglia (BG) and thalamic regions in sleep vs. wakefulness based on electrophysiology and the use of transgenic animals. It is time to revisit this subject now that the study of neural activity in humans using modern techniques such as DBS is possible [2].
- Understanding how neural activity changes in sleep vs. wakefulness has the potential to provide a better framework that improves our understanding of sleep mechanisms.

Conclusion

- Results from this study provide evidence that the level of neural activity in all recorded regions changes over night. Specifically, the neural activity decreases from wakefulness to sleep and increases from sleep to wakefulness state.
- Spectral analysis demonstrates that similar activity patterns, representing sleep/wakefulness states, are observable in some EEG and intracranial recordings.
- There is a possibility to define sleep stages using intracranial recordings from BG and thalamic regions as a future study.

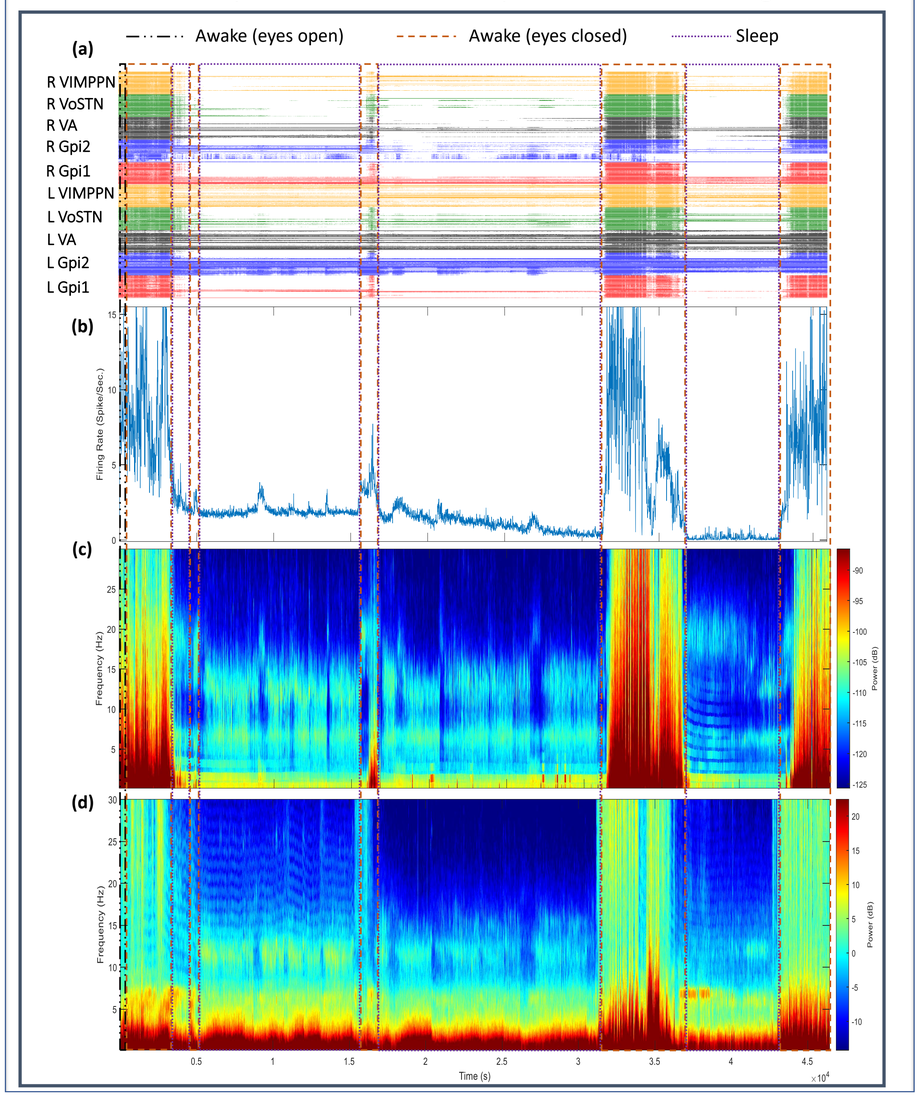
Results

Figure 3. P1 results. (a) Spike raster of bilateral GPi1, GPi2, GPi3, VoSTN, and VIMPPN. (b) Example of calculated firing rate from right VIMPPN electrode. (c) Example of spectral analysis from right GPi2. (d) Spectral analysis of Occipital EEG recordings that can be used to separate different stages of P1 (i.e., sleep/wakefulness) . Results show that neural activity decreases from wakefulness to sleep and increase from sleep to wakefulness in all regions.



Results

Figure 4. P2 results. (a) Spike raster of bilateral Gpi1, Gpi2, VA, VoSTN, and VIMPPN. (b) Example of calculated firing rate from right VIMPPN electrode. (c) Example of spectral analysis from right VIMPPN. (d) Spectral analysis of Occipital EEG recordings that can be used to separate different stages of P2 (i.e., sleep/wakefulness). Result shows that neural activity decreases from wakefulness to sleep and increases from sleep to wakefulness in all regions.



OBJECTIVE

- Our goal is to study and compare how neural activity changes in sleep vs. wakefulness in Basal Ganglia (BG), thalamus, and brain stem using spike data and frequency domain analysis in two pediatric subjects who underwent DBS surgery.

MATERIALS AND METHODS

Patients: We used intracranial data from two pediatric patients who underwent DBS surgery. The data was collected on the second night after DBS surgery was performed. Table 1 shows patient demographics.

Subject	Mutation	Symptoms	Sex	Age
P1	PKAN	Dystonia, Oropharyngeal	M	23
P2	KMT2B	Chorea, Dystonia	M	10

Data: Intracranial data was recorded from 10 Stereoelectroencephalography (SEEG) electrodes placed in **globus pallidus internus** (GPi) and **subthalamic nucleus** (STN) in BG, ventral oralis (VO) and ventralis intermediate nucleus (VIM) in thalamus, and **pedunculopontine nucleus** (PPN) in brain stem, bilaterally in two children with dystonia. Modified "10-20" montage video telemetry Surface EEG was simultaneously recorded through clinical electrodes using the in-room hospital telemetry system.

Figure 1. The schematic of temporary SEEG electrode implanted in target regions. Black squares represent macro/stimulation contacts while little circles represent micro contacts.

MATERIALS AND METHODS

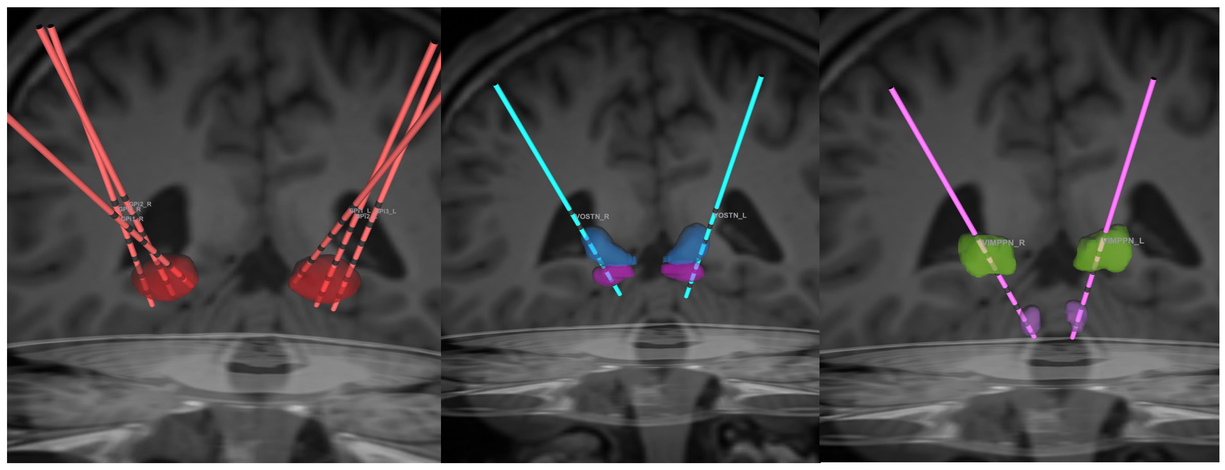


Figure 2. View of SSEG electrodes in bilateral GPi (left), Vo and STN (middle), VIM and PPN (right); normalized scans visualized onto the Montreal Neurological Institute (MNI) space. Deep brain boundaries were defined with the DISTAL atlas. All pairs of DBS electrodes correspond to a single patient (P1), represented with different colors (red, blue, and pink).

Spike analysis: Spike analysis was performed on the entire night of intracranial recordings. Signals are bandpass filtered between 350 Hz and 3000 Hz using an 8th order Butterworth filter. A nonlinear energy operator (NEO) was applied to the data to aid in spike detection. Peak detection was performed on the NEO, where the amplitudes of detected peaks were between four and seventy times the standard deviation of the noise. Following event detection, wavelet decomposition was used to extract features from detected events and a Gaussian Mixture Model (GMM) was used to cluster detected events. Events with low probability of belonging to any clusters were removed. Events associated with the same cluster were identified as a "spike" belonging to the same originating neuron(s).

Frequency domain analysis: Spectral analysis- a quantitative approach that enables us to explain a signal in terms of its underlying oscillations at different frequencies- was performed on the entire night of sleep intracranial recording and EEG data [4].

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