Functional interactions in human cortex during sleep and wake

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Introduction. We are regularly and naturally unconscious during non-dream sleep, so understanding the neural differences between sleep and wake is key to understanding the neural correlates of consciousness.

Methods & Results: We evaluated functional interactions between brain regions in intracranial electroencephalography (iEEG) by calculating the coherence between pairs of bipolar electrodes over 10-second windows. The coherence between electrodes *a* and *b* is defined as:

$$C_{ab}(f) = \frac{|G_{ab}(f)|}{\sqrt{G_{aa}(f)G_{bb}(f)}}$$

where G_{aa} and G_{bb} are the auto-spectral densities and G_{ab} is the cross-spectral density. For details, see Wang 2018. We compared coherence between sleep and wake states.

Subject ID	% sleep	Hours of data	10-fold Loss % (chance = 50)
1	43.4	84	5.00
2	14.5	168	5.75
3	32.6	134	9.55
4	23.0	49	7.87
5	43.0	90	6.54
6	39.2	121	7.88
7	27.8	64	5.93
8	25.3	93	7.52
9	45.2	110	6.92
10	46.9	60	4.17
11	28.3	116	6.26
12	48.7	39	5.27
13	30.7	125	9.96
14	30.9	110	4.85
Average	34.2 (10.3)	97.4 (36.0)	5.38 (0.53)

Table 1: Each 30-minute segment of the patient video was manually annotated as either sleep or wake. Sleep was defined as a continuous period without movement and with eyes closed. 1,363 hours were annotated in total, with 445 hours (32.7%) of sleep. 50% of subjects were female, with average age of 24.4 (SD = 12.7). The fourth column reports 10-fold cross-validation losses for SVMs trained on the annotated iEEG data.

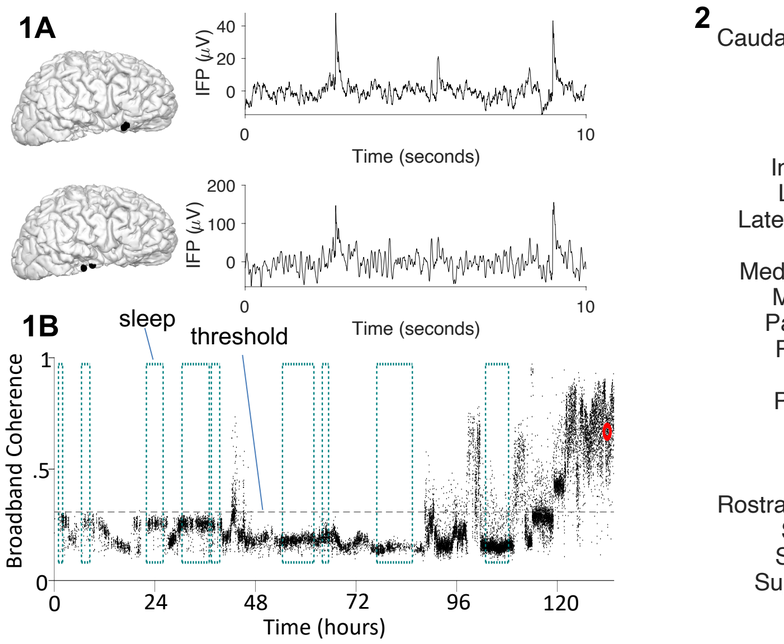
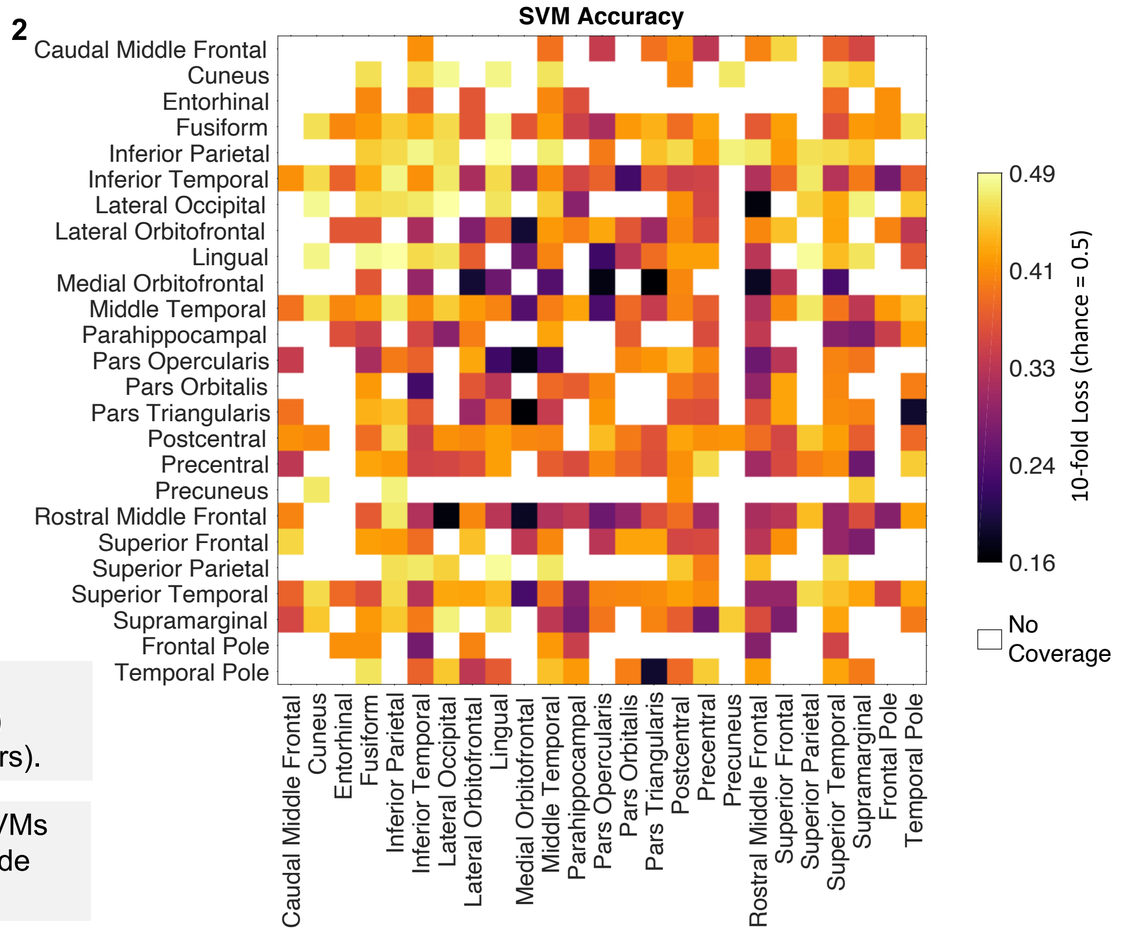
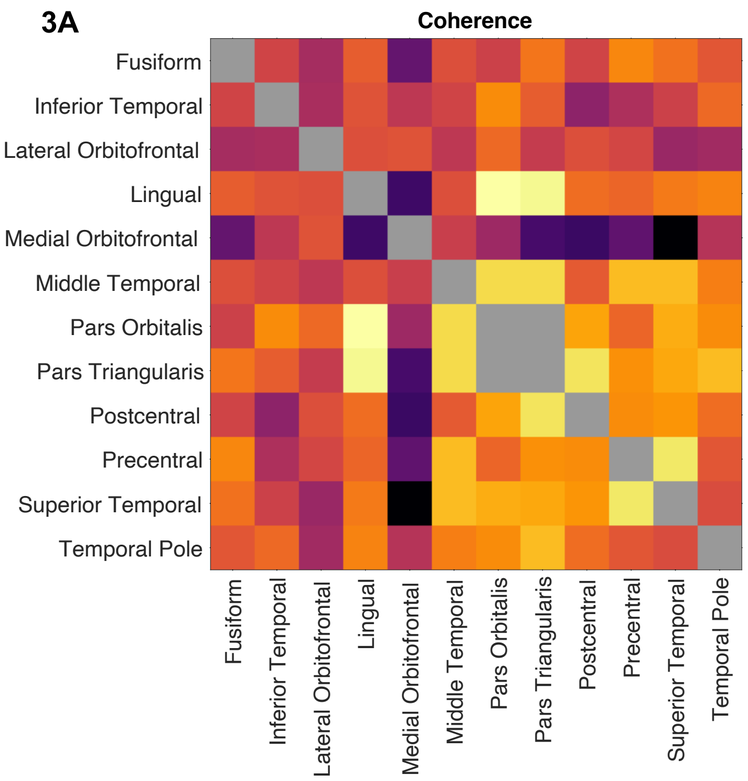


Figure 1 (above): (A) Example intracranial field potentials for two bipolar electrodes (Subject 3). **(B)** Coherence values for Subject 3's entire stay (134 hrs).

Figure 2 (right): 10-fold cross-validation loss for SVMs trained on coherence values of each bipolar electrode pair (n = 20,017, mean .40, SD .12, chance = .5)





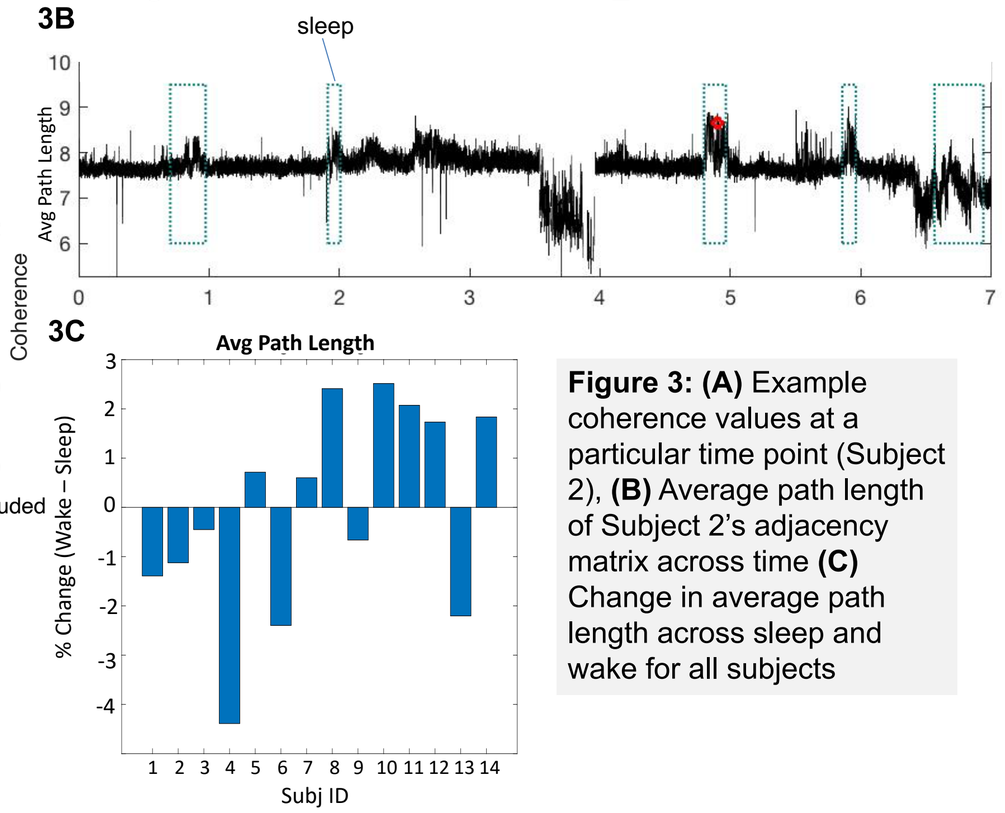


Figure 3: (A) Example coherence values at a particular time point (Subject 2), **(B)** Average path length of Subject 2's adjacency matrix across time **(C)** Change in average path length across sleep and wake for all subjects

Conclusions: The preliminary results suggest that we can: **(1)** automatically classify sleep versus wake with a high level of accuracy in iEEG data, **(2)** distinguish between sleep and wake based on pairwise interactions between brain areas, and **(3)** characterize sleep and wake according to changes in network properties

Further questions? *a_tao@college.harvard.edu* ; **Conflicts of Interests:** None; **Funding Sources:** Harvard College Research Program, NSF, NIH