Functional Mapping Using Infra-slow Gamma Band Fluctuations in Spontaneous Electrocorticography
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Introduction
Resting state functional networks were defined using fMRI: correlations in BOLD signal persisted during stimulus-free activity, corresponded spatially with functional cortex, and were used to describe attentional systems such as the default mode network. Correlations in spontaneous, infra-slow (<0.1 Hz) fluctuations in gamma band (70-100 Hz) signal recorded using electrocorticography (ECoG) also appear to reflect the functional organization of the brain, appearing in auditory and visual sensory cortex, motor cortex and the default mode network, and may be a neurophysiological correlate to the BOLD co-fluctuations that are seen in resting state fMRI (1-4). To date, however, correlations in spontaneous, infra-slow ECoG have not been used to perform functional mapping.

Methods
We used a data-driven method examining correlations in spontaneous ECoG to characterize the connectivity between cortical areas and map cortical function. Our algorithm uses correlations in spontaneous, infra-slow (<0.1 Hz) gamma band power fluctuations to identify functional networks using a spectral clustering algorithm (5). Consistently appearing networks were compared to clinical mapping results obtained using electrocortical stimulation (Figure 1). We also examined functional relationships between these networks to identify attentional systems that are known exhibit anti-correlated activity.

Results
We show that correlations in spontaneous, infra-slow fluctuations gamma band power can be used to identify motor and visual cortex (Figure 2). There is also evidence that other functional networks such as attentional systems, including the Default Mode Network, are identified by this algorithm (Figure 3). Interestingly, the functional relationship of these networks, namely anti-correlated activity, is borne out, with negative correlations between DMN and attentional areas being found.

Conclusions
This technique, which we are calling Infra-Slow Clustering (ISC), uses correlations in spontaneous ECoG to identify groups of electrodes corresponding to functional networks such as somatomotor cortex. It may be useful in mapping functional cortex without electrical stimulation or patient cooperation as it uses only spontaneous ECoG signals.

Learning Objectives
Participants should be able to:
1) Describe the relevance of the resting state to functional mapping.
2) Discuss the relationship between infra-slow fluctuations in electrocorticographical signals and cortical function.
3) Describe the basis for using spontaneous connectivity in ECoG to map cortical function.

References
(A) Significant correlations between infra-slow gamma band power are used to generate clusters for 250-second segments. Over all time segments, electrodes that cluster together are in turn clustered to give the final results (B,C).
Motor cortex as defined by ECS is shaded in green (A,B, top). Schematic representations of electrodes and mapping are shown (A-D). Function is denoted by color: yellow – hand; face – cyan; leg – red; vision – green; language – blue. Mapping derived from ECS is denoted with lines to reflect bipolar stimulation. ISC-derived clusters are indicated as electrodes in solid color. Note in (B) that face motor in anatomically consistent areas is detected on the contralateral hemisphere by our algorithm (though not assessed with ECS).
Infra-slow spectral clustering identifies putative Default Mode Network cortex, which is anti-correlated with attentional network cortex.

Selected seed regions corresponding to task-negative areas derived from fMRI studies include the pCC (posterior cingulate cortex) and LP (lateral parietal) areas; task-positive regions include the SMA (supplemental motor area), FEF (frontal eye fields), iPL (inferior parietal lobule), DLPFC (dorsolateral prefrontal cortex), MT (middle temporal gyrus) and ins (insula/frontal operculum) (6). Task-negative clusters are denoted with circles, and task-positive areas with inverted triangles. Shading of the cortex indicates the ratio of positive to negative correlation in infra-slow, spontaneous gamma band power.