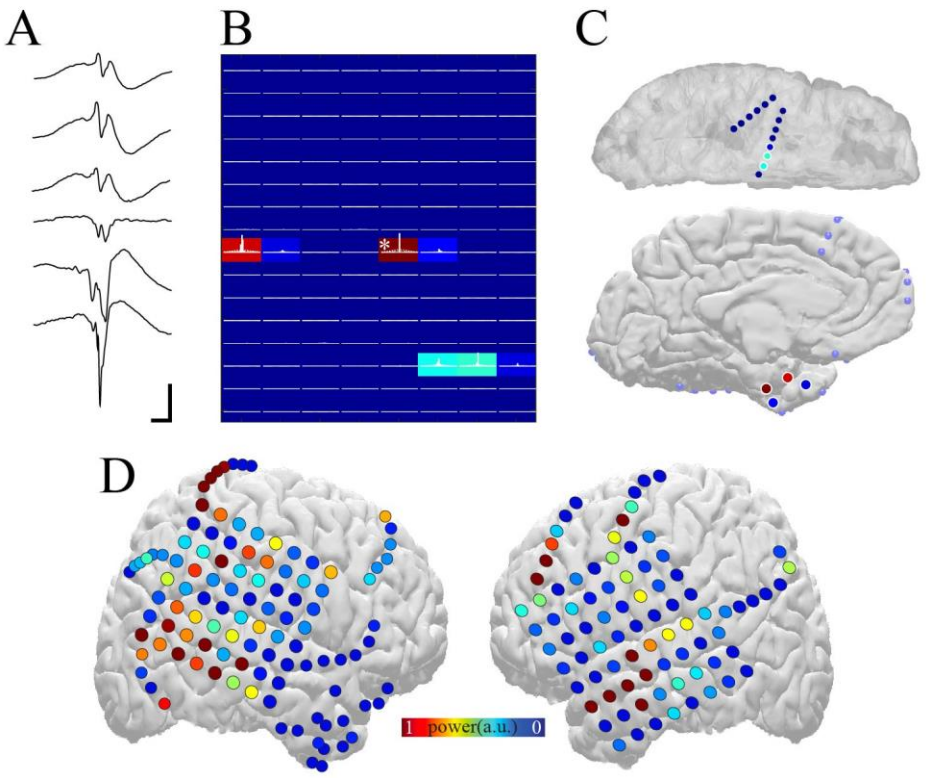
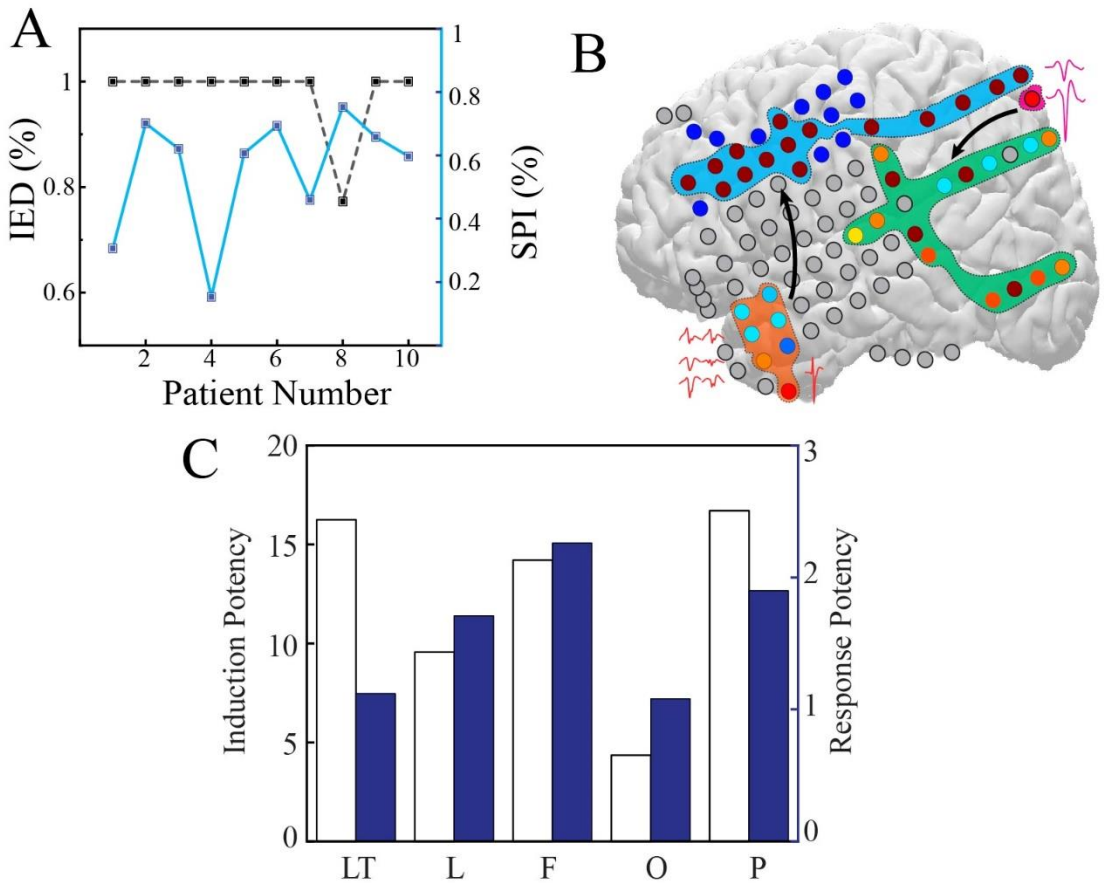
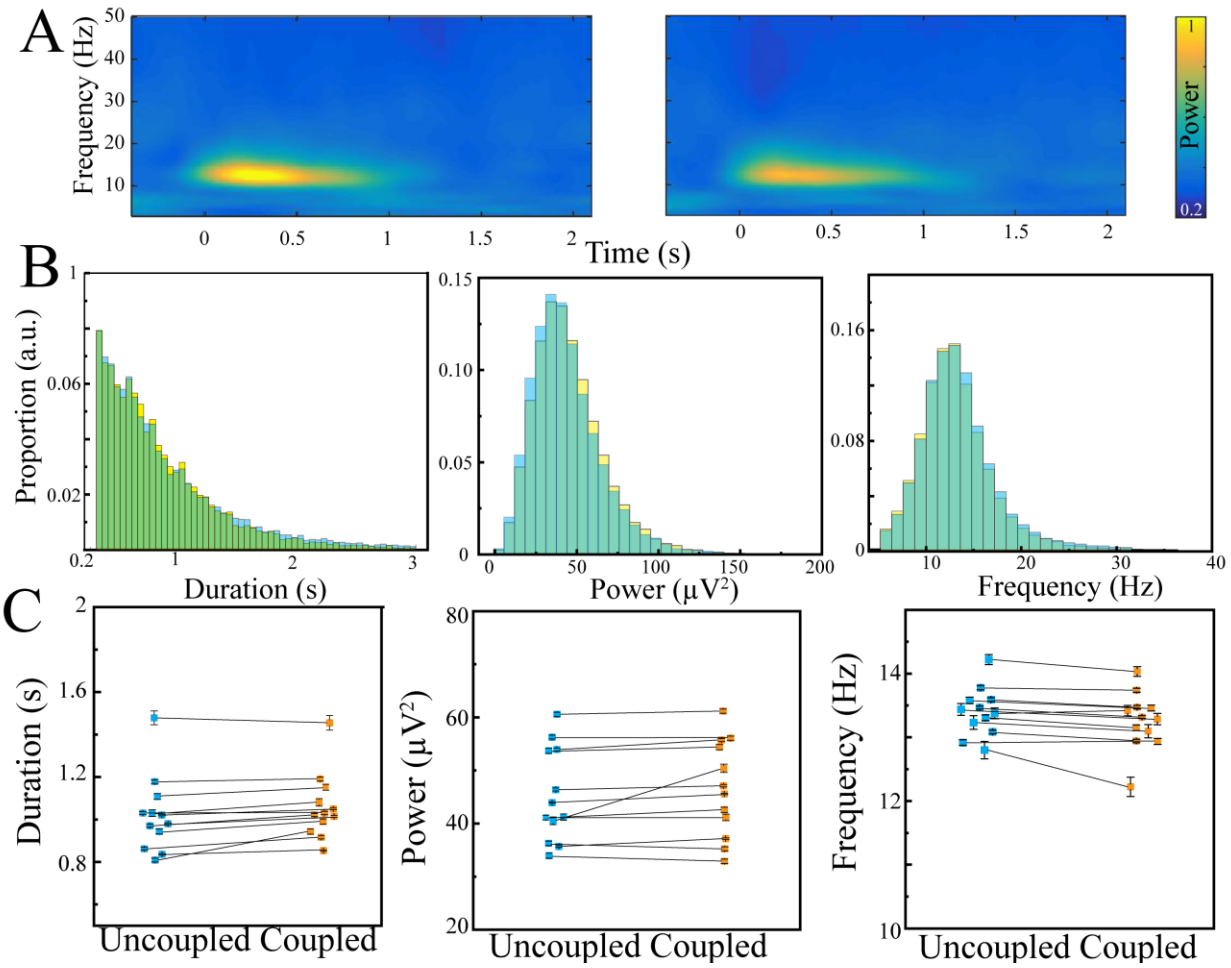
Supplementary Figures:



Supplementary Figure 1: IED waveforms and networks.
(**A**) Sample IED across electrodes (scale bar 50 ms, 500 μV).
(**B**) Cross-correlograms of IED occurrence across all electrodes. Background color represents strength of zero bin correlation. Reference IED electrode marked by white star.
(**C**) Location of correlated IED electrodes projected onto image of pial surface, lateral view (bottom) and inferior view (top).
(**D**) Anatomically different patterns of IED-spindle coupling in two patients. Warmer colors signify higher correlation, separating the electrodes into IED-coupled and IED-uncoupled zones.



Supplementary Figure 2: Patient-specific variation in IED-spindle coupling.
(**A**) Proportion of electrodes with detected IEDs that are capable of generating coupled spindles (black) and proportion of electrodes that display coupled spindles (blue) across patients.
(**B**) Separate IED foci are capable of producing anatomically different patterns of spindle coupling within the same patient. Colors within green and blue backgrounds represent amount of significant IED-spindle correlation per electrode. Colors within pink and orange backgrounds represent strength of IED correlation and IED waveforms are plotted adjacent to each IED focus. Black arrows represent IED-spindle coupling. Warmer colors signify higher correlation.
(**C**) Potency of electrodes located in each lobe to induce spindles (white) or respond with spindles (blue) normalized by number of IED and spindle expressing electrodes respectively.

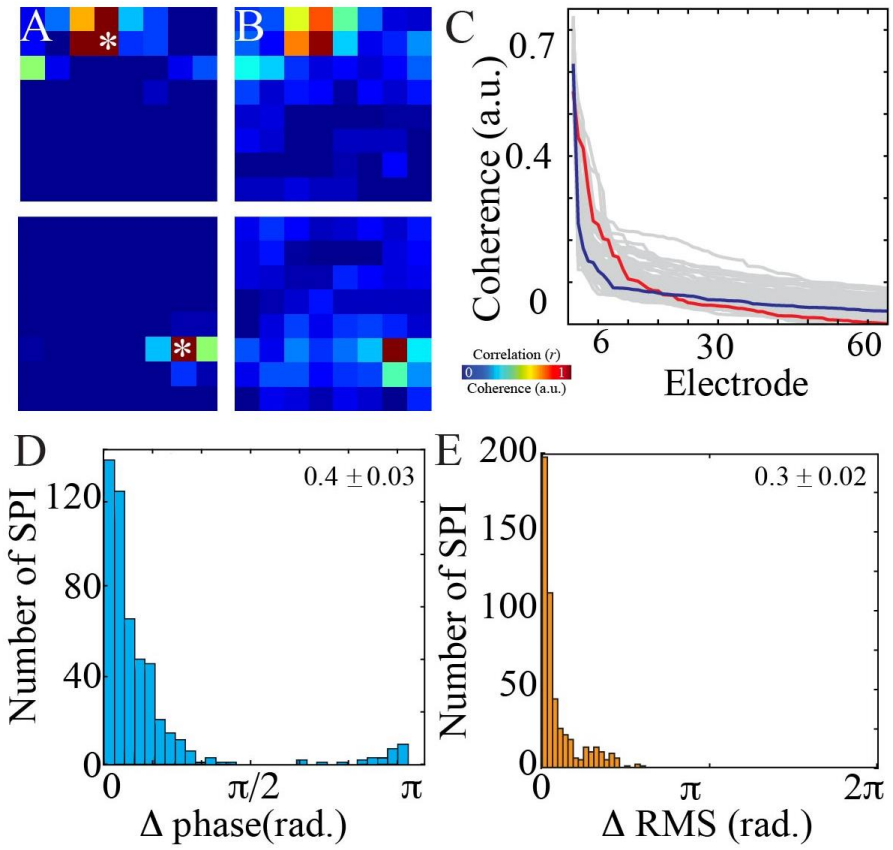


Supplementary Figure 3: Coupled and uncoupled spindles share similar basic oscillatory properties.

(**A**) Trigger-averaged spectrograms of coupled (left) and uncoupled (right) spindles from the same electrode.

(**B**) Distribution of oscillation duration (left), power (middle), and frequency (right) for uncoupled (blue) and coupled (yellow) spindles across patients (n = 36,786 coupled and 35,340 uncoupled spindles from n = 10 patients); overlap between distributions is in green.

(**C**) Relationship between average duration (left), power (middle), and frequency (right) for uncoupled (blue) and coupled (orange) spindles across all patients (bars represent s.e.m.).



Supplementary Figure 4: Spindle correlation and coherence result in similar measures of spatial extent.

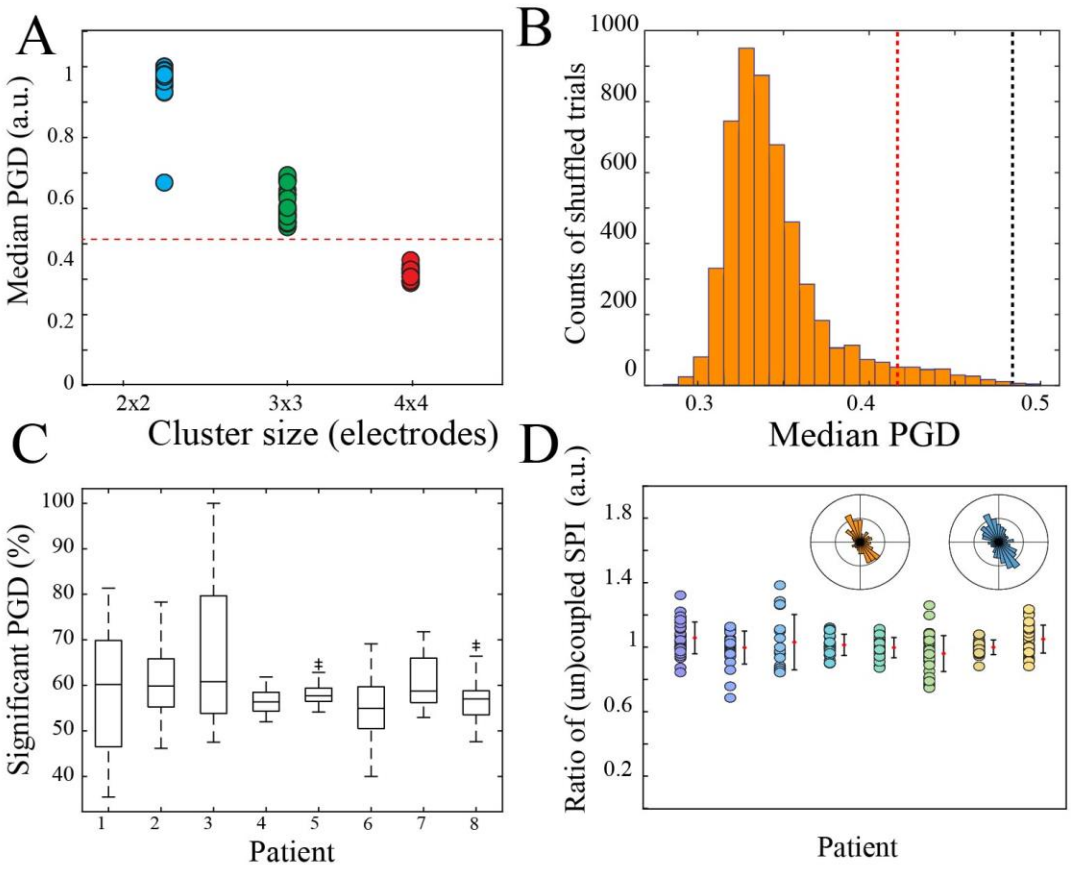
(**A**) Spindle-spindle cross-correlation values plotted as a color map across a subdural grid for a spatially extensive electrode (upper) and a spatially restricted electrode (lower). Colors represent normalized values of cross-correlation zero bin.

(**B**) Spindle coherence values obtained for same electrodes as in A). Colors represent strength of coherence. Reference electrodes marked with a white star.

(**C**) Spindle coherence for all electrodes on a subdural grid, ranked from highest to lowest coherence (gray). Red line is electrode from upper panels of A) and B); blue line is electrode from lower panels of A) and B).

(**D**) Instantaneous phases of spindle start time are highly similar when computed using time or frequency domain analysis (histogram of instantaneous phase differences calculated for sample channel; n = 500, mean = 0.408 ± 0.0287 rad).

(**E**) Spatial phase gradients are minimally different when computed with start time of spindles extracted by time or frequency domain analysis (histogram of spatial phase gradient differences calculated for sample cluster ; n = 500, mean = 0.294 ± 0.0165 rad).



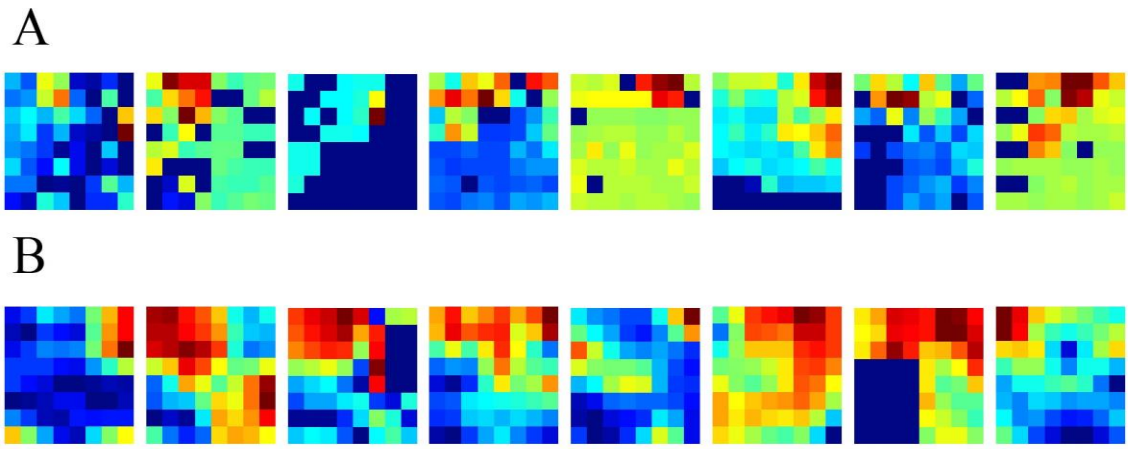
Supplementary Figure 5: Calculation and characterization of PGD.

(**A**) Median PGD values computed across all trials for electrode clusters of various sizes (2 × 2, 3 × 3, 4 × 4). Red line indicates the PGD threshold calculated for this grid based on 3 × 3 electrode cluster size.

(**B**) Sample shuffled distribution of median PGD values from a cluster of 3 × 3 electrodes; phase values were shuffled 500 times for each spindle event. Red line indicates the 95th percentile of the distribution. Black line indicates the unshuffled median PGD values across trials for this cluster.

(**C**) Box plot showing the percentage of significant PGD values (PGD > shuffling-based significance threshold) across patients. Box represents 25th, median, and 75th percentile; whiskers show range.

(**D**) Percentage of significant PGD values is unchanged between spindles that are coupled vs. uncoupled to IEDs within 1 second across patients. Inset shows sample polar plots of propagation direction(s) for coupled (left) and uncoupled (right) spindles.



Supplementary Figure 6: Maximal spindle spatial extent and propagation demonstrate anatomical co-localization.
Color maps demonstrating variation of spindle spatial extent (top) and propensity for directional travel (bottom) for each patient.

Patient	Age at iEEG (years)	Gender	Clinical seizure onset zone	Number and type of electrodes for analysis
1	22	M	Temporo-occipital	126 Subdural grid 8 strips 4 depths
2	29	M	Temporo-occipital	126 2 overlapped subdural grids 8 strips 4 depths
3	54	F	Inferior mesial frontal	126 Subdural grid 8 strips 2 depths
4	25	M	Superior parietal	122 2 overlapped subdural grids 9 strips 5 depths
5	50	M	Anterior/basal mesial temporal	126 Subdural grid 7 strips 5 depths
6	27	M	Lateral temporal	126 Subdural grid 11 strips 2 depths
7	53	F	Posterior temporal/inferior parietal	110 Subdural grid 5 strips 4 depths
8	56	F	Mesial temporal	126 Subdural grid 9 strips 4 depths
9	35	F	Mesial temporal/insula	126 Subdural grid 9 strips 5 depths
10	35	F	Anterior mesial temporal	126 Subdural grid 11 strips 2 depths

Supplementary Table 1: Demographic characterization of epilepsy patients and electrode coverage.

Lobe	Individual ordered regions
Lateral temporal	Inferior temporal gyrus Superior temporal gyrus Middle temporal gyrus Temporal pole
Limbic	Insular cortex Cingulate cortex Entorhinal cortex Parahippocampal cortex Hippocampus Amygdala
Frontal	Frontal polar* Middle frontal Superior frontal Orbitofrontal* Pars (triangularis, opercularis) Precentral gyrus
Occipital	Cuneus Lateral occipital* Fusiform gyrus Lingual gyrus
Parietal	Postcentral Superior parietal lobule Inferior parietal lobule* Precuneus* Supramarginal Paracentral lobule*

Supplementary Table 2: List of parcellated ordered brain regions. *denotes no IEDs present in these regions across patients.