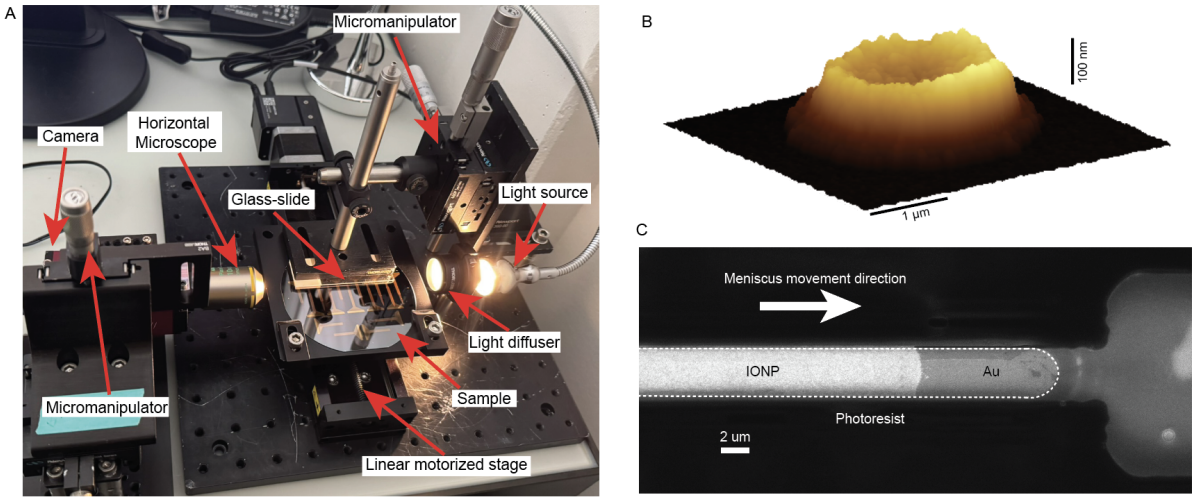
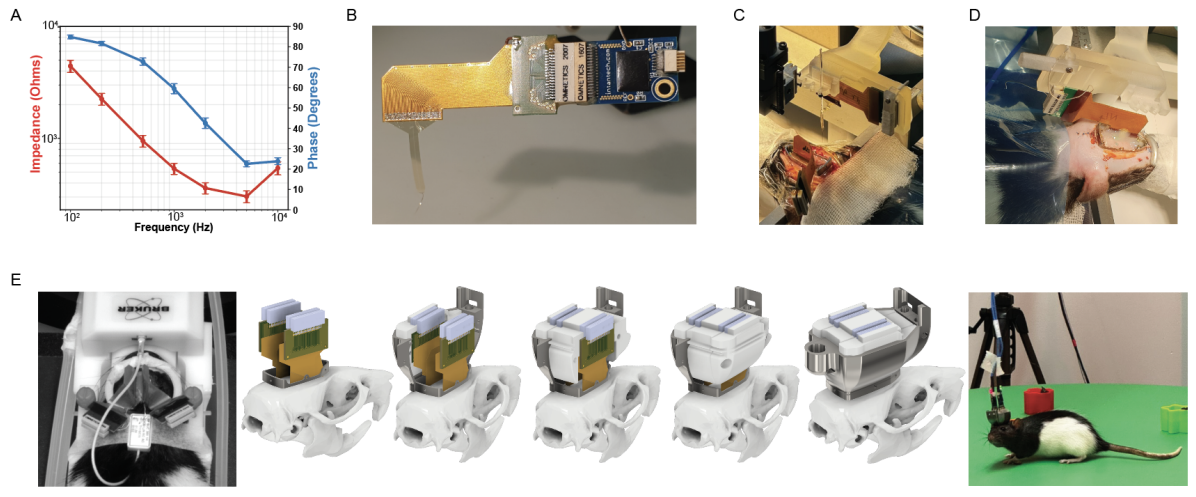
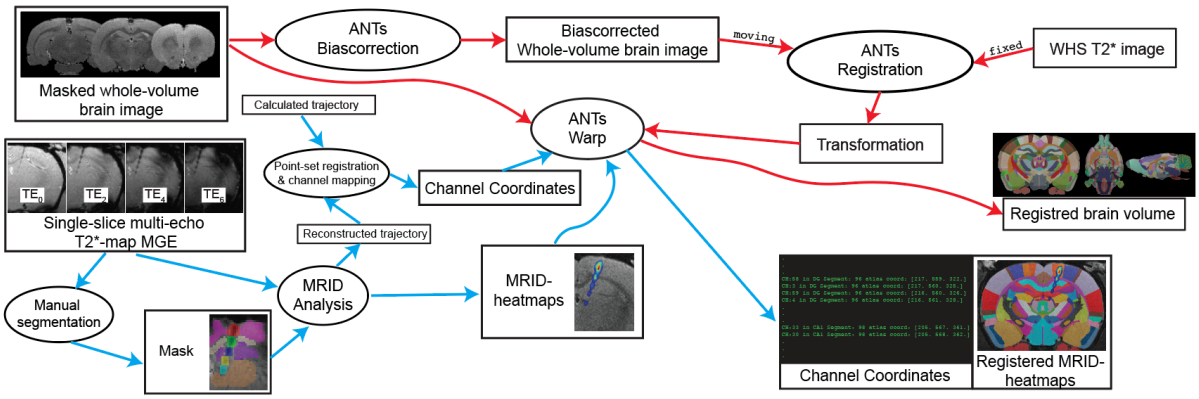
Supplementary



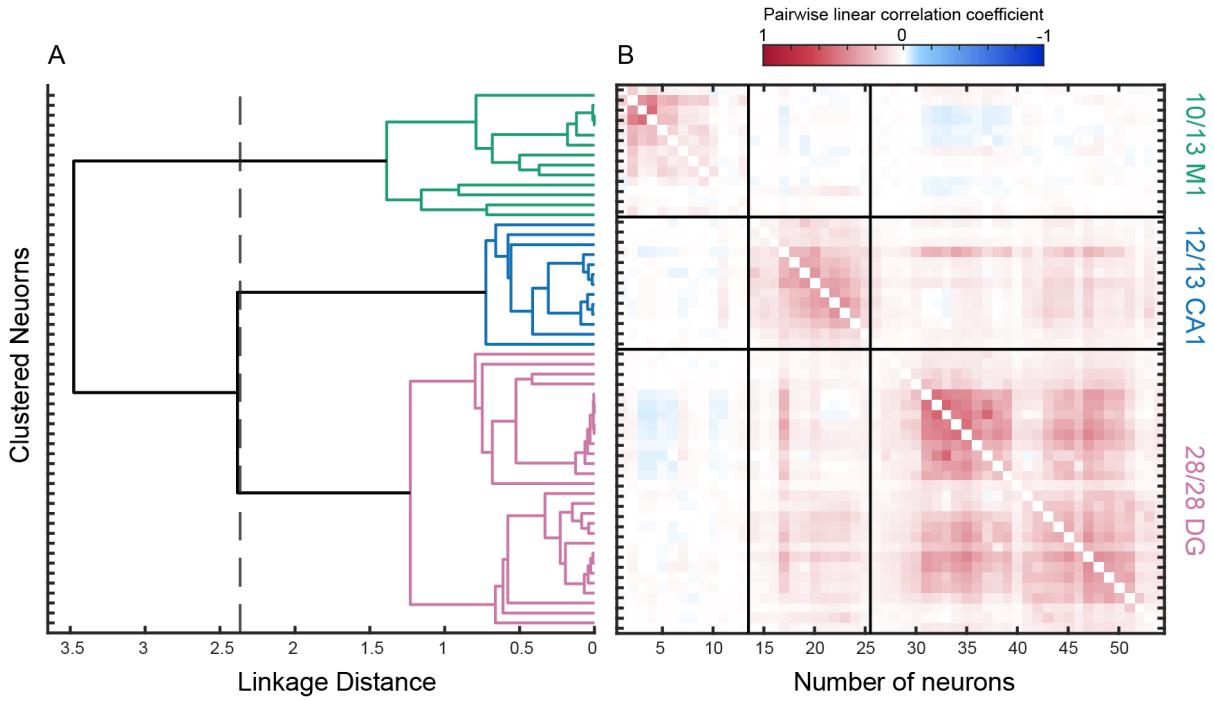
Suppl. Fig. 1. Custom-setup for IONP coating and coating characterization. **A.** IONP custom coating setup with a horizontal microscope on the side for contact angle measurement. **B.** 3D Atomic force microscopy image of a circular IONP assembly shows the crater-like shape. **C.** Dot-matrix CCA coating was tested with strip-shaped traps instead of dots. IONPs were coated homogeneously along the strip until the trailing edge. There is a gap (~15 µm) towards the trailing edge.



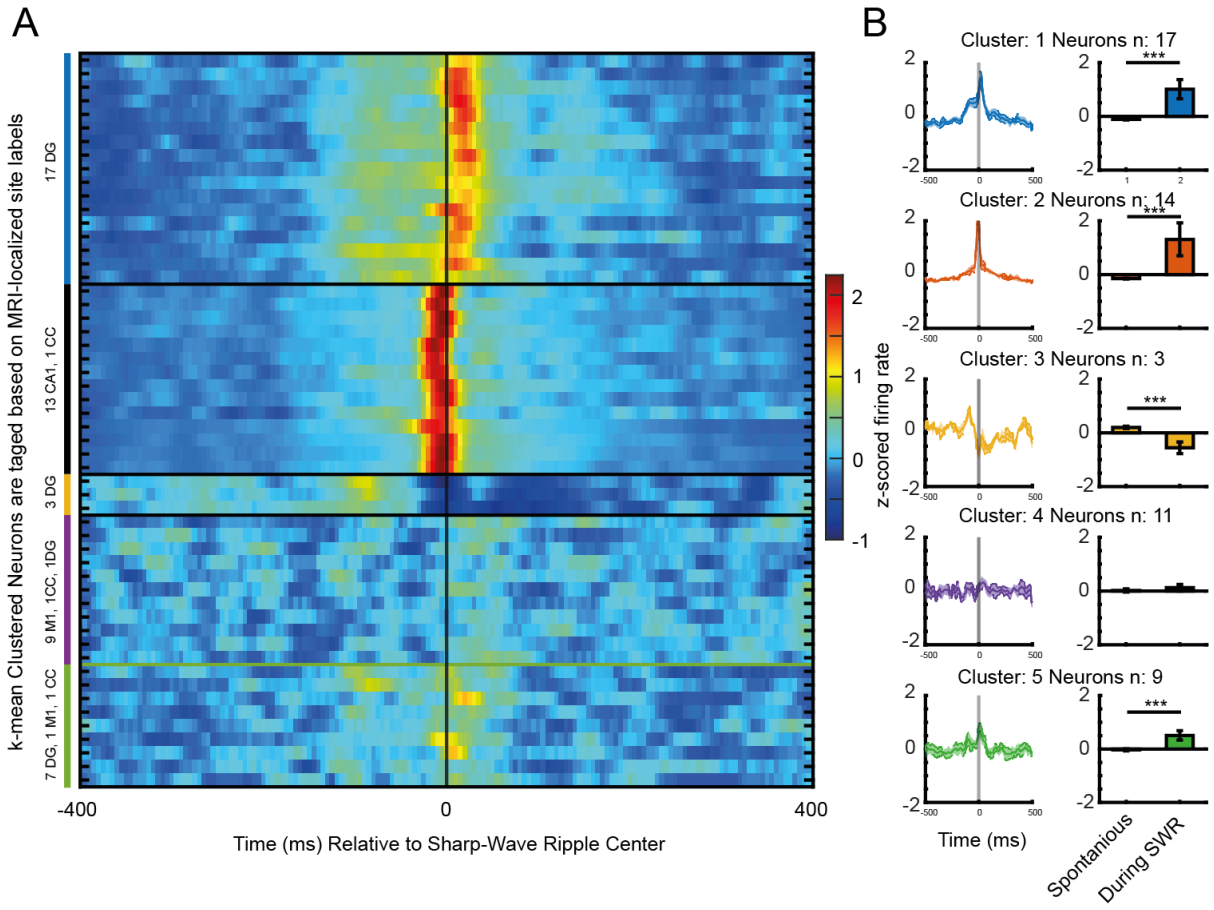
Suppl. Fig. 2. Electrode in-vitro characterization and chronic MRI-compatible recording setup. **A.** Electrode impedances measured in vitro in Ringer's solution (at 1kHz). **B.** A sample electrode device assembled with connector PCBs and recording headstage. **C.** Implantation of UFTEs. **D.** During the implantation, flex-PCBs are cemented onto skull with their lateral anchors. **E.** Modular 3D printed housing with titaniumHelmet for chronic MRI scanning and freely-moving awake recordings.



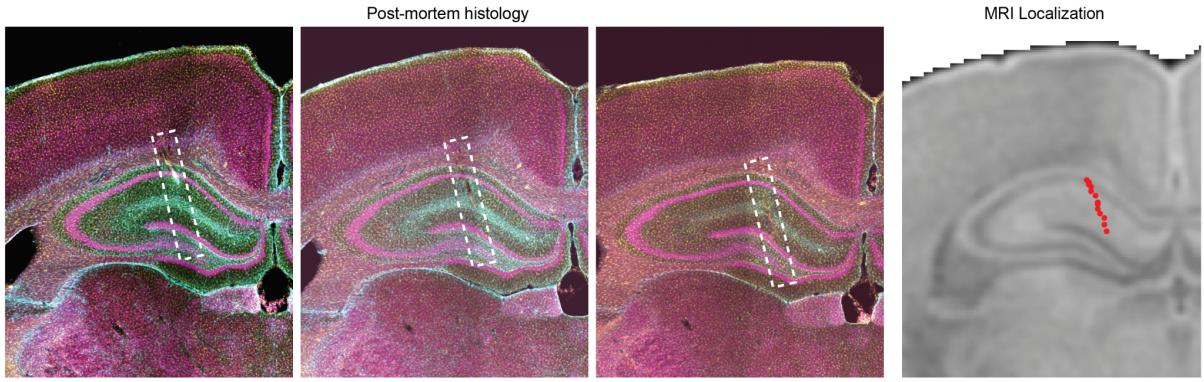
Suppl. Fig. 3. MRI image registration and MRID-tag image analysis pipeline explained. MRI image preprocessing and WHS reference atlas registration pipeline is explained with flow of red arrows. Image processing pipeline for analyzing the patterns induced by MRID-tags and electrode channel localization is explained with flow of blue arrows.



Suppl. Fig. 4.1. Hierarchical clustering of pairwise correlation of neuronal activity. A. Dendrogram of clustered neurons based on pairwise correlation of z-scored firing activity (bin size: 25ms). Hierarchical clustering was performed using the Ward linkage method, grouping neurons according to their pairwise correlation patterns. The x-axis represents the linkage distance, while the y-axis denotes individual neurons sorted by clustering results *Note: This does not represent the dorsoventral (D-V) axis anymore, as in Figure 4F*. The vertical dashed line indicates the threshold determined by the elbow method, which optimally defines the number of clusters. **B.** Heatmap of the correlation matrix displaying pairwise correlations between neuronal firing rates. Warmer colors indicate higher correlations, while cooler colors reflect weaker or negative correlations. Clusters identified in (A) represent functionally similar neuronal groups, delineating anatomical structure. The numbers on the right side of the pairwise correlation matrix indicate how many matched neurons were found within grouped neurons, based on hierarchical clustering of pairwise correlations using MRI localization labeling.



Suppl. Fig. 4.2. PCA based – K-means clustering of population activity during SWR. A. We identified patterns or clusters of similar neuronal activity in response to SWRs (*n* = 463). After identifying functional clusters, neurons were labeled with anatomical structures based on MRI tagging of channels. The Y-axis represents MRI-localized labels for neurons, while the X-axis shows the time interval from -400 ms to +400 ms around SWRs. **B.** In the first column, we present the average z-scored firing rate of the functionally clustered neuronal population around SWRs. In the second column, a t-test was performed to compare the average z-scored firing rate during the SWR (50ms around) with that of an equivalent time window before the SWR. *p<0.01, **p<0.001, ***p<0.0001



Suppl. Fig. 5. Post-mortem histology validates MRID-based electrode localization. Post-mortem histology slices with electrolytic lesions reveal the trajectory of the implantation (**white dashed-line rectangles)**. Localized and registered electrode channels on the DWI

WHS image (**red circles)** shows the corresponding electrode channel locations based-on MRID analysis.