Contribution ID: **17** Type: **Talk**

HippUnfold v2: improved robustness, detail, and minimized distortion

Tuesday 28 October 2025 15:30 (15 minutes)

The hippocampus is an extension of the neocortex with highly convoluted folding that varies between individuals. This variability presents a significant shape-fitting challenge that must be addressed for precise inter-individual alignment, parcellation, and detailed mapping of hippocampal structure and function. We previously developed HippUnfold, which uses deep neural networks to segment hippocampal tissue types (e.g., grey matter, its high-myelin laminae, and the hippocampal sulcus) and computationally unfold them into a topologically consistent coordinate space (DeKraker et al., 2022, 2023, 2024; Karat et al., 2023). Multiple pretrained models are available for different imaging modalities (T1w, T2w MRI) and populations (healthy adults, Alzheimer's disease, neonates), and networks can be customized for specific use cases.

However, segmentation errors can propagate into the unfolding stage, producing distortions or failures. Here, we present HippUnfold v2, a major refactoring of the codebase that substantially improves robustness to imperfect segmentations while preserving subject-specific detail. This is achieved without the use of spatial regularization, smoothing, or interpolation that reduce fine anatomical features. In addition, other key updates include:
1. A modified unfolding algorithm that minimizes distortion between
folded and unfolded spaces,
2. Standard surface tessellations redesigned for more uniform face sizes,
3. A support pipeline for generating study-specific unfolded atlases, and
4. Codebase improvements for easier installation, faster runtime, and simpler BIDS-like output structure.

These advances were evaluated on diverse 3T (n=51) and 7T (n=10) MRI datasets. v2 showed qualitatively improved surface fidelity and quantitatively higher midthickness surface identifiability (greater intra- vs. inter-subject similarity), indicating better preservation of individual shape features. Failure rates from segmentation imperfections were also reduced.

Overall, HippUnfold v2 delivers improved precision in hippocampal shape modelling, greater resilience to imperfect inputs, and a more maintainable and user-friendly pipeline—facilitating detailed and reproducible mapping of this complex brain structure.

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Session Classification: Session 2: Mapping & Atlases