

Decoding Anatomical Structure from Neural Population Activity using Self-supervised Learning

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TL; DR

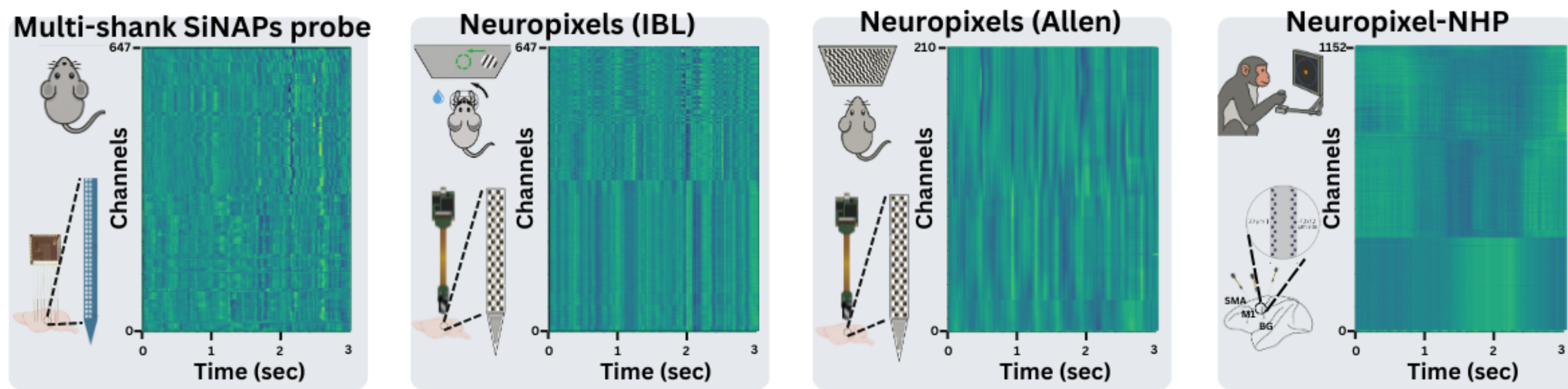
Task. In vivo localization of recording sites/channels in high density probe[1]

Approach. domain adapt a self supervised model [2] to decode anatomical identity from raw LFP signals and generalize across labs/species

Findings/Novelty. LFP encodes rich anatomical information [3]; Lfp2Vec enables zero-shot transfer to new subjects/labs; and learns generalizable embeddings across tasks by adapting a pre-trained audio model [4]

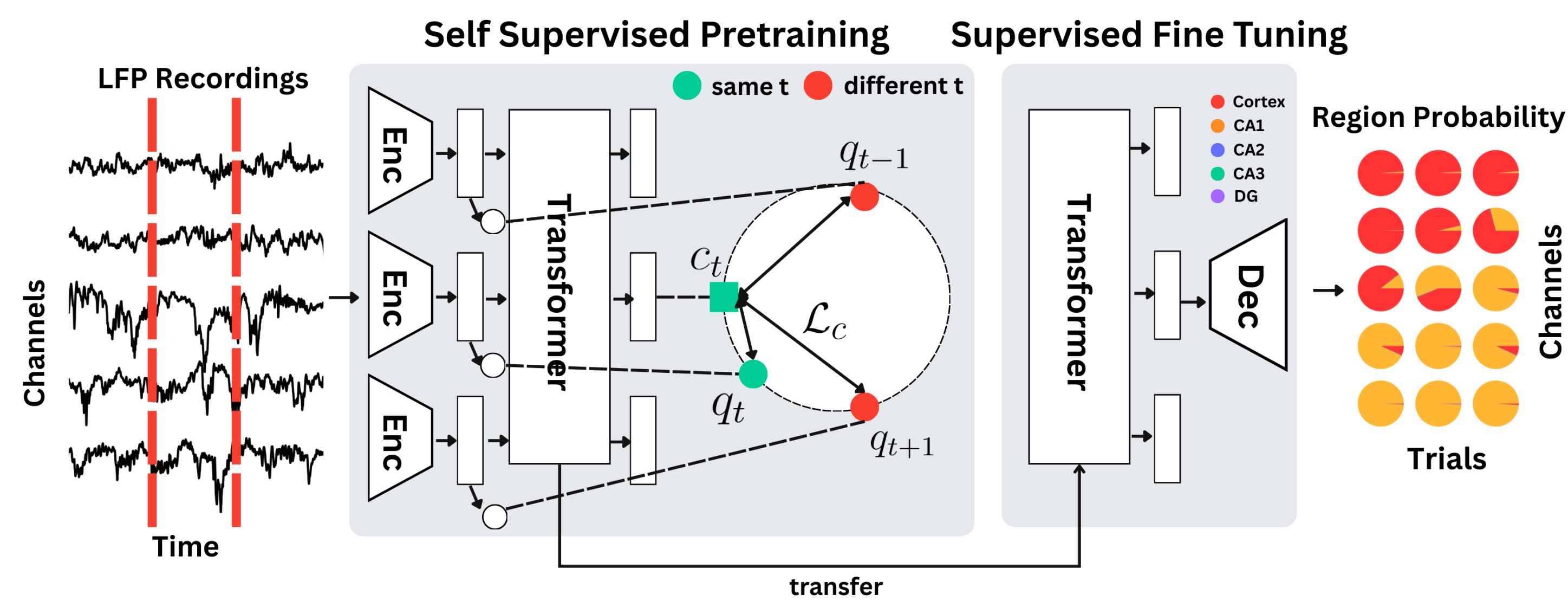
Datasets

- **SiNAPs probe:** 7 sessions, 3212 channels, 193K trials, spontaneous task
- **Neuropixels:** 14 sessions, 1360/2131 channels, 82K/213K trials, visual
- **Neuropixel-NHP:** 3 sessions, 1152 channels, 552K trials, motor task

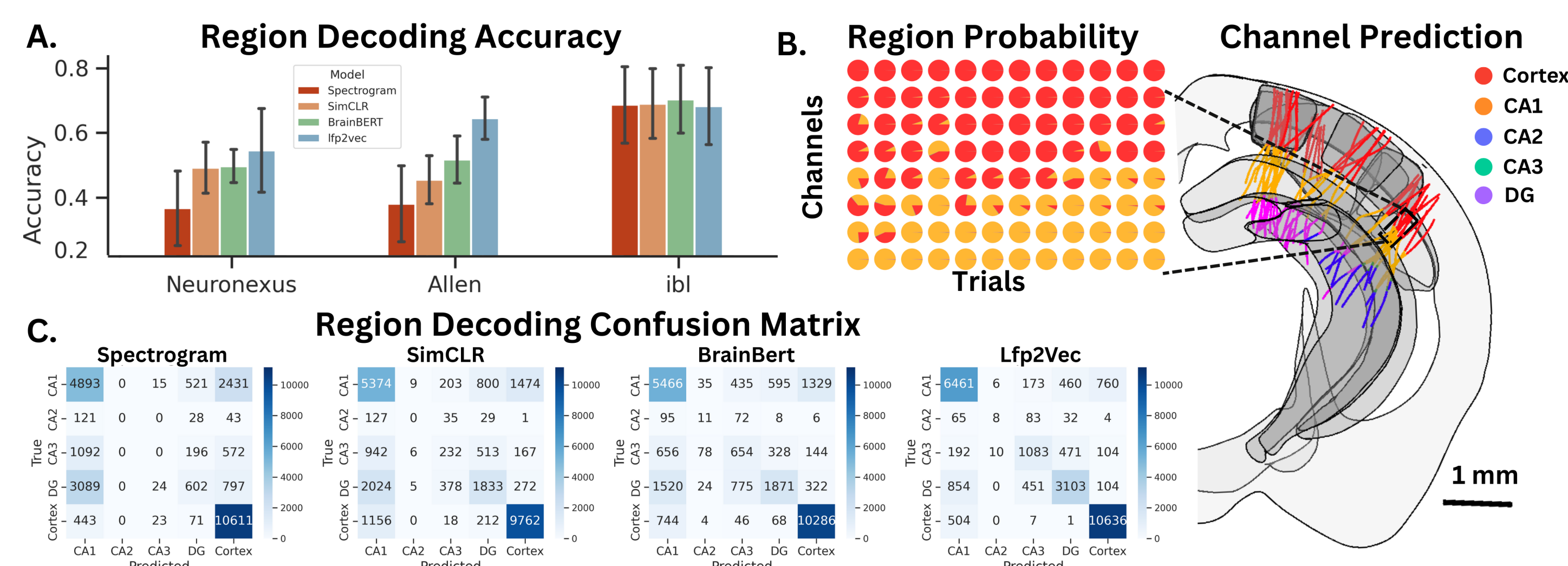


Self Supervised Learning Framework

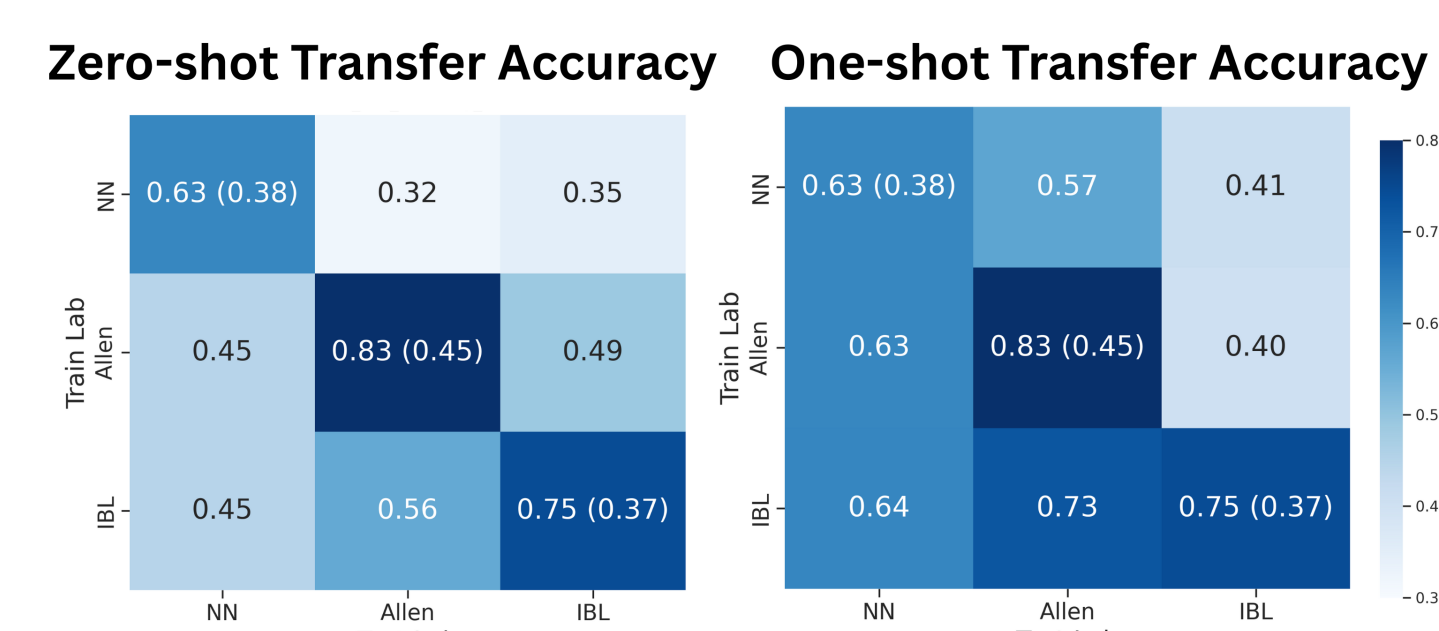
Given raw 3s LFP waveforms for each channel, predict its brain regions y



Localization across subjects/labs/species

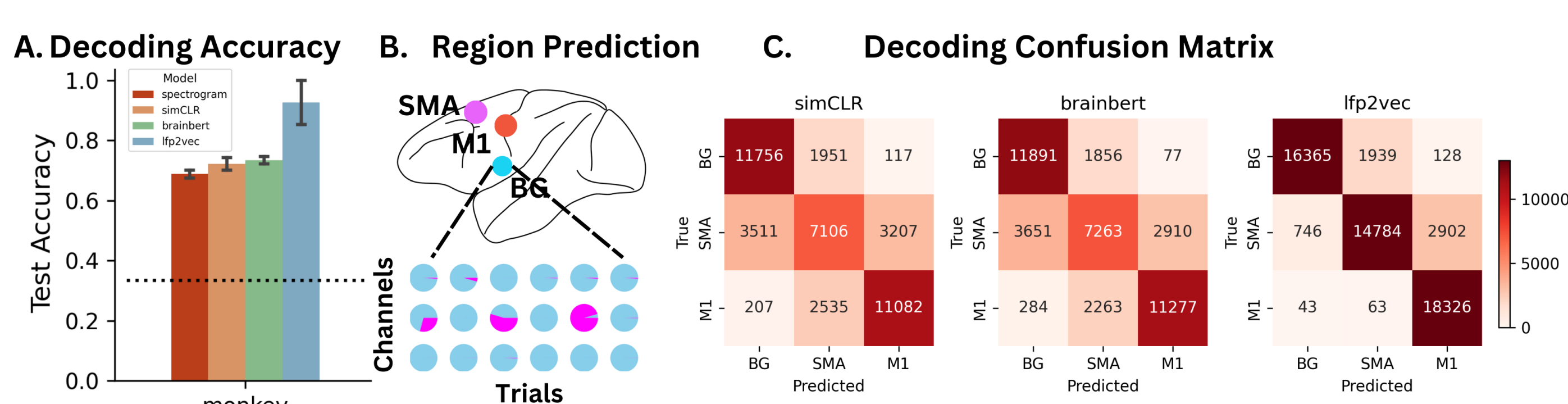


- **Across Subjects,** Lfp2Vec enables zero-shot region decoding within same lab, with channel prediction showing anatomical consistency



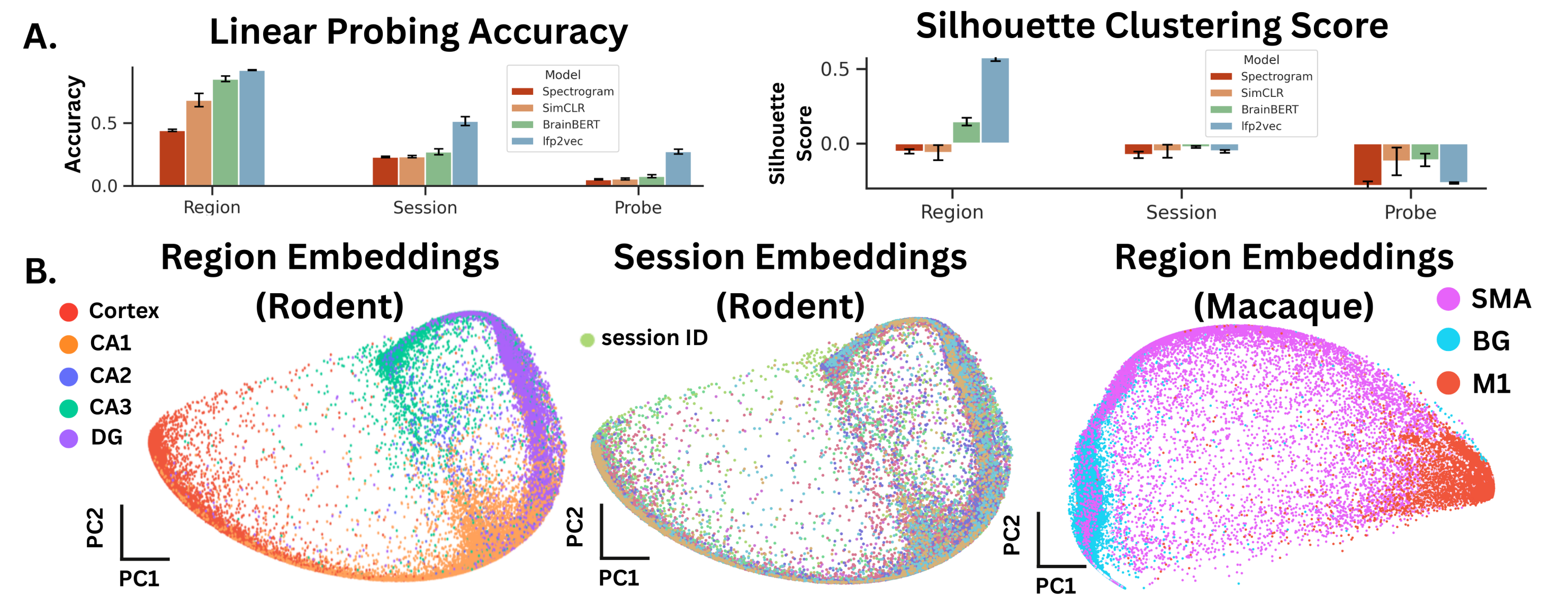
- **Across Lab,** Lfp2Vec enables zero-shot transfer with similar probe/setup (Allen/IBL)
- **One-shot enables transfer across different probe/setup (Allen/NN)**

- **Across Species,** Lfp2Vec enables zero-shot region decoding in macaque



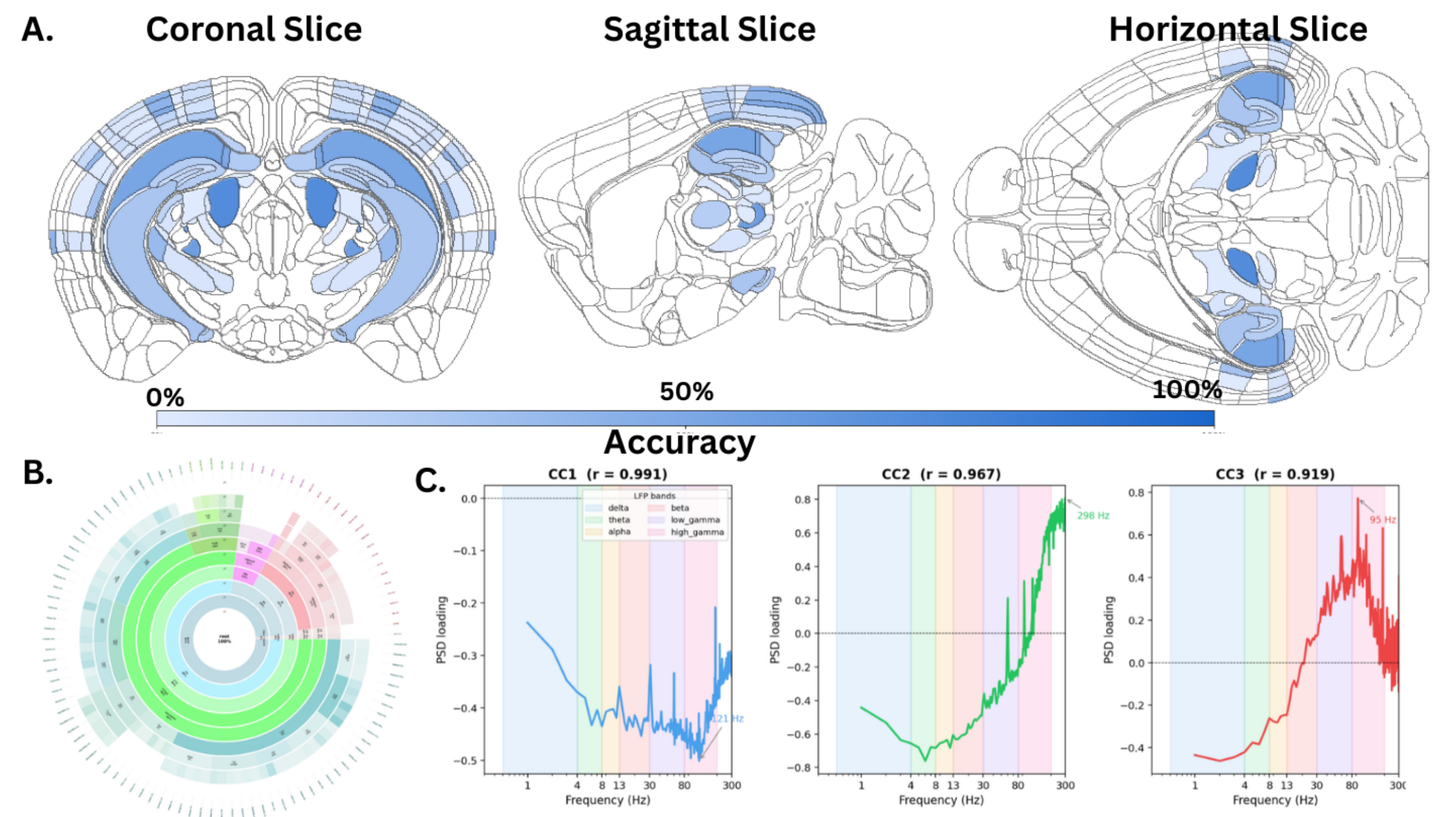
Learning region-aware embeddings

- Across species channel embeddings cluster by region in Lfp2Vec
- Linear probe accuracy, silhouette score of region/session/probe clusters show embeddings are not biased by session/probe identity



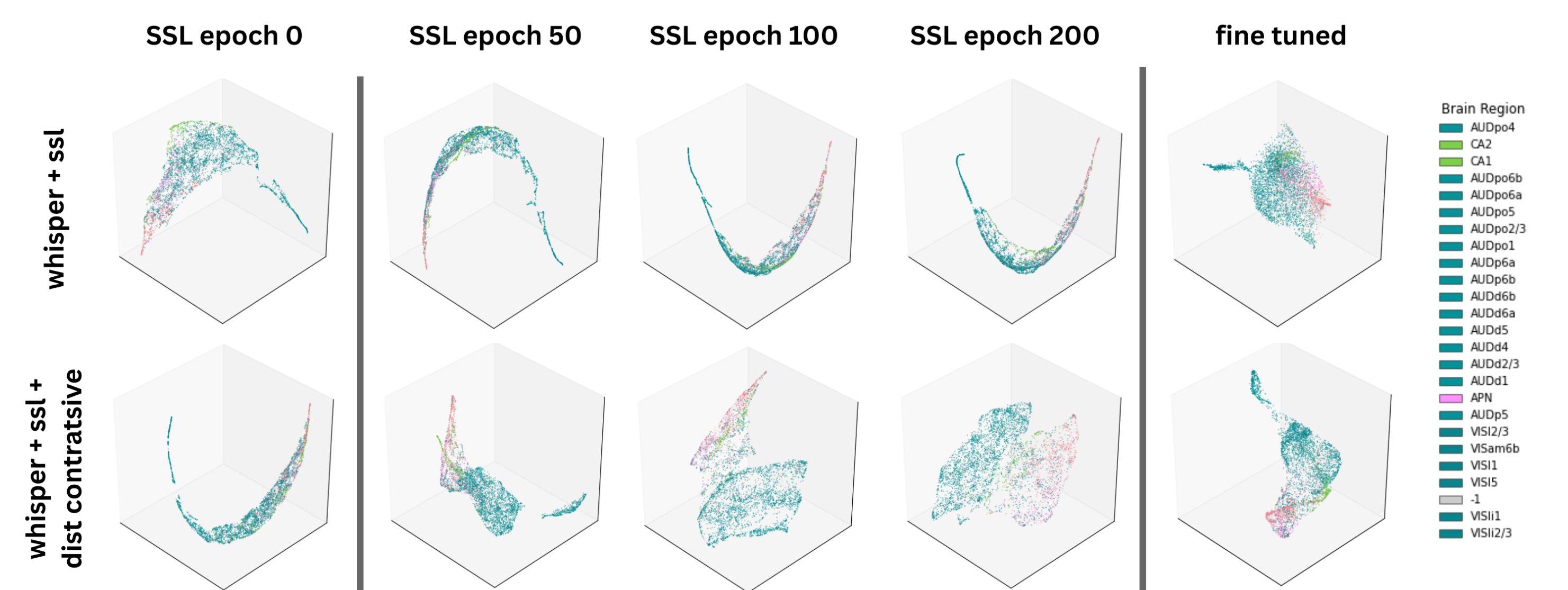
Scaling up to whole brain recordings

- LFP signal encodes brain region identity across the whole brain
- Lfp2vec embeddings encodes higher frequency features



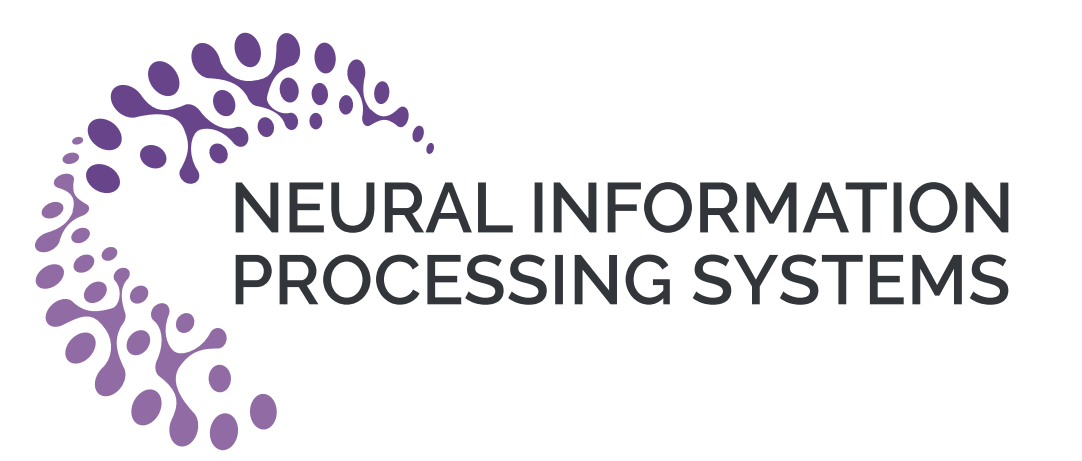
Future Direction: Expanding Models and Objectives

- Train parameter-efficient Whisper model with distance contrastive loss
- Region clusters emerge as training progresses and are more separated with contrastive objectives



References & Acknowledgements

- [1] Sunkin et al. NAR, 2013
- [2] Kostas et al. Frontiers, 2021
- [3] Tolossa et al. eLife, 2024
- [4] Baevski et al. NeurIPS, 2020



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