Neural Embeddings Rank:
Aligning 3D latent dynamics with movements

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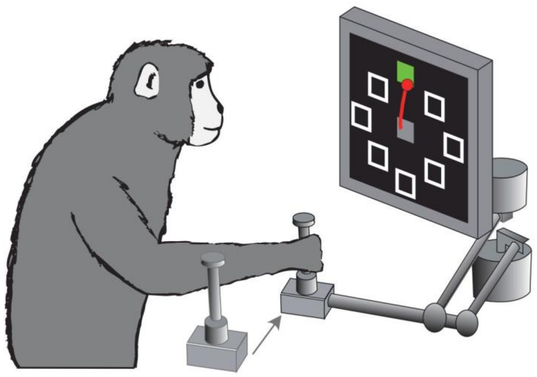
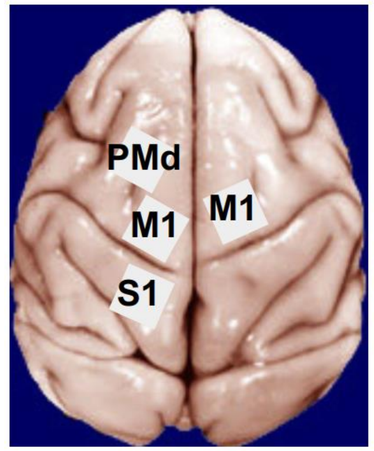
NeurIPS 2024 + NeuroAI and SSL Workshops (**Oral**)

Movements-aligned 3D latent dynamics

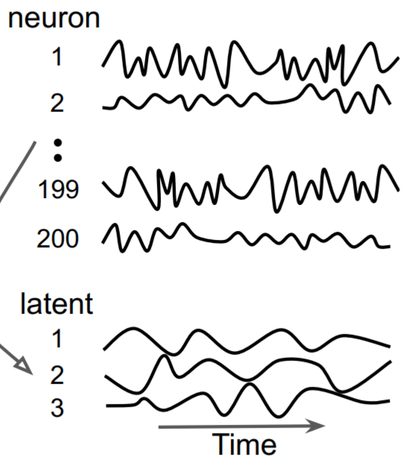


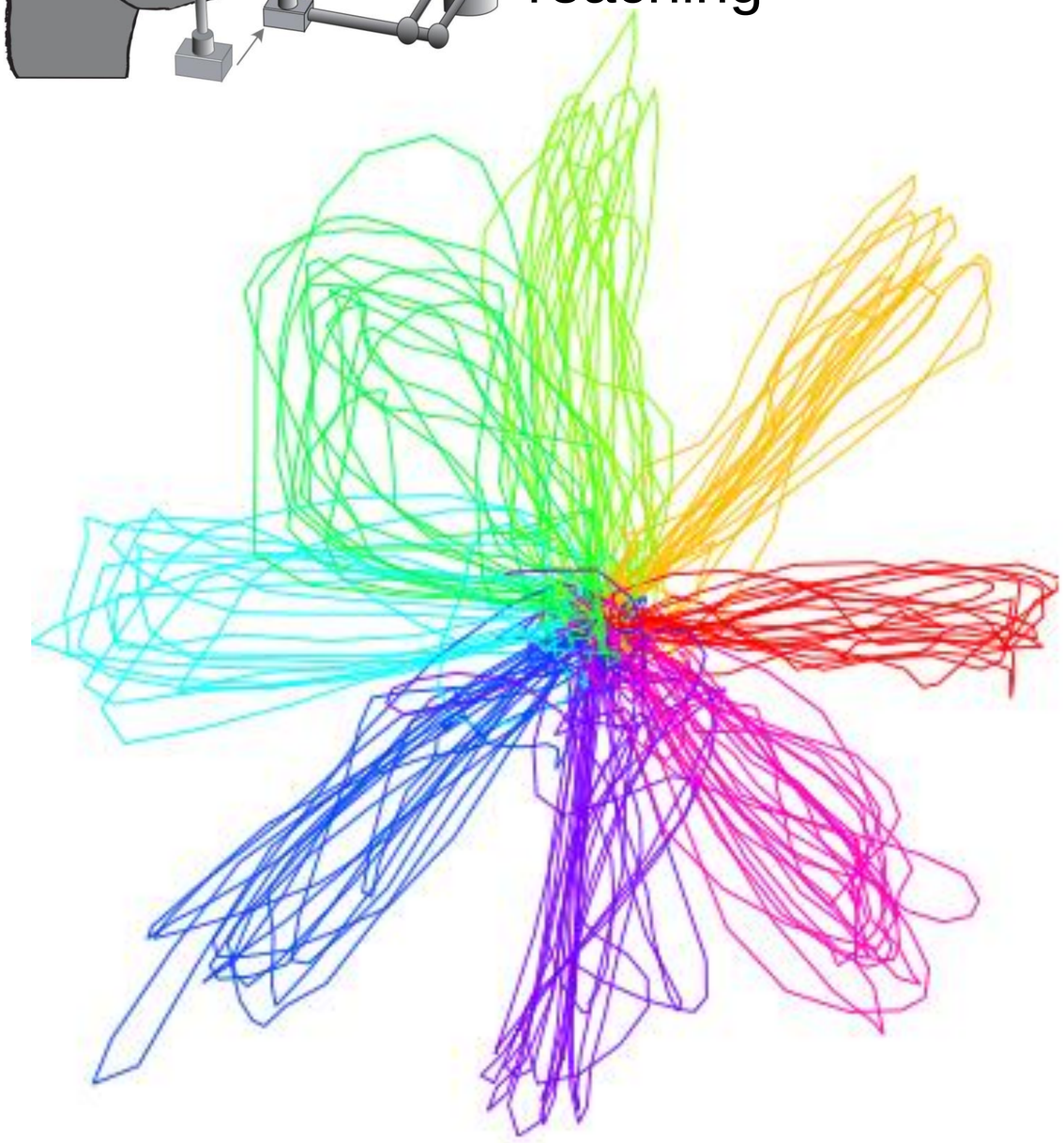
center-out

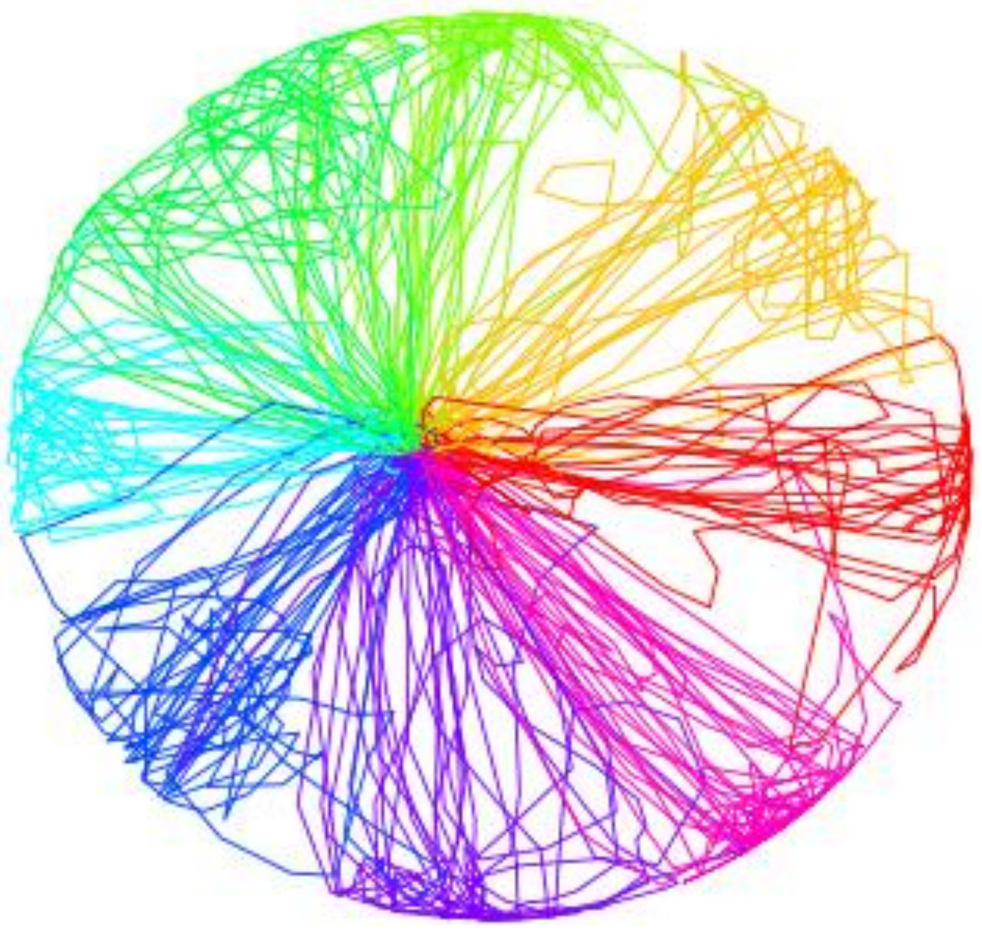
reaching



train







State-of-the-art models are generative and contrastive self-supervised learning (SSL)

pi-VAE: **P**oisson **i**dentifiable **v**ariational **a**uto-**e**ncoder

Learning identifiable and interpretable latent models of high-dimensional neural activity using pi-VAE

Ding Zhou, Xue-Xin Wei

Part of Advances in Neural Information Processing Systems 33 (NeurIPS 2020)

CEBRA: **C**onsistent **EmB**eddings of high-dimensional **R**ecordings using **A**uxiliary variables

Learnable latent embeddings for joint behavioural and neural analysis

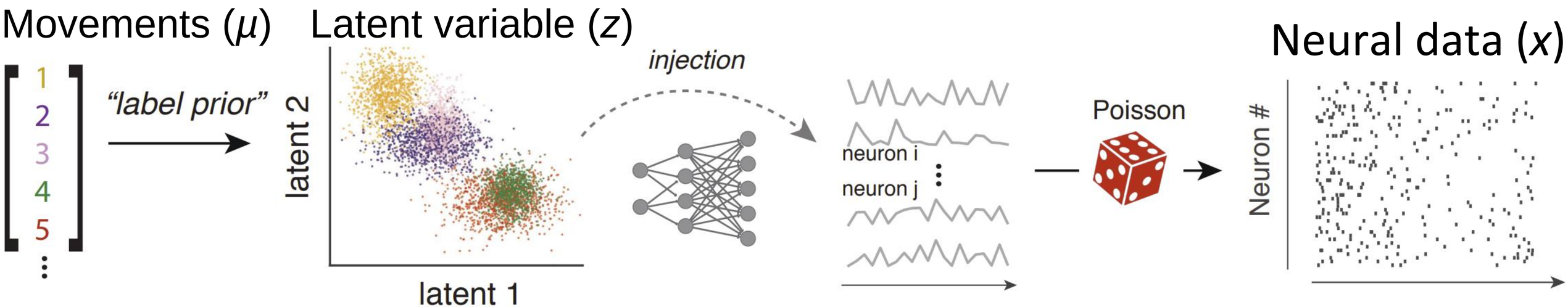
Steffen Schneider, Jin Hwa Lee & Mackenzie Weygandt Mathis

Nature **617**, 360–368 (2023) | Cite this article

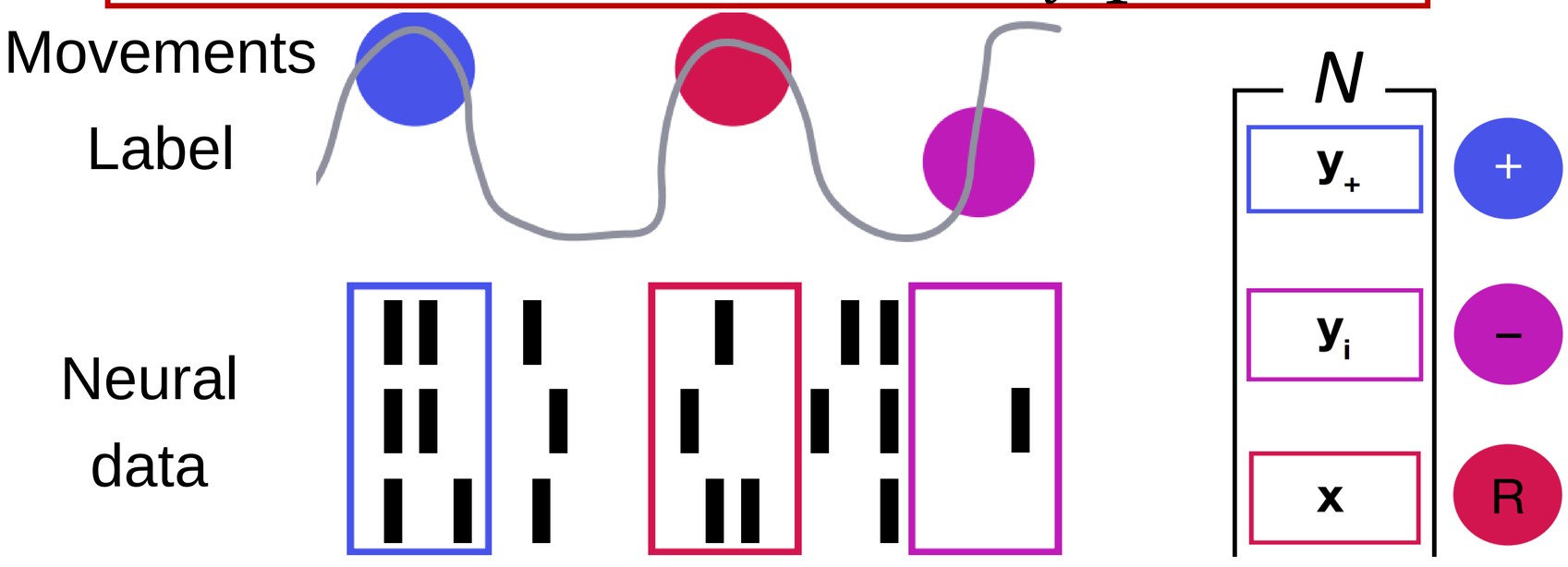
pi-VAE and CEBRA treat movements as distinct classes

$$loss = -\log p(x|z) + \mathrm{KL}(q(z|x,u) \parallel p(z|u))$$

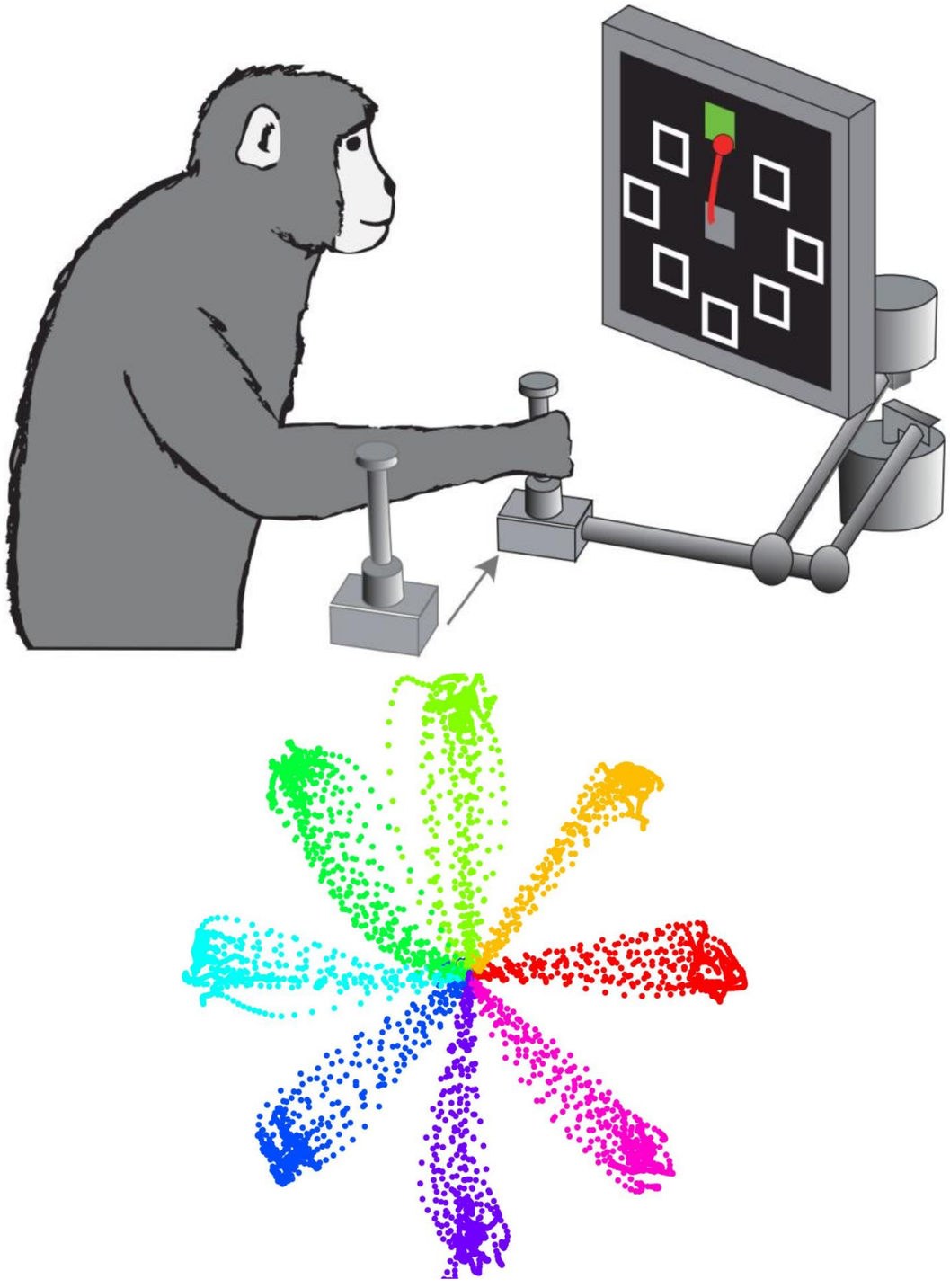
$$q(z|x,u) \propto q(z|x)p(z|u)$$

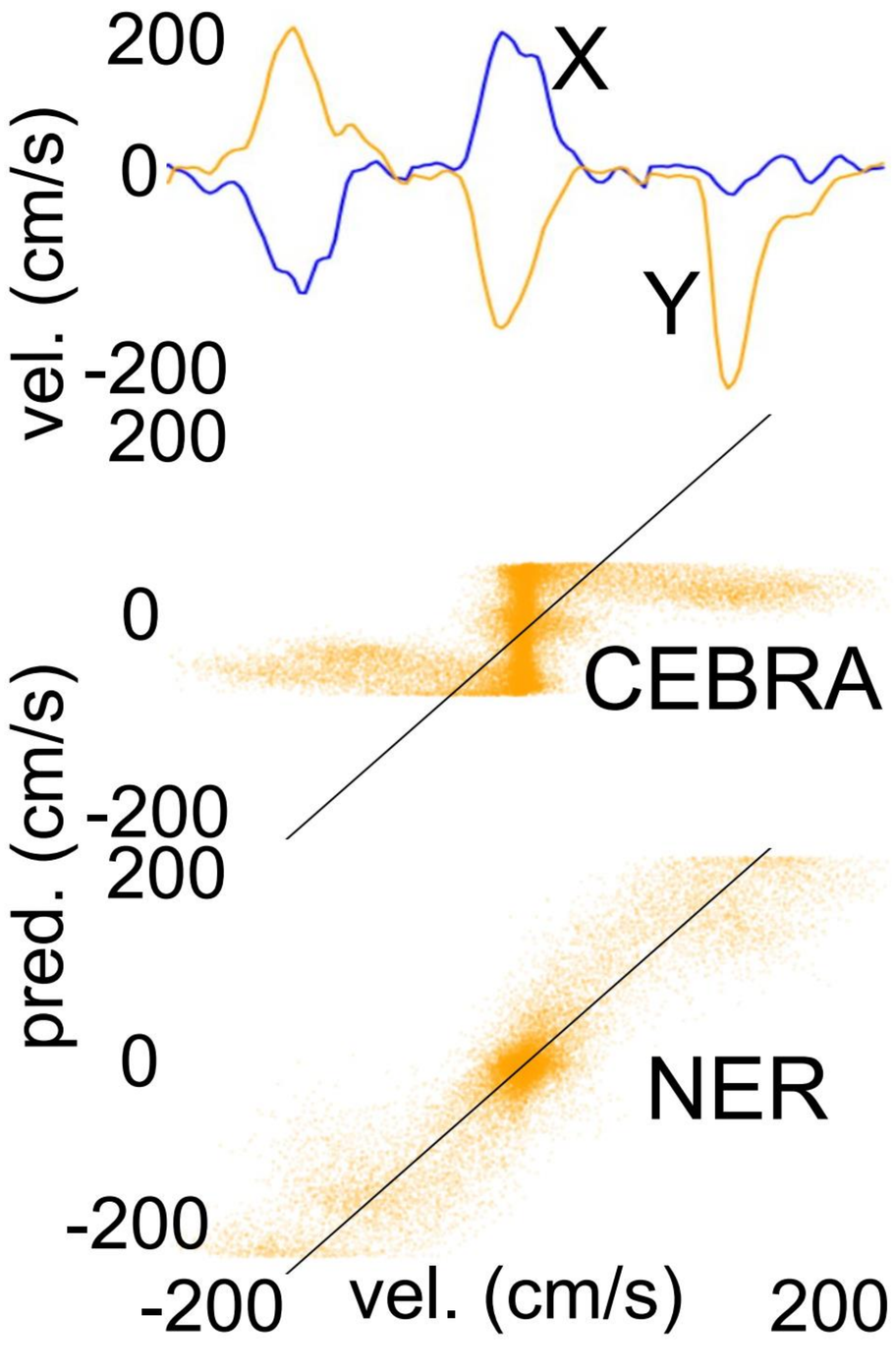


$$loss = -sim(x, y_+) + log \sum_{i=1}^{N} e^{sim(x,y_i)}$$



But movements are continuous and highly imbalanced





Loss functions of CEBRA and NER

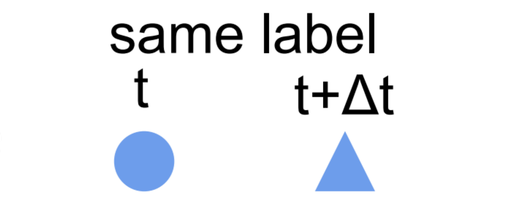
$$l_{CEBRA}^{(i)} = -log\frac{exp(sim(v_i, v_j)/\tau)}{\sum N_{n=1} exp(sim(v_i, v_n)/\tau)}$$

$$l_{NER}^{(i)} = \frac{1}{2N-1}\sum 2N_{j=1,j\neq i} - log\frac{exp(sim(v_i, v_j)/\tau)}{\sum_{v_k \in S_{i,j}} exp(sim(v_i, v_k)/\tau)}$$

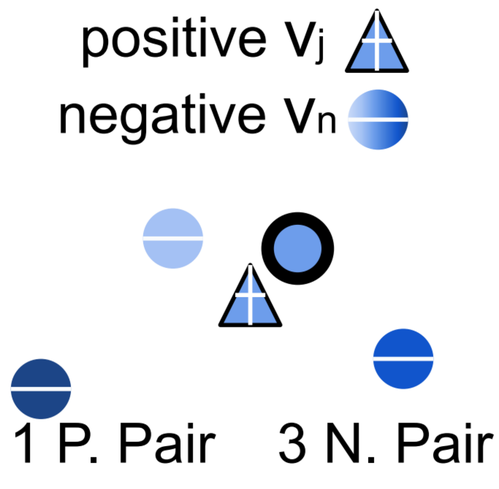
$$S_{i,j} := \{v_k \mid k \neq i, d(y_i, y_k) \geq d(y_i, y_j)\}$$

positive v_j negative v_k

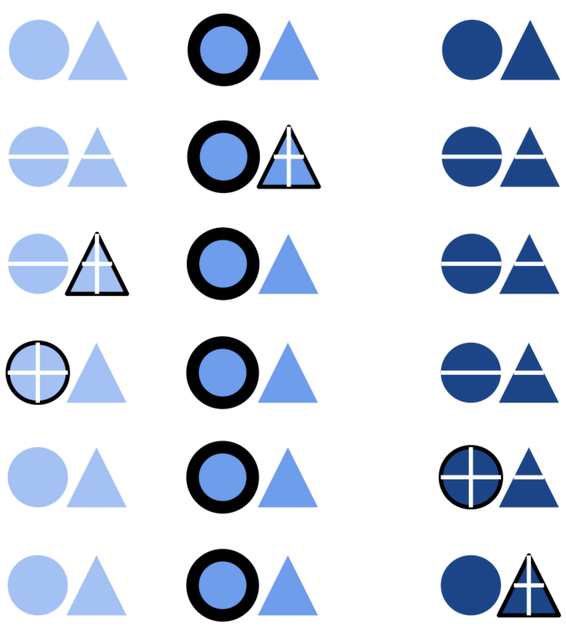
Intuitively, for an anchor V_i, any other embedding V_j in the batch is positively contrasted with it, enforcing the similarity between V_i and V_j to be greater than that between V_i and any other embedding V_k in the batch if the label distance between y_i and y_k is larger than that of y_i and y_j.



CEBRA



NER



label dist. w.r.t. anchor	
rank emb. w.r.t. label	
1 P. Pair	4 N. Pair
1 P. Pair	3 N. Pair
1 P. Pair	2 N. Pair
1 P. Pair	1 N. Pair
1 P. Pair	0 N. Pair

M1 in Left Hemisphere

M1 in Right Hemisphere

a

2016-09-29

2016-10-06

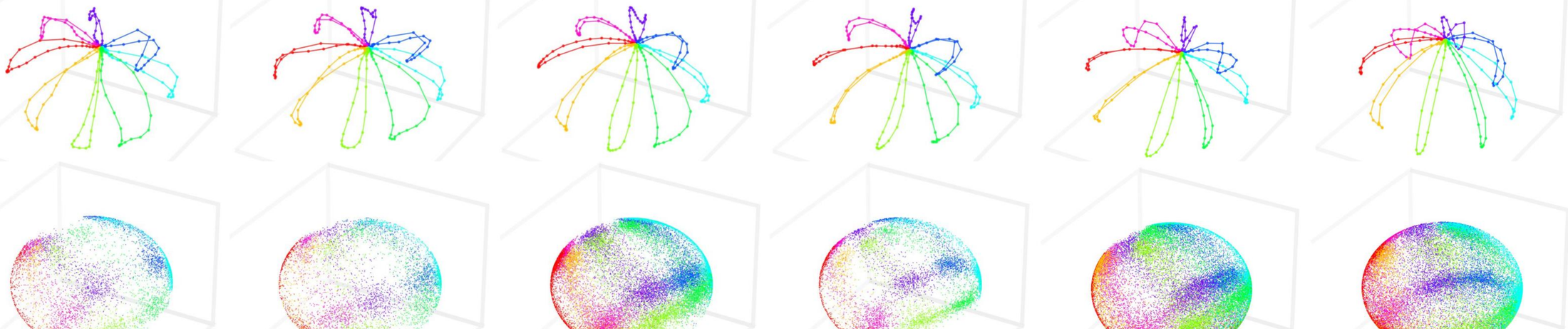
2016-10-14

2016-10-21

2015-03-13

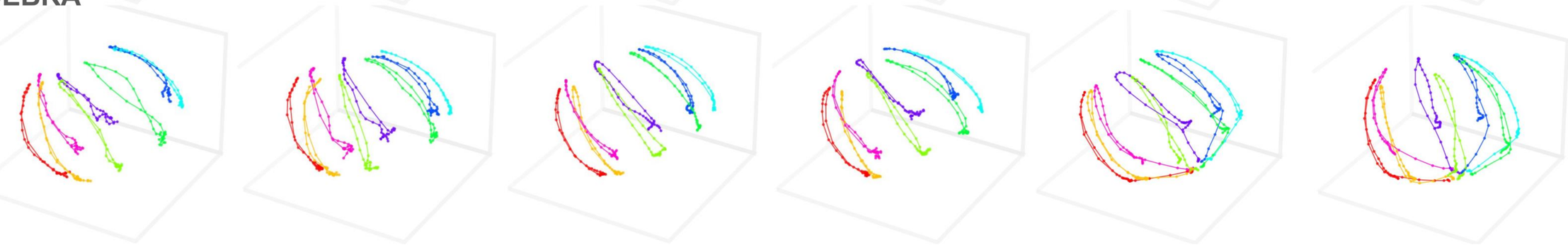
2015-03-19

NER

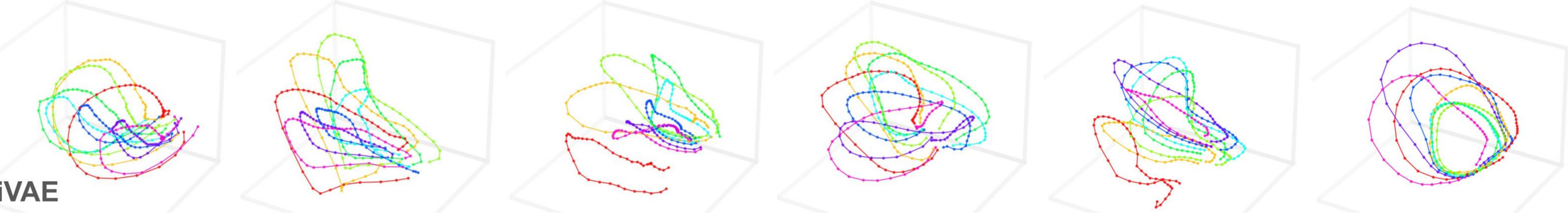


b

CEBRA

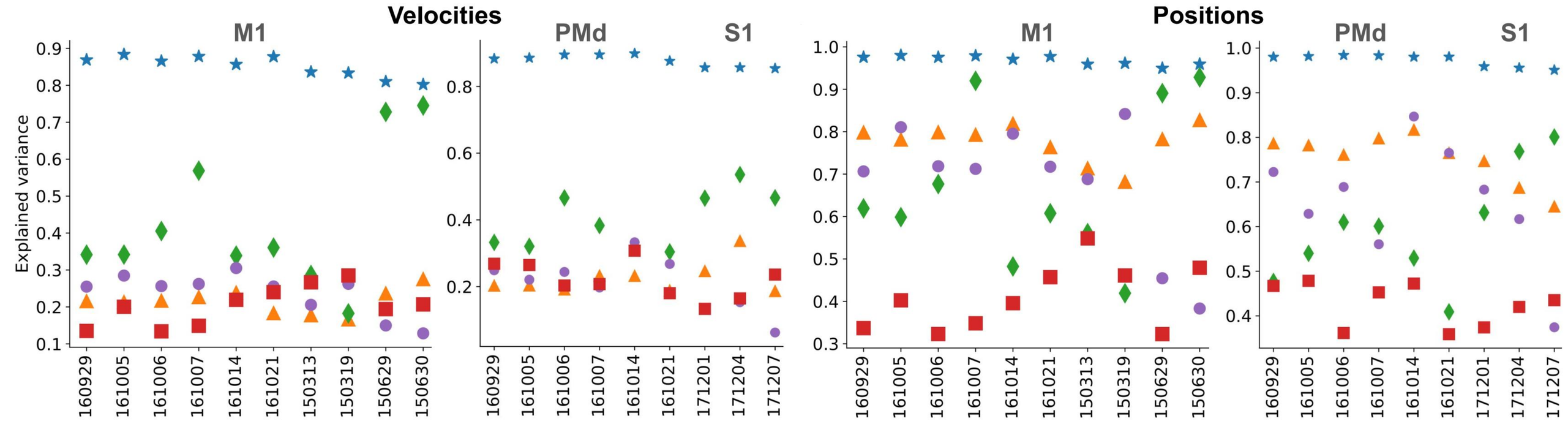


c

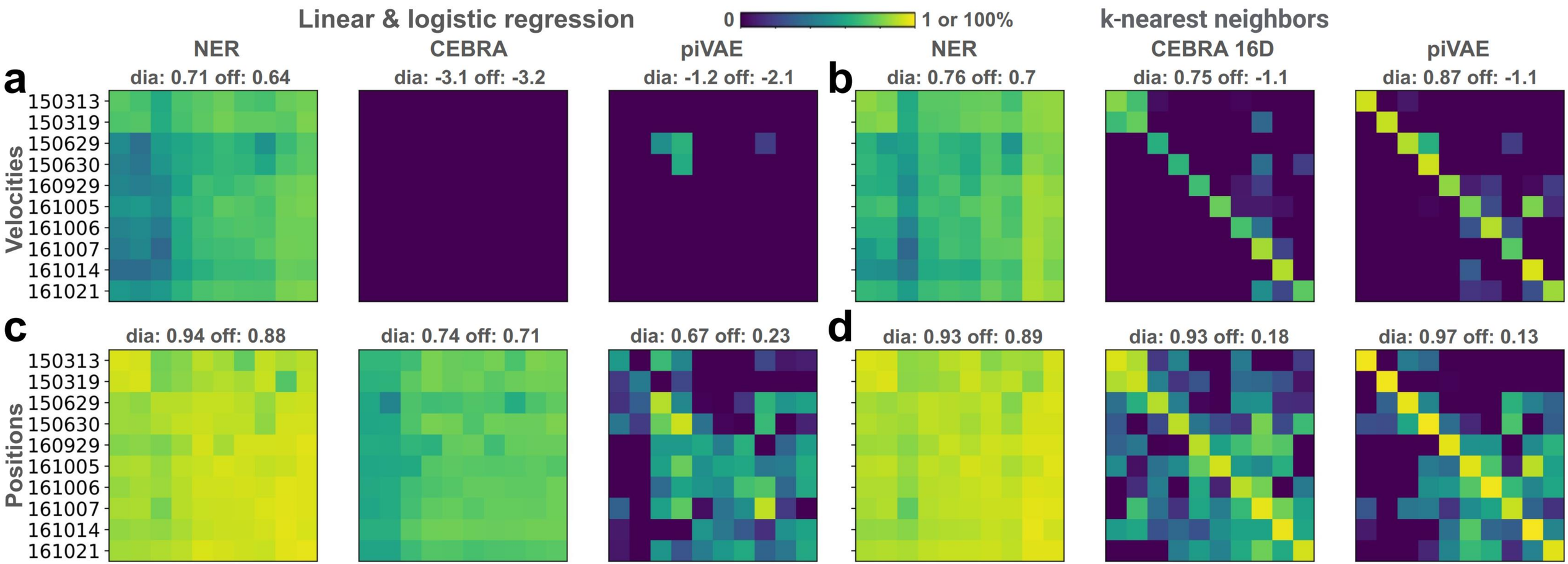


piVAE

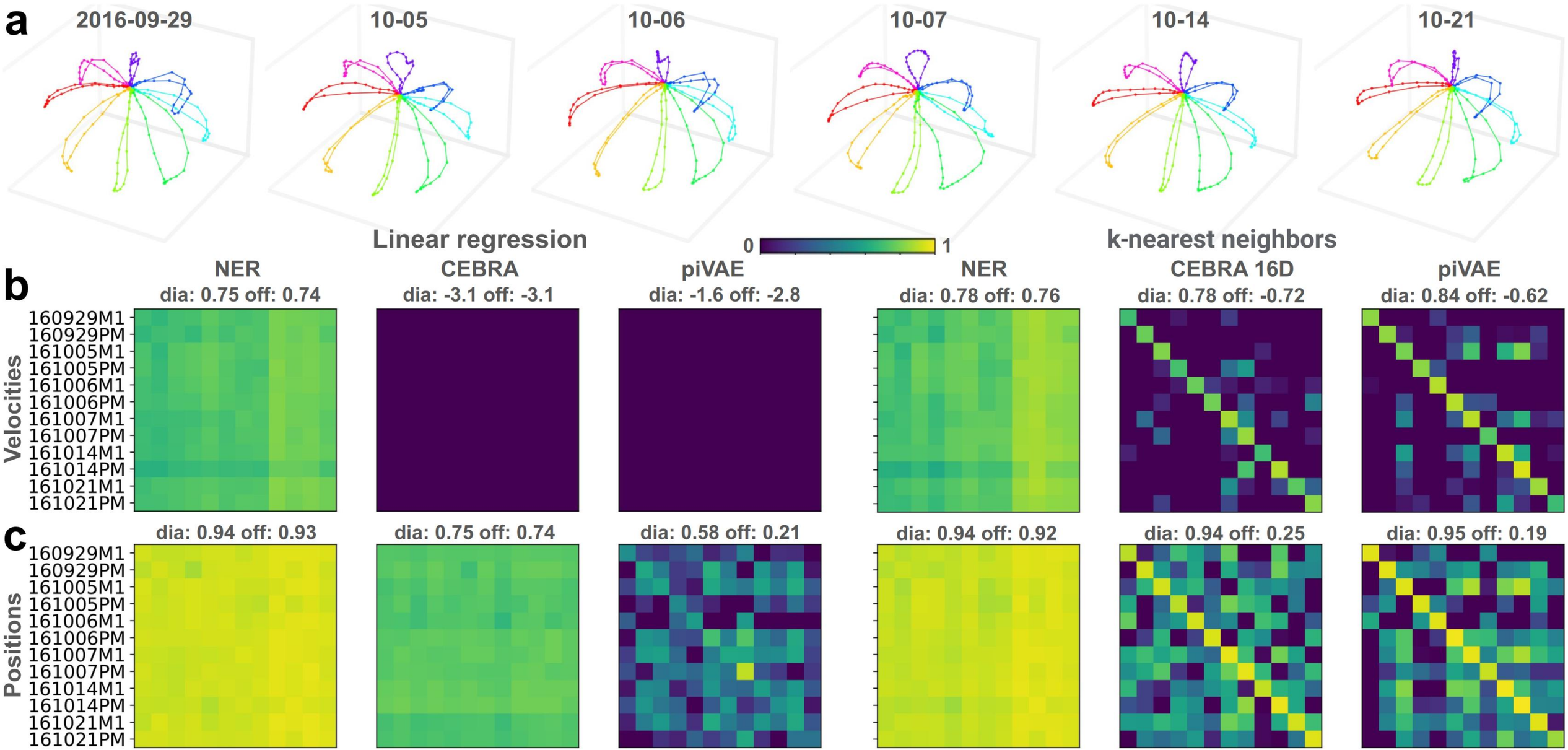
NER explains the largest variance in hand velocities and positions in M1, PMd and S1



Long-term and cross-hemisphere decoding in M1



Latent dynamics in PMd & decoding between M1 & PMd



Code, data, and figures are available

https://github.com/**NeuroscienceAI/NER**

NeuroscienceAI / NER Public

Code | Issues | Pull requests | Actions | Projects | Security | Insights

main | 1 Branch | Tags | Go to file | Code

NeuroscienceAI Update README.md	7c3e528 · 2 days ago	45 Commits
NER_Code_1021	Add NER code to NER_Code_1021 folder	last week
NER_Figs_ipynb	Add Jupyter Notebook to NER_Figs_ipynb folder	2 weeks ago
NER_Figs_pdf	Add files via upload	2 days ago
data	Add raw data to data folder	last week
data_NER	Add NER processed data to data_NER folder	last week
README.md	Update README.md	2 days ago

- Fig1_Method_CEBRA_Lin_Reg_1021.ipynb
- Fig1_Method_NER_Lin_Reg_1021.ipynb
- Fig2_Example_emb.ipynb
- Fig3_Batch_M1_NER_CEBRA.ipynb
- Fig3_Batch_M1_UMAP_PCA_dPCA.ipynb
- Fig3_Batch_M1_piVAE.ipynb
- Fig3_CEBRA_embeddings_rotate.ipynb
- Fig3_NER_embeddings_rotate.ipynb
- Fig3_PCA_embeddings.ipynb
- Fig3_UMAP_embeddings_rotate.ipynb
- Fig3_UMAP_label_embeddings_rotate.ipynb
- Fig3_dPCA_embeddings.ipynb
- Fig3_piVAE_embeddings_rotate.ipynb
- Fig4_Batch_explained_var_kNN.ipynb
- Fig4_Batch_explained_var_linear_reg.ipynb
- Fig4_M1_explained_var.ipynb
- Fig4_PMd+S1_explained_var.ipynb
- Fig5_Batch_M1_self+cross_decode_kNN_1022.ipynb
- Fig5_Batch_M1_self+cross_decode_linear_1022.ipynb
- Fig5_M1_cross_decode.ipynb
- Fig6_Batch_PMd_NER_CEBRA.ipynb
- Fig6_Batch_PMd_piVAE.ipynb
- Fig6_Batch_self+cross_decode_kNN_1023.ipynb
- Fig6_Batch_self+cross_decode_linear_1023.ipynb