What can non-linear embeddings tell us about the way a mouse learns a motor skill?

Concha A[1] Mirande J[1] Molano Ramirez L[2] Hernandez D[2] Esposito MS[2]

[1]Instituto Balseiro, Universidad Nacional de Cuyo - CNEA

[2]CONICET - Departamento de Física Médica, Centro Atómico Bariloche

Overview: quantifying animal behavior

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Can we go deeper?

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  Accelerating rotarod, open field, reaching tasks, etc.
- **Task performance and learning metrics**
  Falling times, reaction times, maximum distances, hit and miss rates etc.
- **Features used to describe animal behavior in detail**
  Body-part positions, velocities, angles, spectrograms, etc.

Overview: computational ethology

- **What is animal behavior?**

  Neural computation: responses to stimuli.

  Control process: actions performed to affect perceptions.

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  Neural manipulation and recordings: becoming more precise and involving more neurons with higher resolutions.

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We need high throughput, rich and unbiased behavior classification!

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- **How to quantify behavior?**

  Simple cases:
  Push a button, pull a lever, cross a defined threshold, etc.
  Complex cases:
  Specific types of movements, locomotion styles, poses, exploring, social interactions, vocal repertoires, etc.

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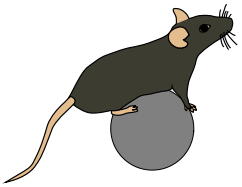
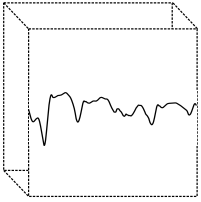
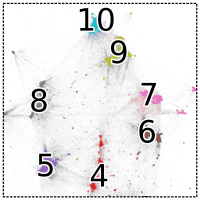
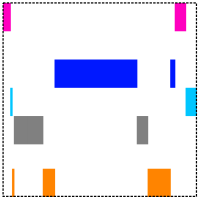
Unsupervised behavior classification!

Unsupervised behavior classification: general pipeline









Physiological signal

- Video recordings
  - Motion tracking (DeepLabCut, LEAP)
  - Image processing
- Audio recordings

Feature extraction

- Body-parts
- Joint angles
- PCA
- Spectrograms (Wavelet, Fourier)

Embedding

- UMAP
- t-SNE

Clustering

- Watershed
- HDBSCAN

Behavior labels

Learning metrics

Performance

Neural activity

Interpretation of behavior labels

Unsupervised behavior classification: application examples

Worms (Eigenworms!)

Stephens GJ, W Bialek et al. (2008) Dimensionality and dynamics in the behavior of *C. elegans*

Flies

Berman GJ et al. (2014) Mapping the stereotyped behaviour of freely moving fruit flies

Social interactions in flies

Klibaite U, Shaevitz JW (2020) Paired fruit flies synchronize behavior: Uncovering social interactions in *Drosophila melanogaster*

Animal vocalizations and bird songs

Sainburg T et al. (2020) Finding, visualizing, and quantifying latent structure across diverse animal vocal repertoires

Mice

Klibaite U et al. (2021) Deep behavioral phenotyping of mouse autism models using open-field behavior

Feature extraction: critical for behavior classification

- **What information do features convey in a motor task?**

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Features		*Behaviors*
Body-part positions and joint angles	$\rightarrow$	Poses
Spectrograms	$\rightarrow$	Movements

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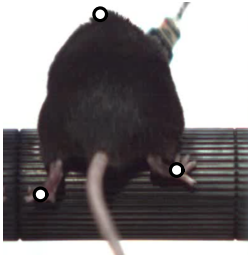
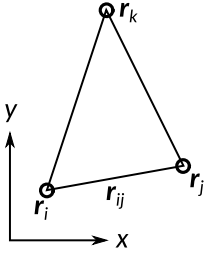
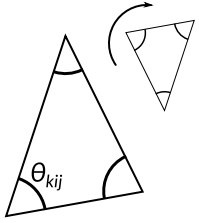
- **So... What can behavior embeddings tell us about motor learning?**

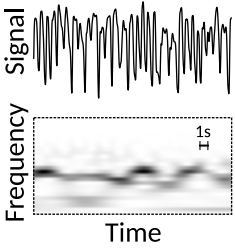
It depends on the features and the experimental protocol!

Feature extraction: some of their properties









Motion tracking	**Body-part positions**	**Joint angles**	**Power spectra**
Invariant to	Rigid translation (only $\mathbf{r}_{ij}$)	Rigid translation, rotation and uniform scaling	Phase shift

Discussion

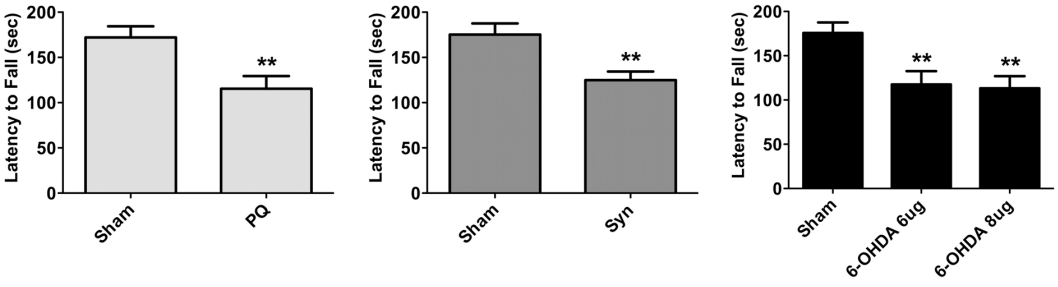
- To capture information about the phase differences between pairs of moving body-parts, we could use the coherence phase of their cross-wavelet spectrum.
- We would like to improve our behavior embeddings, by thinking thoroughly about the features we use.
- We want to use these methods to find correlations with simultaneous neural activity recordings, as well as to quantify behavioral changes during learning.
- Overall, this unsupervised behavior classification paradigm seems promising.

Wrapping up

Thank you for your attention!

Please, take a look at:
Jorge Mirande's oral communication (OC4 $\sim$10:45) and
Leonardo Molano Ramirez' poster (PS5-13, yesterday's session)

Methods: Accelerating rotarod and motor impairment



Campos FL, et al. (2013)
Rodent models of Parkinson's disease: beyond the motor symptomatology