Time-warped state space models for distinguishing movement type and vigor

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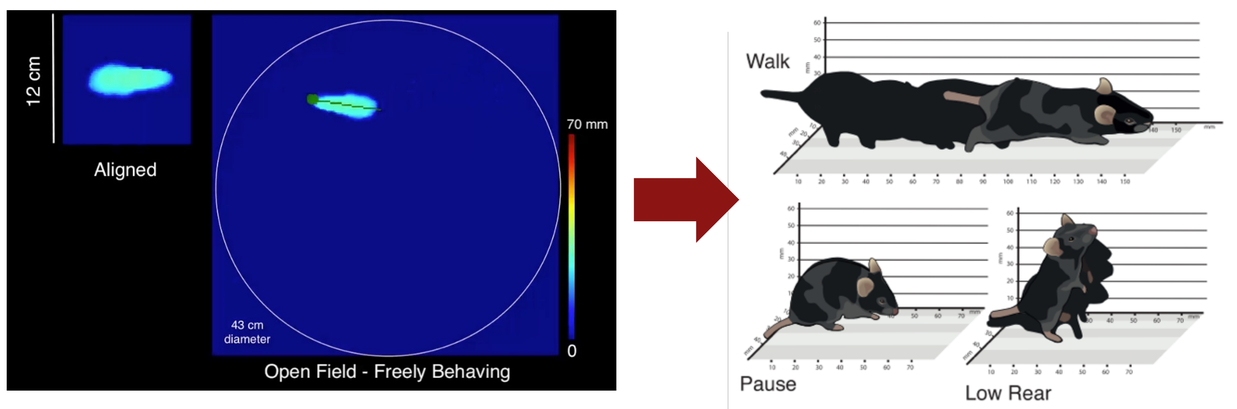
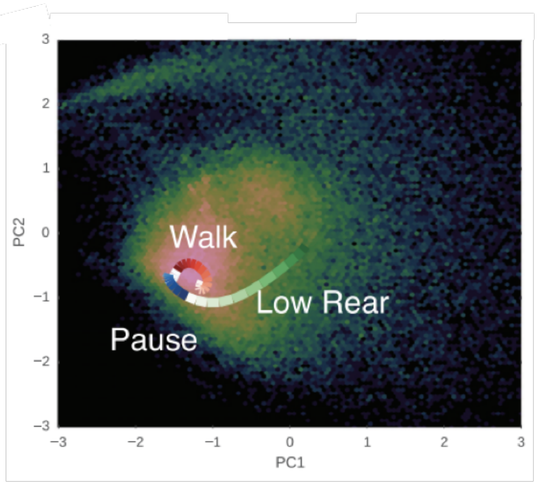
OBJECTIVES



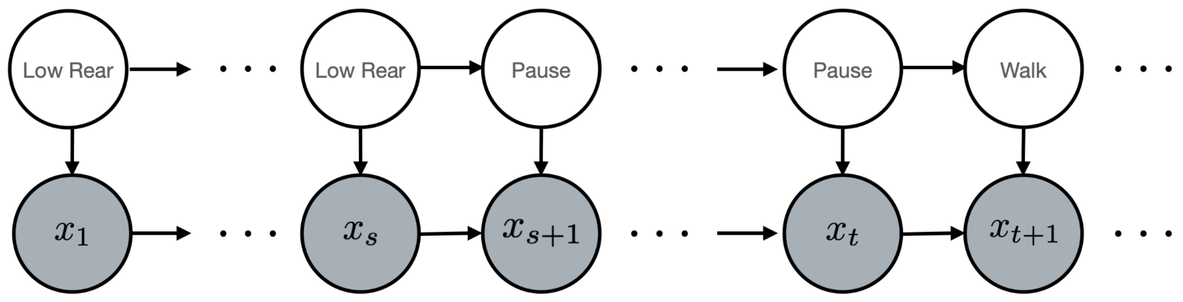
- **Goal**: identify descriptive behavioral syllables from unlabeled videos of mice.
- We propose a model which captures structured variation among syllables through the addition of a variable representing **vigor**, or the speed at which syllables occur.

METHODS

Prior Work: MoSeq

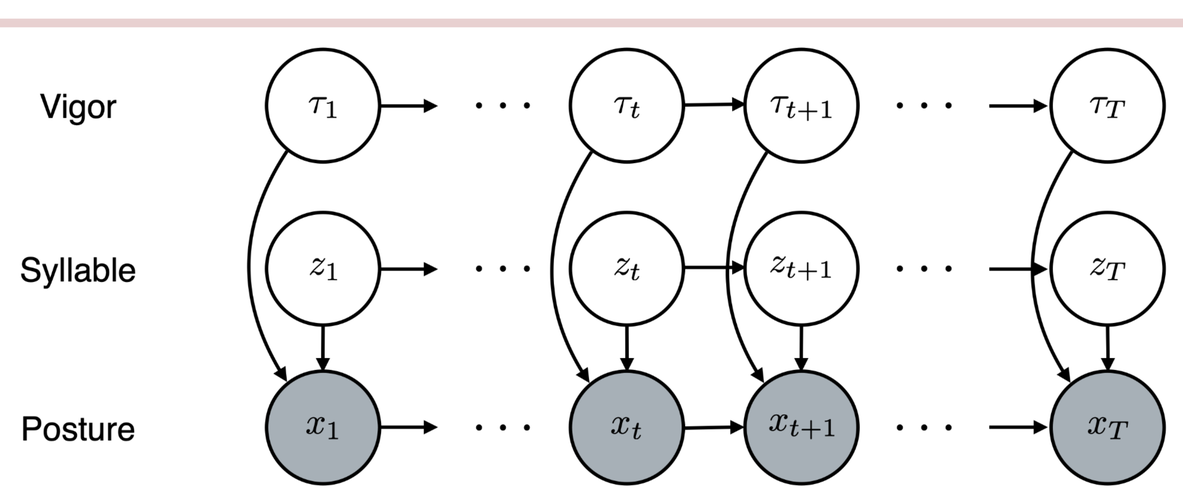


MoSeq [2] takes motion in PC space and identifies a set of behavioral syllables which describe variations in the data via an autoregressive hidden Markov model (ARHMM) with linear dynamics.



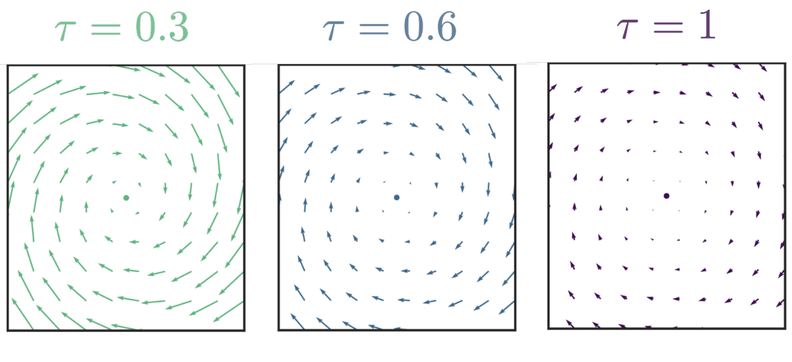
Time-warped ARHMM

- We propose adding a **vigor** variable to MoSeq which augments the behavioral syllable's linear dynamics at each time step.



$$\boldsymbol{x}_{t+1} = \boldsymbol{x}_t + \tau_t^{-1}\left(\boldsymbol{A}_{z_t}\boldsymbol{x}_t + \boldsymbol{b}_{z_t}\right) + \epsilon, \quad \epsilon \sim \mathcal{N}\left(0, \tau_t^{-1}\boldsymbol{Q}_{z_t}\right)$$

$$z_{t+1} \sim \mathsf{Cat}(\boldsymbol{T}[z_t, :]), \quad \tau_{t+1} \sim \mathsf{Cat}(\boldsymbol{H}[\tau_t, :])$$

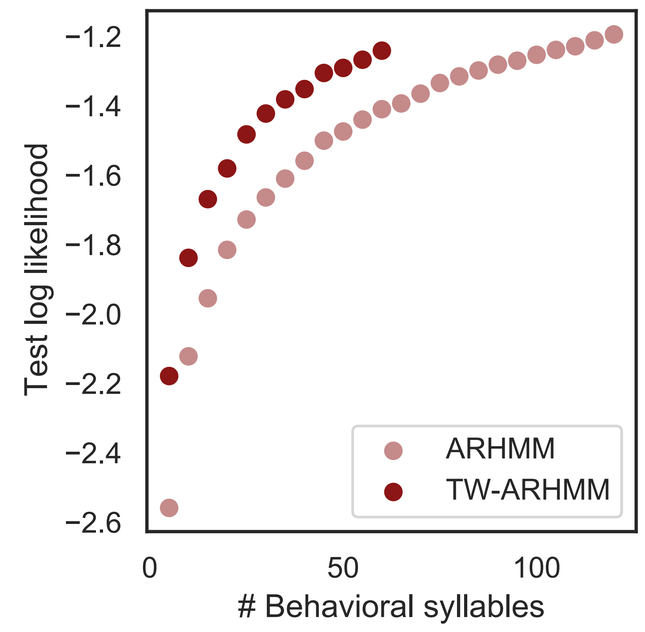


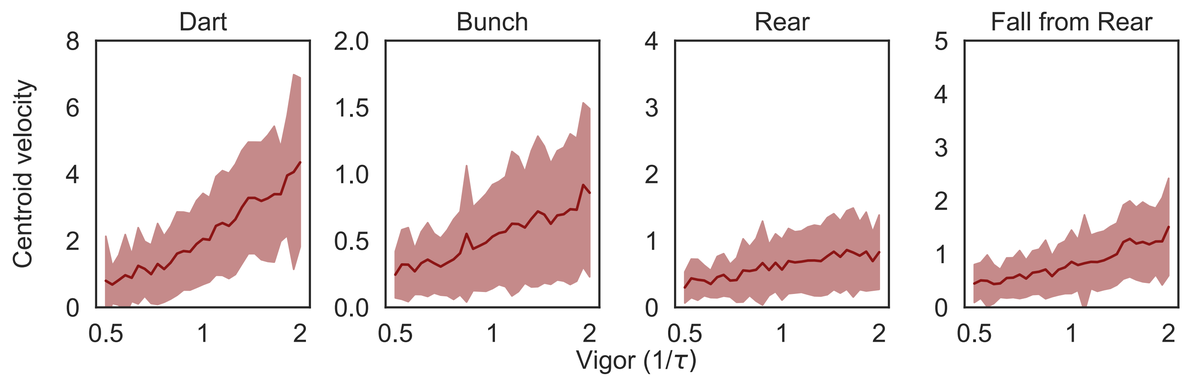
$$\tau \frac{dx(t)}{dt} = Ax(t) + b$$

- Visualization of time-warping for continuous system.

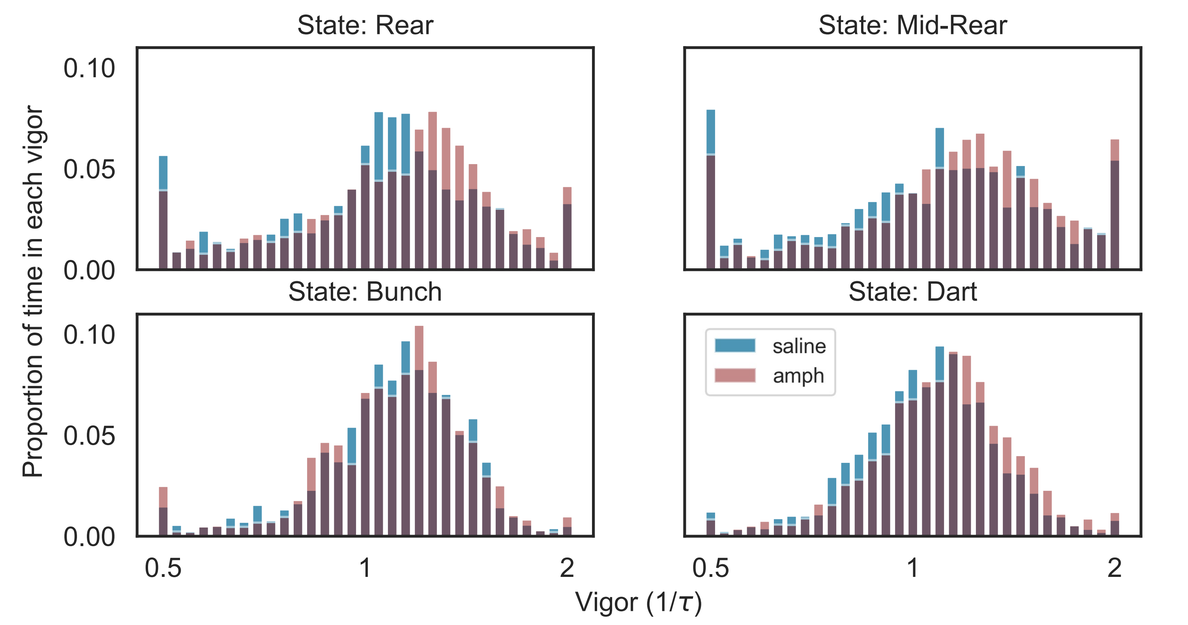
RESULTS

- TW-ARHMM achieves the same test log likelihood as MoSeq (ARHMM) with fewer behavioral syllables.
- This indicates that TW-ARHMM uncovers vigor-related structure in behavioral syllables.





- Strong correlation between vigor variable and centroid velocity in specific syllables.
- In other syllables, vigor variable could represent alternative types of variation.



- Statistically significant shift in vigor variable distribution in certain syllables as a result of drug treatment.
- Video results show subtle differences in behavior across different vigor values.
  - Scan QR code ➔
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CONCLUSIONS & FUTURE WORK

- TW-ARHMM adds interpretable vigor variable to behavioral syllable representation of MoSeq.
- Which other characteristics of behavioral syllables can be disentangled by adding additional variables to the model?
- Investigate possible neural correlate of vigor variable via dopamine dLight data.

REFERENCES

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[2] Wiltschko et al. (2015). "Mapping Sub-Second Structure in Mouse Behavior." *Neuron* 88:1121-35
[3] Wiltschko et al. (2020). "Revealing the Structure of Pharmacobehavioral Space through Motion Sequencing." *Nat Neuro* 23:1433-43