Hierarchical models of time series data in animal behavior

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A typical experimental workflow

Ca trace extraction

50 - 300 simultaneously imaged neurons (out of ~2000 in VMHvl)

2 min

Manual, frame-by-frame annotation

Ca\textsuperscript{2+} imaging data

behavioral video

?
What is behavior, anyway?

Egnor and Branson, 2016

Behavior “ethogram” of the cabbage aphid during mating

Kant, Minor, and Trewick, 2015
What is behavior, anyway?

- Slow
- Expensive
- Low-resolution
- Subjective

Each dot is one 10-minute video

# frames labeled as investigation

# frames labeled as attack
92% of estimated keypoints are within a 0.5cm radius of ground truth.
Problem 1: we can observe the same action in different contexts

- Features extracted from mouse pose decode during behavior.

- Features extracted from lead-up to behavior.
Problem 2: we can observe different actions in (what we think is) the same context

(aphid ethogram)

Is behavior expression stochastic?
Or was there something different about these two cases?
The challenge: can we build models of behavior that reflect these facts?

- Identify animal actions from tracking data
- Look for behavioral “states” under which different actions are expressed
- Look for “equivalence classes” of actions that are expressed interchangeably in a given state

**Diagram:**
- Mating state
- Investigation state
- Aggressive state
- Action 1
- Action 2
- Action 3
- Action 4
- Sensory context
The challenge: can we identify neural correlates of the states in our model?
The challenge: can we identify changes in behavior expression in mutant mice?

<table>
<thead>
<tr>
<th>Line</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTBR</td>
<td>Mutant line with no corpus callosum; less social</td>
</tr>
<tr>
<td>Chd8</td>
<td>More aggressive line</td>
</tr>
<tr>
<td>Cul3</td>
<td>No differences found yet</td>
</tr>
<tr>
<td>Nlgn3</td>
<td>More aggressive line</td>
</tr>
<tr>
<td>C57Bl/6J</td>
<td>Control mice</td>
</tr>
</tbody>
</table>

For each line:
- 8-10 mutant mice
- 8-10 wild-type mice
- 2 testing conditions
- ~6 hours video