Article

Structure of the Zebrafish Locomotor Repertoire Revealed with Unsupervised Behavioral Clustering

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Draelos Lab: Paper Presentation
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Introduction

- **Objective:** To explore zebrafish larvae's locomotor repertoire through unsupervised behavioral clustering

- **Motivation:** Revealing underlying organization of motor behavior in zebrafish helps in understanding neural circuit function and behavior in other organisms

- **Why I chose this**: aligns with my interest in data-driven approaches for understanding animal behaviors and neural functions
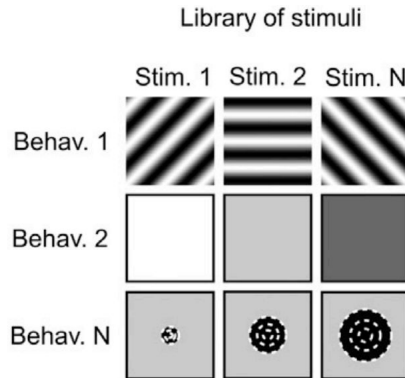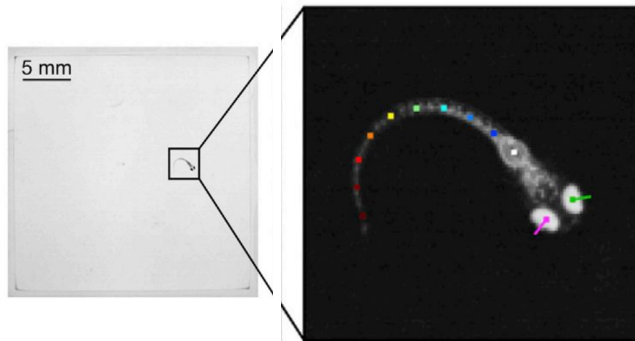
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Note: All media in this presentation are used from the original paper unless mentioned otherwise

Methods & Results

Video recording

- Movements of thousands of zebrafish larvae were recorded using a real-time, high-speed video tracking system
- Performed in 9 different behavioral contexts by varying acoustic and visual stimuli

Nine behavioral contexts:
1. Forward OMR
2. Directional OMR
3. Acoustic startle
4. Dimming
5. Spontaneous Swimming
6. Prey capture
7. Photoaxis
8. Expanding spot
9. Social Context

Detection of Behavior

- Complex behaviors can be constructed from a set of basic motor patterns
- Zebrafish swim in sequence of bouts alternating with passive movement

Data size:
- 11M half beats
- 2M bouts
- 10k+ sequences

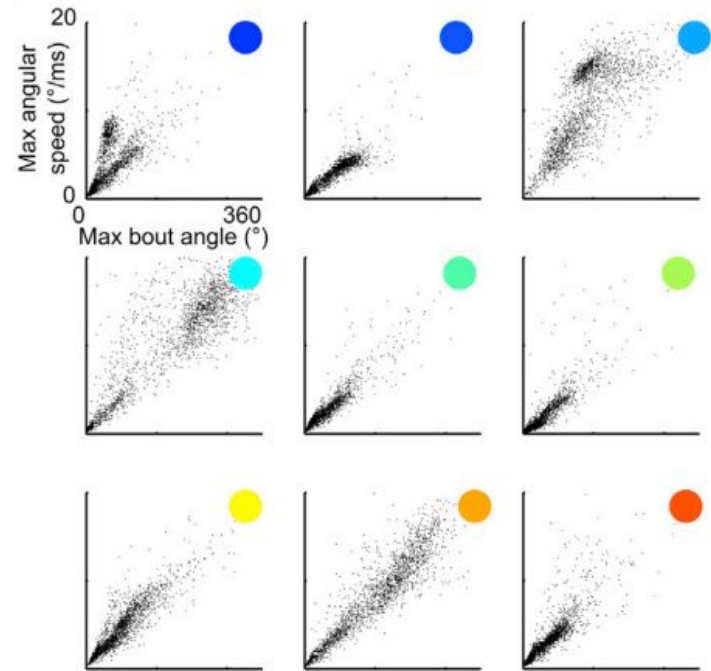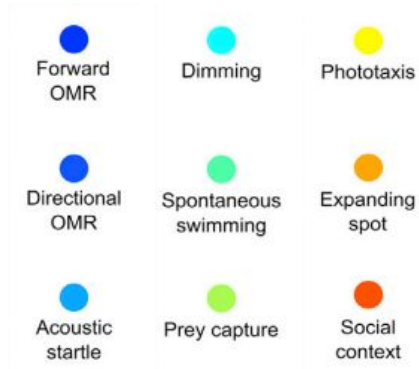Bout and half beat detection
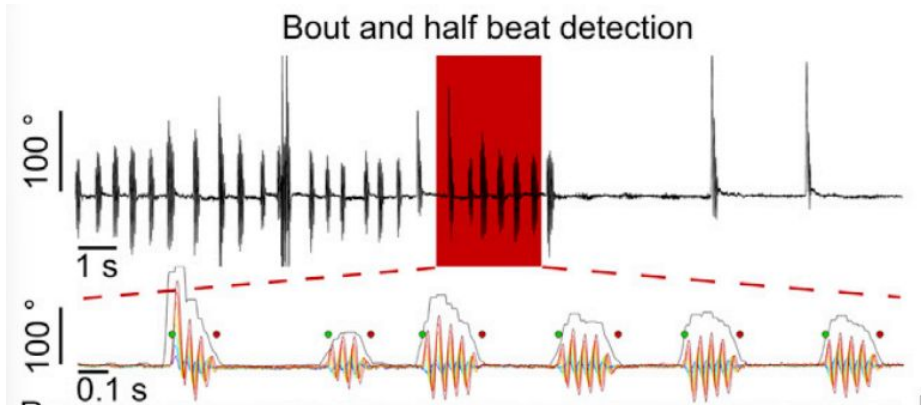
Half beats
side-to-side tail bending movement

Bouts
Alternate sequence of half beats

Transforming Kinematic data

- Transformed time-series data of bouts to individual data points of 73 kinematic parameters such as:
  - Max angular speed
  - Forward distance
 - Bout end angle

Dimension reduction using PCA

- Reduced from d=73 to 4 dimensions
- Shows clustered structure
  - Regions of high density are evident
  - Each behavioral context associated with a distinct distribution
- Kinematic features represented by this space
  - PC 1: Angular speed and tail amplitude
  - PC 2: Second half beat amplitude
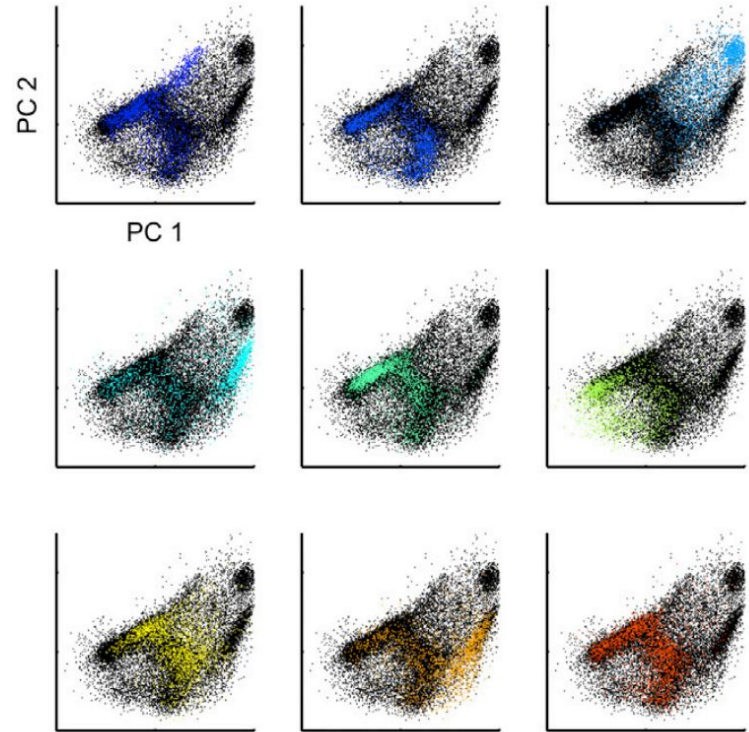
Clustering: Stage 1

- Clustering performed to identify the basic set of swim types
- Processed in two stages to correct biases in sampling behaviors with different counts
- Divided data into sets based on stimulus parameters to observe rarer swim types
- Identified clusters in each set using **clusterdv**
- Whole set of clusters pooled to form a library

Clusterdv
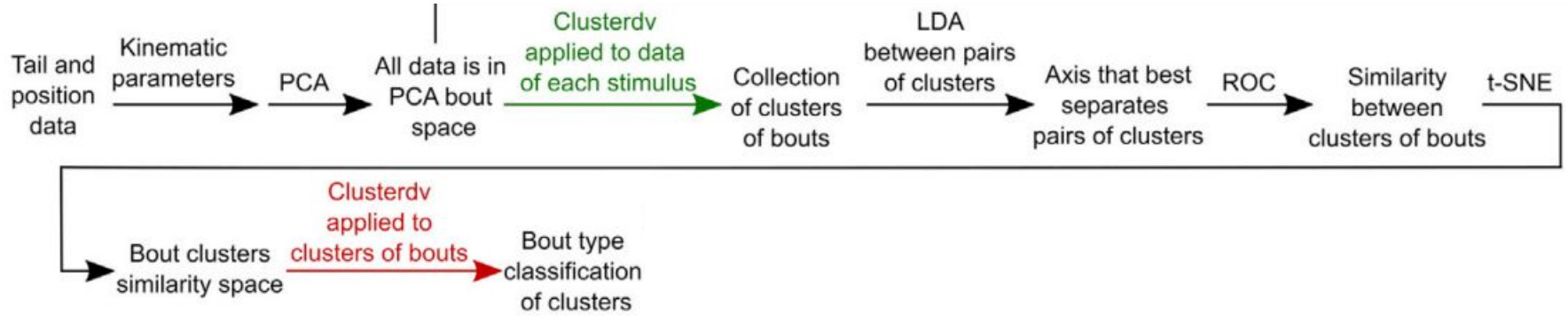unsupervised estimation of density-based clusters across datasets
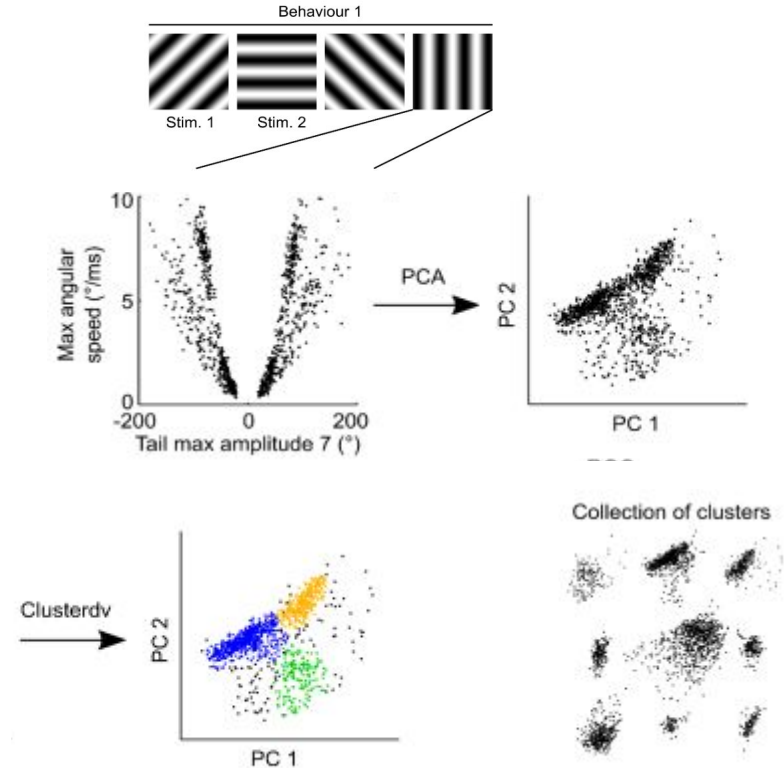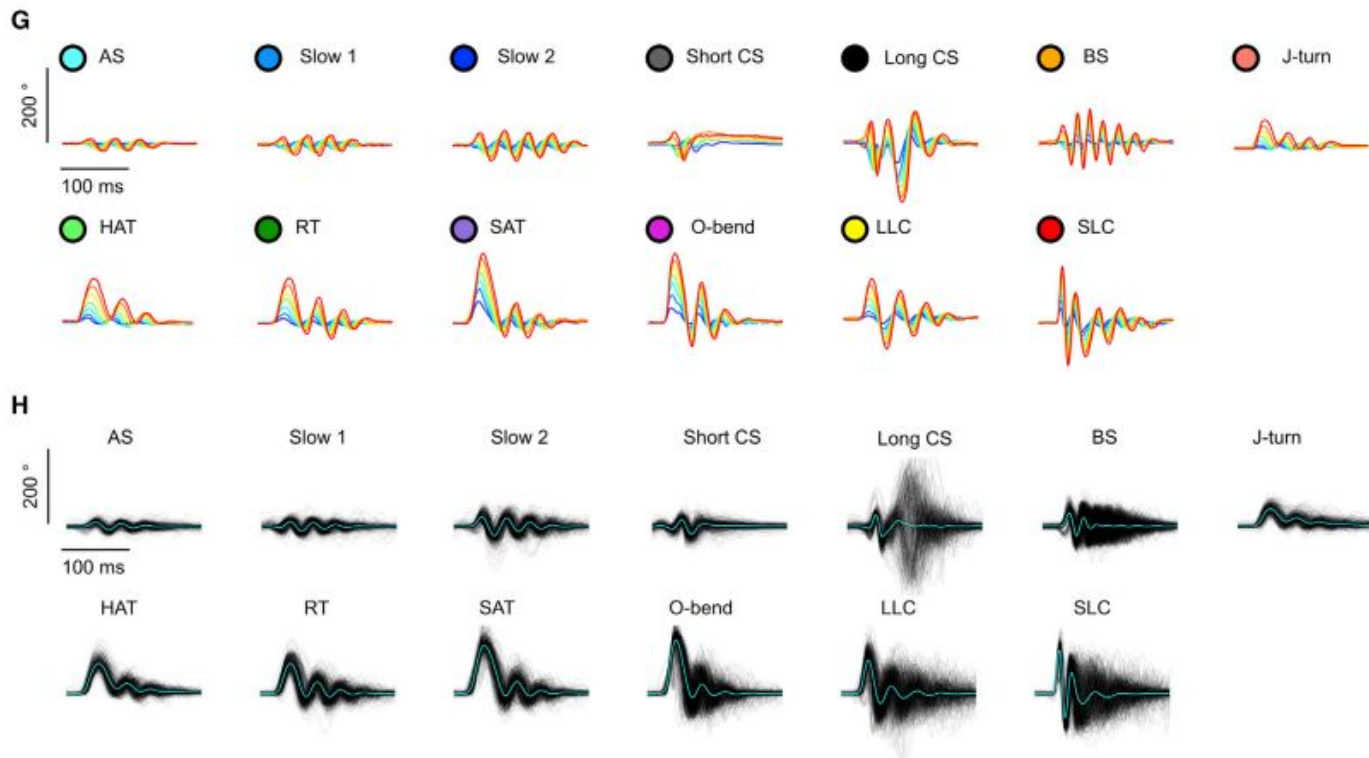
Clustering: Stage 2

- A: Similarity of clusters quantified along maximum separable axis
- B: Used this to embed them into 3D space using t-SNE
- C: Clusterdv applied again to identify **13** groups
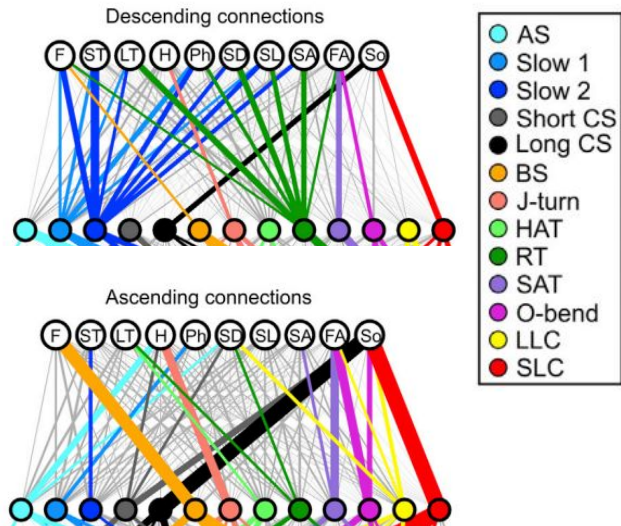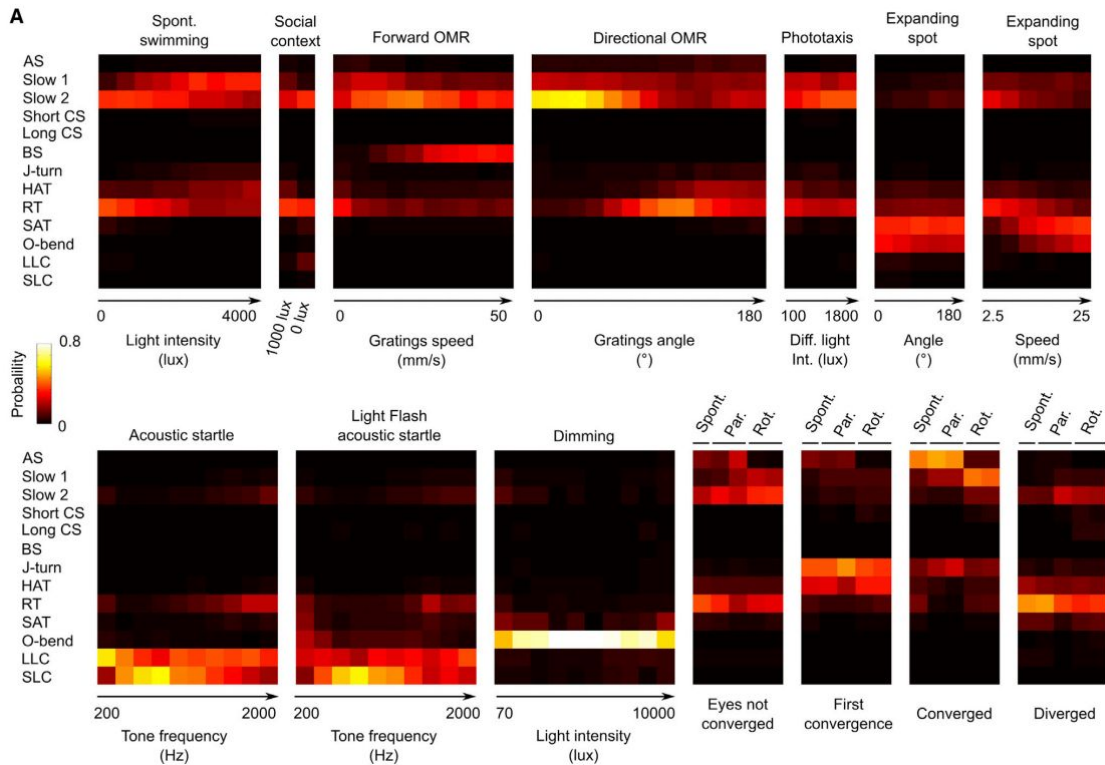- F: Density map of bouts in the top-2 PC space
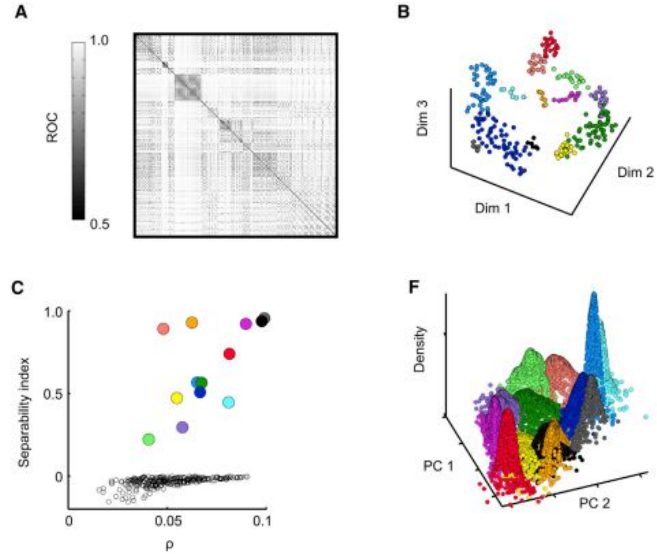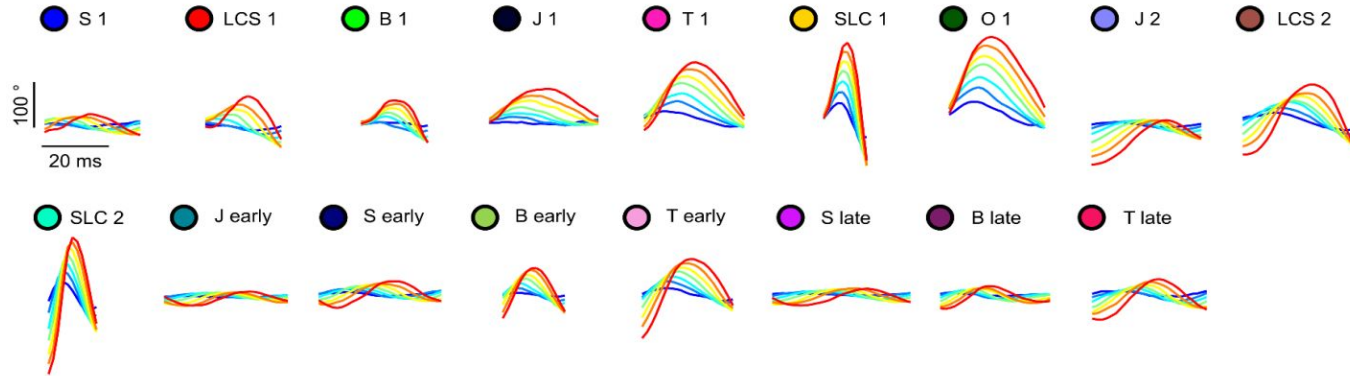
Analysis pipeline

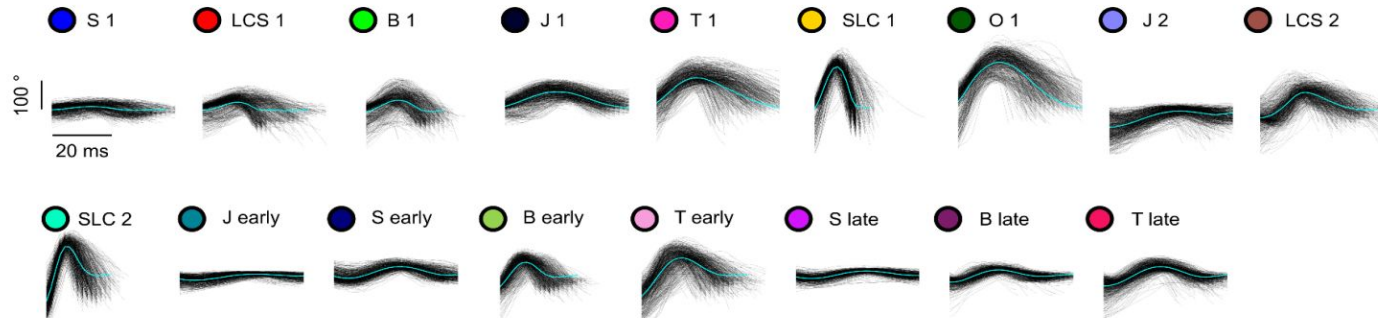# Thirteen Bout Types

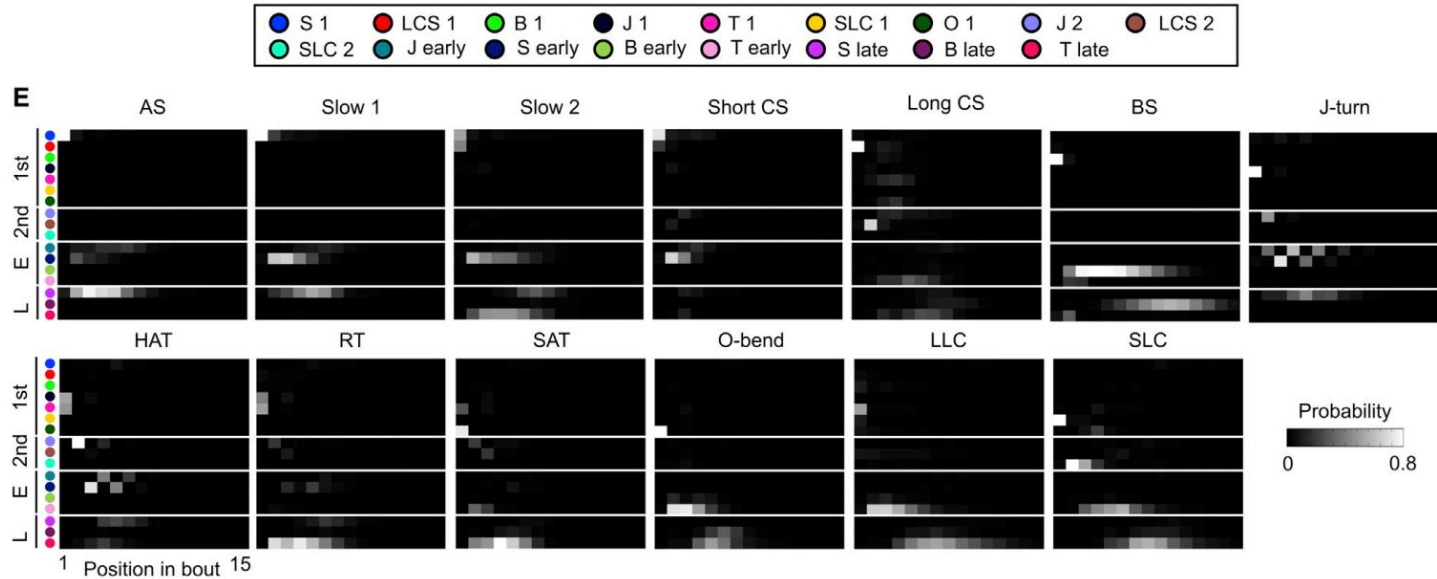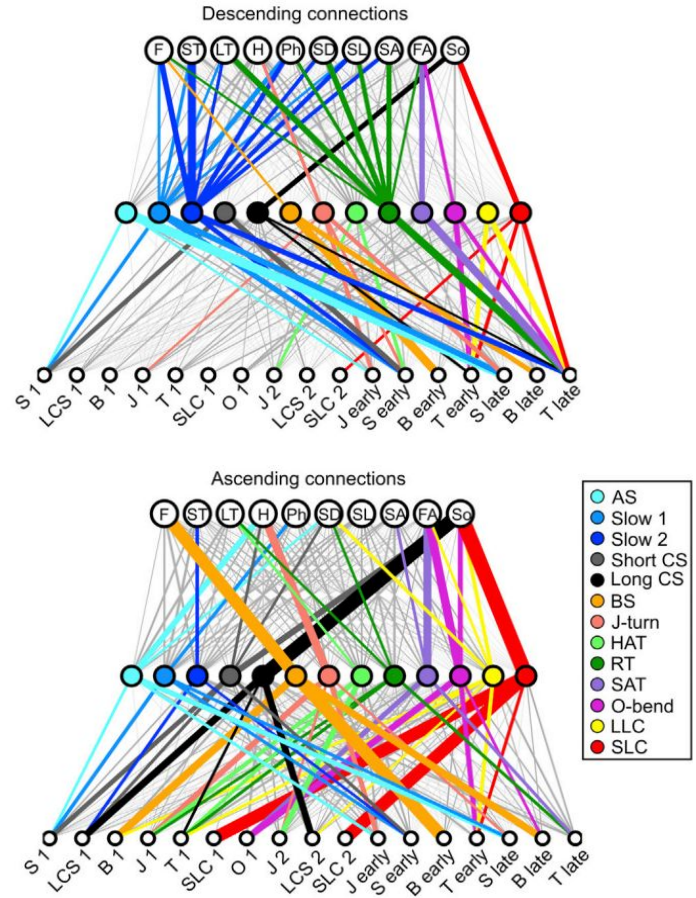# Bout types across behaviors

Seventeen Half beat types

Half beat across bouts

Behavioral Hierarchy

- Zebrafish locomotor behavior has a hierarchical temporal organization
- Categories at one level consist of different, overlapping combinations of lower level

Discussion

Discussion

- A fundamental question in ethology: distinct movement categories versus a smooth continuum
  - distinct categories evidence: multiple peaks in the distribution of certain kinematic parameters
  - smooth continuum evidence: kinematic parameters vary in a continuous fashion sometimes

- Unsupervised methods provide an unbiased way to analyze behavior and enable the discovery of new features
- This analysis captured categories previously described as well as identified novel ones

Questions?