analyze_single_anemotaxis

November 20, 2025

1 Analysis of a single `trx.mat` file of an (anemotaxis) experiment

There are two ways to use this file -

1. As a standalone file, in which case, add a value of `single_path` in the cell (Cell [3] or Cell [4]) after the one where all the libraries are imported - where it says *Load single `trx.mat` file*. The value of `single_path` in the cell (Cell[3] or Cell [4]) should overwrite the blank value in the `single_path` variable below.

2. As part of a batch run (using the `batch_run_single_experiments.py` script), in which case, DON'T uncomment the cell where it says *Load single `trx.mat` file*. The `papermill` library of the `batch_run_single_experiments.py` script will take care of the parameter `single_path` in the next cell. It is intentionally hence left blank (`single_path = ""`)

[1]:
```
# Parameters
single_path = ""
```

[2]:
```
# Parameters
single_path = "/Users/sharbat/Projects/anemotaxis/data/
↪FCF_attP2-40@UAS_TNT_2_0003/p_5gradient2_2s1x600s0s#n#n#n/20240223_112627/
↪trx.mat"
```

[3]:
```
import sys
import os as os
import numpy as np
import matplotlib.pyplot as plt
from matplotlib.gridspec import GridSpec
from datetime import datetime
import core.data_loader as data_loader
import core.data_processor as data_processor
import viz.plot_data as plot_data
import utils.preprocessing as preprocessing

# Set matplotlib style
%matplotlib widget
%load_ext autoreload
%autoreload 2
plt.style.use('../anemotaxis.mplstyle')
```

[4]:
```
# Load single `trx.mat` file
# If you are using this notebook as a standalone notebook please add here
# single_path = '/path/to/trx.mat'
```

[5]:
```
trx_data = data_loader.load_single_trx_file(single_path, show_progress=True)
```

```
Processing file: /Users/sharbat/Projects/anemotaxis/data/FCF_attP2-
40@UAS_TNT_2_0003/p_5gradient2_2s1x600s0s#n#n#n/20240223_112627/trx.mat
Number of larvae: 41
```

```
Processing larvae:   0%|          | 0/41 [00:00<?, ?it/s]
```

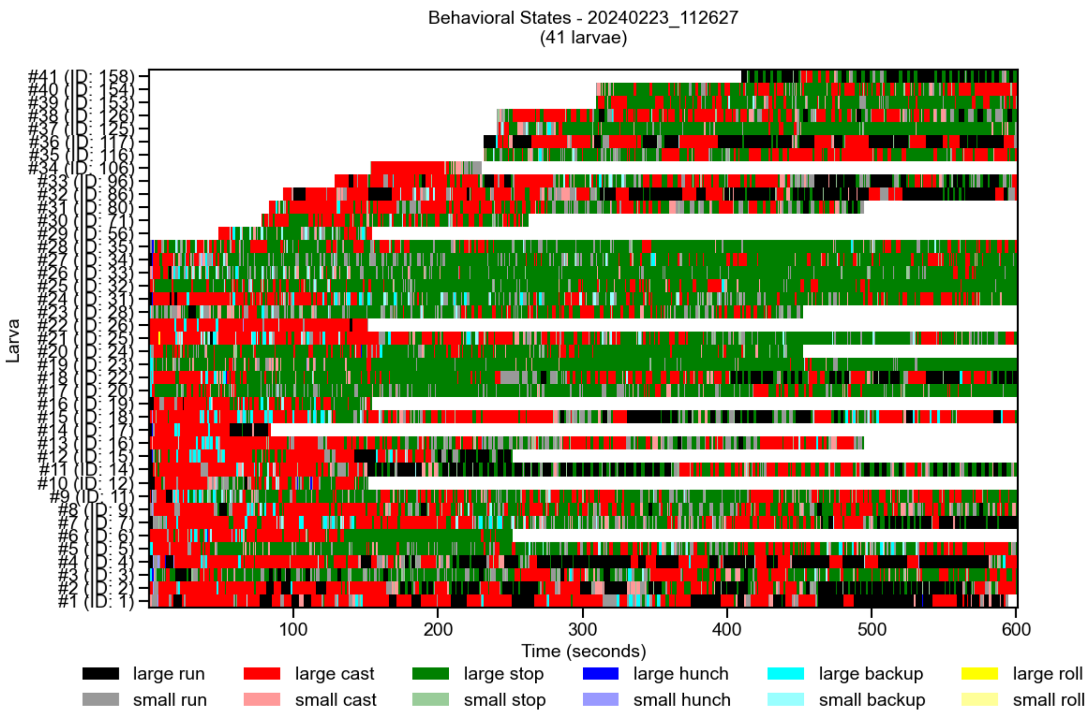
```
Processing larvae: 100% | 41/41 | Completed at: 2025-11-20 16:20:15 | Time
taken: 00:02
```

[6]:
```
# Get the parent directory of single_path and create analyses folder if it␣
↪doesn't exist
# this is to save analysis results and figures if needed
parent_dir = os.path.dirname(single_path)
output_dir = os.path.join(parent_dir, 'analyses')
os.makedirs(output_dir, exist_ok=True)
```

1.0.1 Ethogram

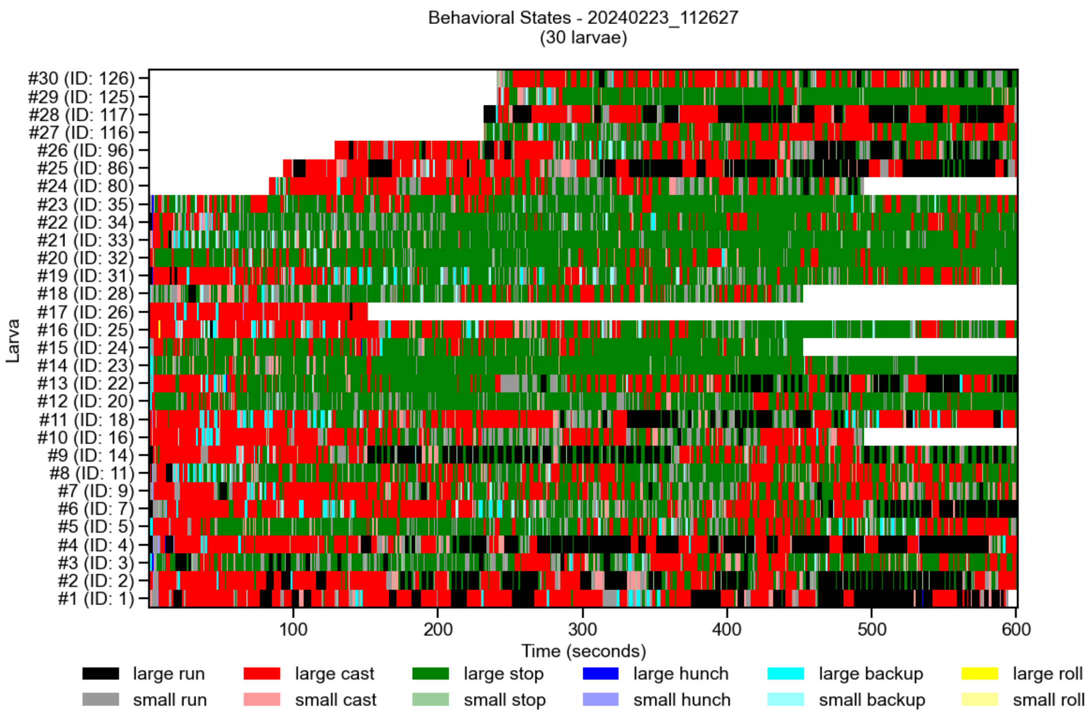
1. Raw ethogram
2. Filtering by duration (for anemotaxis, total duration is 600, usual minimum is 300s)
3. Filtering by removing larvae with excessive stop time (more than 0.5 of total time in stop)
4. Filtering by merging short stop sequences (less than 2s for cast, less than 3s for run)

[7]:
```
results_behavior_matrix = plot_data.plot_global_behavior_matrix(trx_data)
```



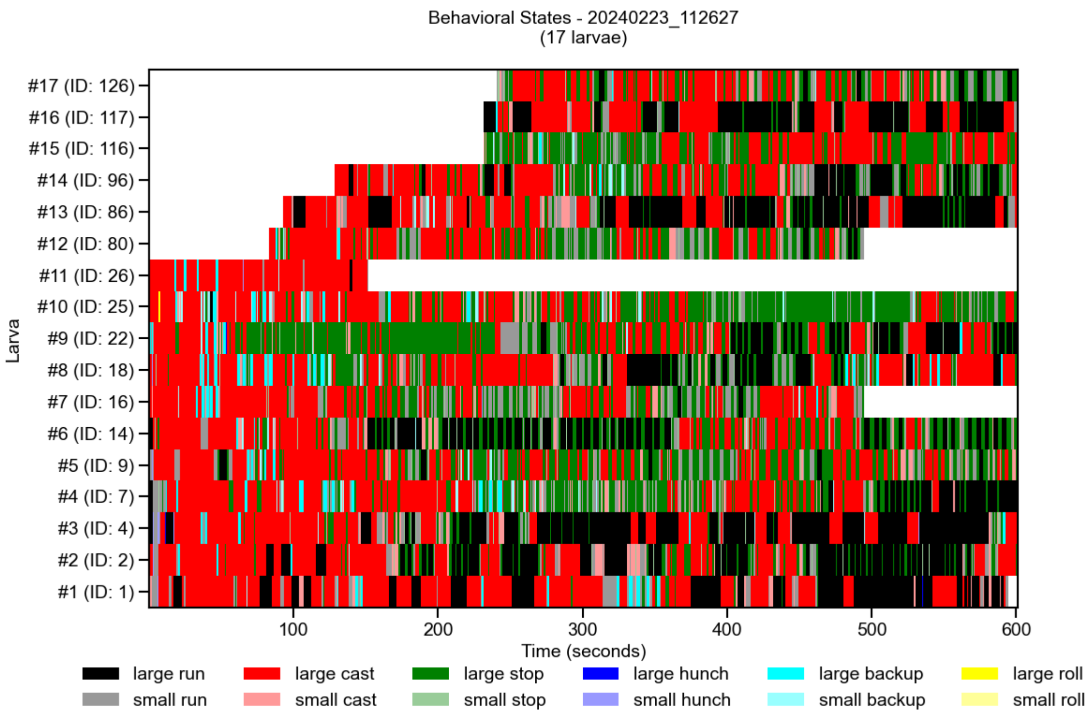
[8]:
```python
## Filtering by duration (for anemotaxis, total duration is 600, usual minimum␣
↪is 300s)
min_total_duration= 300
trx_filtered_by_duration = preprocessing.filter_larvae_by_duration(trx_data,␣
↪min_total_duration=min_total_duration)
results_filtered_behavior_matrix = plot_data.
↪plot_global_behavior_matrix(trx_filtered_by_duration)
```

```
Duration filtering results (threshold: 300.0s):
  - Removed 11 larvae with <300.0s total duration
  - 30 larvae remaining
```



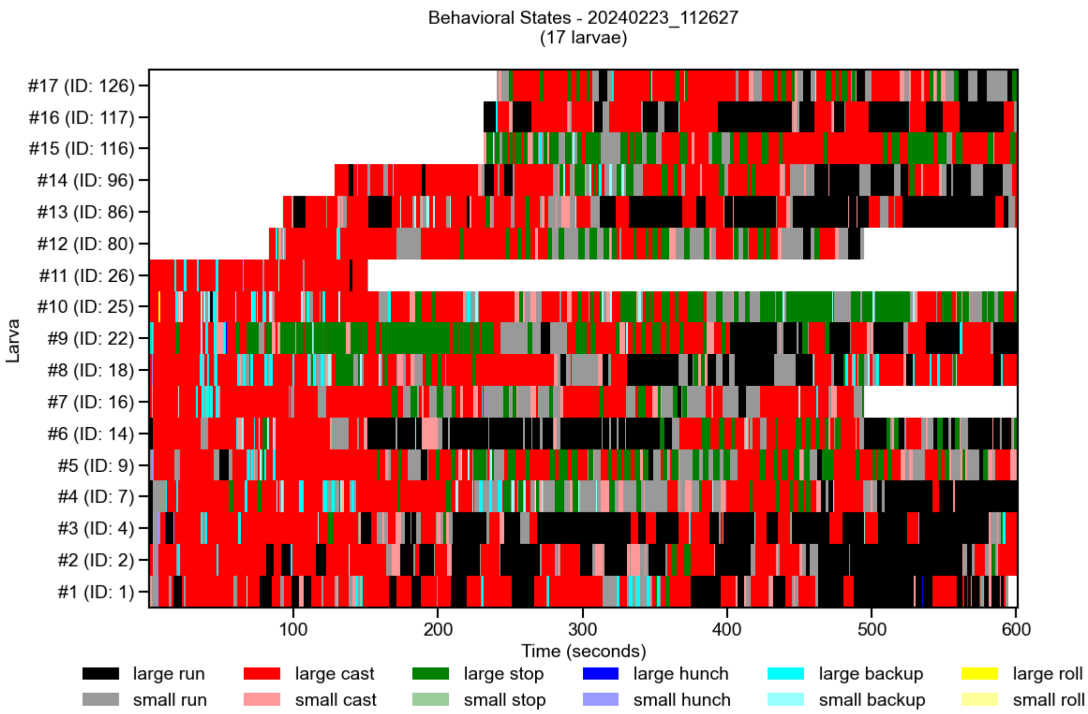

```
[9]: ## Filtering by removing larvae with excessive stop time (more than 0.5 of␣
     ↪total time in stop)
     max_stop_percentage = 0.5
     trx_filtered_by_removing_stops = preprocessing.
      ↪filter_larvae_by_excess_stop_time(trx_filtered_by_duration,␣
      ↪max_stop_percentage=max_stop_percentage)
     results_filtered_behavior_matrix = plot_data.
      ↪plot_global_behavior_matrix(trx_filtered_by_removing_stops)
```

```
Excess stop time filtering results (threshold: 50%):
  - Removed 13 larvae with >50% time in stop state
  - 17 larvae remaining
```




```
[10]: ## Merging short stop sequences (less than 2s for cast, less than 3s for run)
trx_filtered_by_merging = preprocessing.
  ↪merge_short_stop_sequences(trx_filtered_by_removing_stops,␣
  ↪min_stop_duration_cast=2.0, min_stop_duration_run=3.0)
results_merged_behavior_matrix = plot_data.
  ↪plot_global_behavior_matrix(trx_filtered_by_merging)
fig_behavior = plt.gcf()  # Get current figure
fig_behavior.savefig(os.path.join(output_dir, 'behavior_matrix_filtered.pdf'),
                    bbox_inches='tight',
                    dpi=300,
                    transparent=True,
                    facecolor='none')
print(f"Behavior matrix figure saved to: {os.path.join(output_dir,␣
  ↪'behavior_matrix_filtered.pdf')}")
```

```
Merged 965 sequences with short stops:
  - 379 cast-stop-cast sequences
  - 509 run-stop-run sequences
  - 77 mixed sequences (run-stop-cast or cast-stop-run)
Total duration saved: 997.62 seconds
```




```
Behavior matrix figure saved to: /Users/sharbat/Projects/anemotaxis/data/FCF_att
P2-
40@UAS_TNT_2_0003/p_5gradient2_2s1x600s0s#n#n#n/20240223_112627/analyses/behavio
r_matrix_filtered.pdf
```

1.0.2 Event probabilites over orientation and time

[11]:
```
# Analyze run probability by orientation and over time
run_prob_results = data_processor.analyze_run_probability_by_orientation(
    trx_filtered_by_merging, bin_width=10, sigma=2)

run_prob_time_results = data_processor.analyze_run_probability_over_time(
    trx_filtered_by_merging, window=60, step=20
)

# Analyze turn probability by orientation and over time
turn_prob_results = data_processor.analyze_turn_probability_by_orientation(
    trx_filtered_by_merging, bin_width=10, sigma=2, min_turn_amplitude=45,␣
 ↪output_dir=output_dir)
turn_prob_time_results = data_processor.analyze_turn_probability_over_time(
    trx_filtered_by_merging, window=60, step=20, min_turn_amplitude=45
)
```

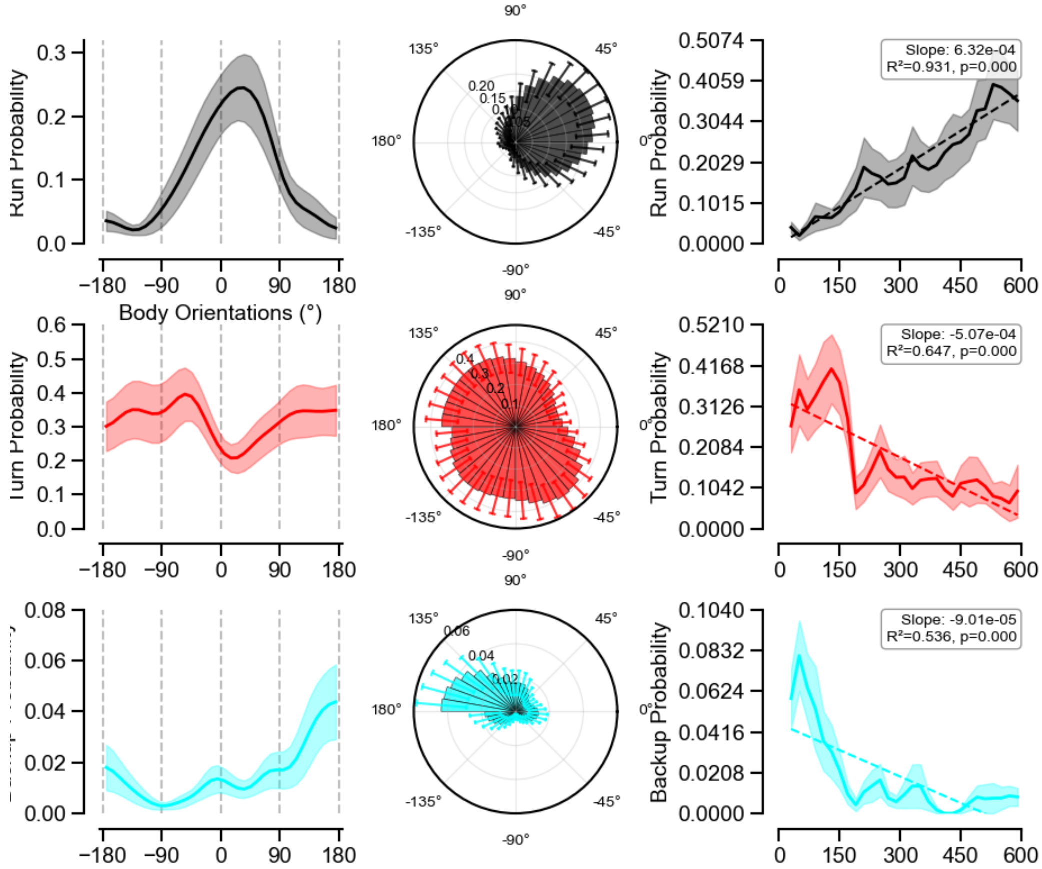
```python
# Analyze backup probability by orientation and over time
backup_prob_results = data_processor.analyze_backup_probability_by_orientation(
    trx_filtered_by_merging, bin_width=10, sigma=2)
backup_prob_time_results = data_processor.analyze_backup_probability_over_time(
    trx_filtered_by_merging, window=60, step=20)
```

```
 Cast & Turn Analysis Summary:
   Total casts processed: 444
   Total turns detected: 69
   Overall turn rate: 15.5%
   Min turn amplitude: 45°
   Orientation change stats:
     Mean: 25.9°
     Median: 12.6°
     Range: 0.0° - 179.2°
Detailed cast/turn info written to: /Users/sharbat/Projects/anemotaxis/data/FCF_
attP2-
40@UAS_TNT_2_0003/p_5gradient2_2s1x600s0s#n#n#n/20240223_112627/analyses/turn_pr
obability_orientation_details.json
```

[12]:
```python
# Create figure with asymmetric spacing - polar plots closer to left
fig = plt.figure(figsize=(10, 8))
gs = GridSpec(3, 3, figure=fig,
              left=0.08, right=0.90,
              top=0.93, bottom=0.07,
              wspace=0.4,               # Reduced overall spacing
              hspace=0.4,
              width_ratios=[0.6, 0.6, 0.6])  # Left wide, middle narrow, right␣
 ↪wide

# Row 1: Run analysis
ax1 = fig.add_subplot(gs[0, 0])
ax2 = fig.add_subplot(gs[0, 1], projection='polar')
ax7 = fig.add_subplot(gs[0, 2])


plot_data.plot_orientation_histogram(run_prob_results, plot_type='run', ax =␣
 ↪ax1)
plot_data.plot_orientation_histogram_polar(run_prob_results, plot_type='run',␣
 ↪ax=ax2, bar_style=True, tick_fontsize=10)
ax2_pos = ax2.get_position()
ax2.set_position([ax2_pos.x0 - 0.04, ax2_pos.y0, ax2_pos.width, ax2_pos.height])


plot_data.plot_metric_over_time(run_prob_time_results, plot_type='run', ax=ax7,␣
 ↪show_xlabel=False)
```

```
# Row 2: Turn analysis
ax3 = fig.add_subplot(gs[1, 0])
ax4 = fig.add_subplot(gs[1, 1], projection='polar')
ax8 = fig.add_subplot(gs[1, 2])

plot_data.plot_orientation_histogram(turn_prob_results, plot_type='turn',␣
 ↪ax=ax3, ylabel='Turn Probability', show_xlabel=False)

plot_data.plot_orientation_histogram_polar(turn_prob_results, plot_type='turn',␣
 ↪ax=ax4, bar_style=True, tick_fontsize=10)
ax4_pos = ax4.get_position()
ax4.set_position([ax4_pos.x0 - 0.04, ax4_pos.y0, ax4_pos.width, ax4_pos.height])

plot_data.plot_metric_over_time(turn_prob_time_results, plot_type='turn',␣
 ↪ax=ax8, show_xlabel=False)

# Row 3: Backup analysis
ax5 = fig.add_subplot(gs[2, 0])
ax6 = fig.add_subplot(gs[2, 1], projection='polar')
ax9 = fig.add_subplot(gs[2, 2])


plot_data.plot_orientation_histogram(backup_prob_results, ax=ax5,␣
 ↪ylabel='Backup Probability', color = 'cyan',show_xlabel=True)

plot_data.plot_orientation_histogram_polar(backup_prob_results,␣
 ↪plot_type='backup', ax=ax6, bar_style=True, tick_fontsize=10)
ax6_pos = ax6.get_position()
ax6.set_position([ax6_pos.x0 - 0.04, ax6_pos.y0, ax6_pos.width, ax6_pos.height])
plot_data.plot_metric_over_time(backup_prob_time_results, plot_type='backup',␣
 ↪ax=ax9, show_xlabel=True)

fig.savefig(os.path.join(output_dir, 'behavioral_analysis_summary.pdf'),
            bbox_inches='tight',
            dpi=300,
            transparent=True,       # Transparent background
            facecolor='none')       # No face color

print(f"Saved to: {output_dir}")
```

```
Saved to: /Users/sharbat/Projects/anemotaxis/data/FCF_attP2-
40@UAS_TNT_2_0003/p_5gradient2_2s1x600s0s#n#n#n/20240223_112627/analyses
```



[13]:
```
# Analyze turn amplitude by orientation and over time
turn_amp_results = data_processor.analyze_turn_amplitudes_by_orientation(
    trx_filtered_by_merging, bin_width=20, sigma=0.1, min_turn_amplitude=45
)
turn_amp_time_results = data_processor.analyze_turn_amplitudes_over_time(
    trx_filtered_by_merging, window=60, step=20, min_turn_amplitude=45
)



# Analyze run velocity by orientation and over time
velocity_results = data_processor.analyze_run_velocity_by_orientation(
    trx_filtered_by_merging, bin_width=15, sigma=2
)

velocity_results_pooled = data_processor.
 ↪analyze_run_velocity_by_orientation_pooled(
    trx_filtered_by_merging, bin_width=15, sigma=2
)
velocity_time_results = data_processor.analyze_run_velocity_over_time(
```

```
    trx_filtered_by_merging, window=60, step=20
)
```

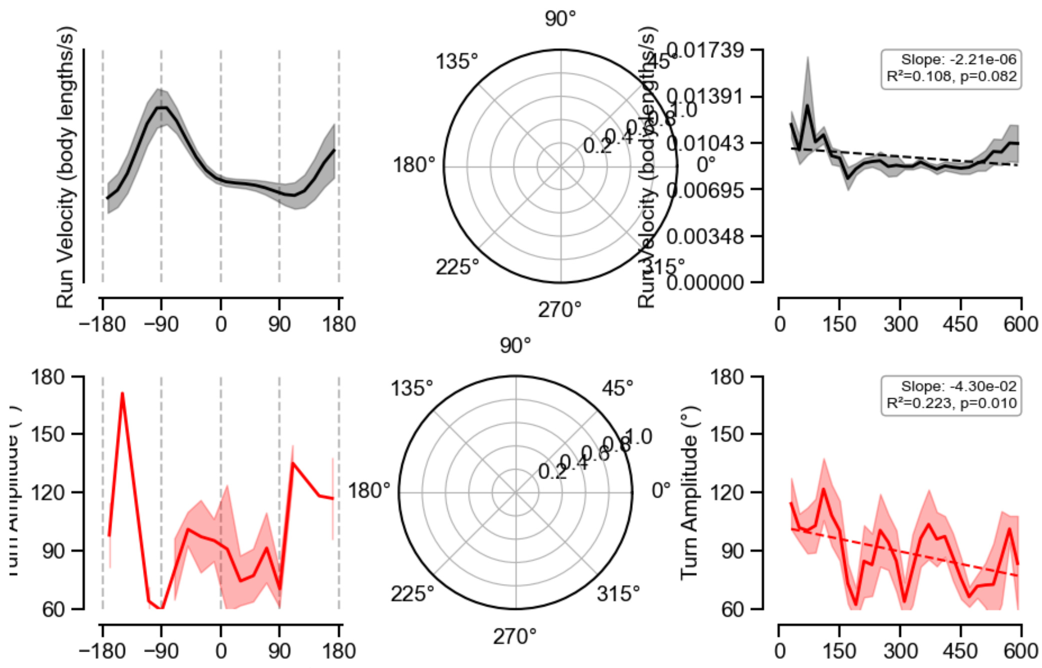
```
/Users/sharbat/Projects/anemotaxis/src/core/data_processor.py:977:
RuntimeWarning: Mean of empty slice
  mean_hist = np.nanmean(hist_arrays, axis=0)
/Users/sharbat/Projects/anemotaxis/src/core/data_processor.py:978:
SmallSampleWarning: After omitting NaNs, one or more axis-slices of one or more
sample arguments is too small; corresponding elements of returned arrays will be
NaN. See documentation for sample size requirements.
  se_hist = stats.sem(hist_arrays, axis=0, nan_policy='omit')
/Users/sharbat/Projects/anemotaxis/src/core/data_processor.py:1120:
SmallSampleWarning: After omitting NaNs, one or more axis-slices of one or more
sample arguments is too small; corresponding elements of returned arrays will be
NaN. See documentation for sample size requirements.
  se_hist = stats.sem(hist_arrays, axis=0, nan_policy='omit')
```

[14]:
```
# Create combined figure with asymmetric spacing - polar plots closer to left
fig_combined = plt.figure(figsize=(10, 6))
gs_combined = GridSpec(2, 3, figure=fig_combined,
                      left=0.08, right=0.90,
                      top=0.93, bottom=0.10,
                      wspace=0.4,              # Reduced overall spacing
                      hspace=0.4,
                      width_ratios=[0.6, 0.6, 0.6])  # Left wide, middle␣
↪narrow, right wide

# Row 1: Run Velocity Analysis
ax_vel1 = fig_combined.add_subplot(gs_combined[0, 0])
ax_vel2 = fig_combined.add_subplot(gs_combined[0, 1], projection='polar')
ax_vel3 = fig_combined.add_subplot(gs_combined[0, 2])


# Linear plot
plot_data.plot_orientation_histogram(velocity_results_pooled, ax=ax_vel1,␣
↪show_xlabel=False, ylabel='Run Velocity (body lengths/s)')
ax_vel1.set_ylim(0.005,0.015)
# ax_vel1_y_ticks = [0.01, 0.011, 0.012, 0.013, 0.014]
# ax_vel1.set_yticks(ax_vel1_y_ticks)

# Polar plot
# plot_data.plot_orientation_histogram_polar(velocity_results_pooled,␣
↪ax=ax_vel2, bar_style=True, tick_fontsize=10)
# ax_vel2_pos = ax_vel2.get_position()
# ax_vel2.set_position([ax_vel2_pos.x0 - 0.04, ax_vel2_pos.y0, ax_vel2_pos.
↪width, ax_vel2_pos.height])
```

```python
# Time series plot
plot_data.plot_metric_over_time(
    velocity_time_results, color = 'black',ylabel='Run Velocity (body lengths/
↪s)',
    show_individuals=False, show_error=True, ax=ax_vel3, show_xlabel=False
)

# Row 2: Turn Amplitude Analysis
ax_amp1 = fig_combined.add_subplot(gs_combined[1, 0])
ax_amp2 = fig_combined.add_subplot(gs_combined[1, 1], projection='polar')
ax_amp3 = fig_combined.add_subplot(gs_combined[1, 2])

# Set minimum amplitude
min_amp = 60

# Check if we have ANY valid (non-NaN) data
if turn_amp_results and 'mean_hist' in turn_amp_results:
    mean_hist = np.array(turn_amp_results['mean_hist'])
    has_data = np.any(~np.isnan(mean_hist))
else:
    has_data = False


# Linear plot
plot_data.plot_orientation_histogram(turn_amp_results, ax=ax_amp1, ylabel='Turn␣
↪Amplitude (°)',
                                     show_xlabel=True, min_amplitude=min_amp,␣
↪plot_type='turn_amplitude')

# Polar plot - only if there's valid data
# plot_data.plot_orientation_histogram_polar(turn_amp_results, ax=ax_amp2,␣
↪bar_style=True,
#                                      tick_fontsize=10, min_amplitude=min_amp,␣
↪plot_type='turn_amplitude')
ax_amp2_pos = ax_amp2.get_position()
ax_amp2.set_position([ax_amp2_pos.x0 - 0.04, ax_amp2_pos.y0, ax_amp2_pos.width,␣
↪ax_amp2_pos.height])

# Time series plot
plot_data.plot_metric_over_time(
    turn_amp_time_results, plot_type='turn_amplitude',
    show_individuals=False, show_error=True, ax=ax_amp3, show_xlabel=True,
    min_amplitude=min_amp
)
```

```python
# Save the combined figure
fig_combined.savefig(os.path.join(output_dir, 'velocity_amplitude_analysis.
 ↪pdf'),
                    bbox_inches='tight',
                    dpi=300,
                    transparent=True,
                    facecolor='none')
print(f"Combined velocity & amplitude figure saved to: {os.path.
 ↪join(output_dir, 'velocity_amplitude_analysis.pdf')}")

plt.show()
```

```
Combined velocity & amplitude figure saved to: /Users/sharbat/Projects/anemotaxi
s/data/FCF_attP2-
40@UAS_TNT_2_0003/p_5gradient2_2s1x600s0s#n#n#n/20240223_112627/analyses/velocit
y_amplitude_analysis.pdf
```

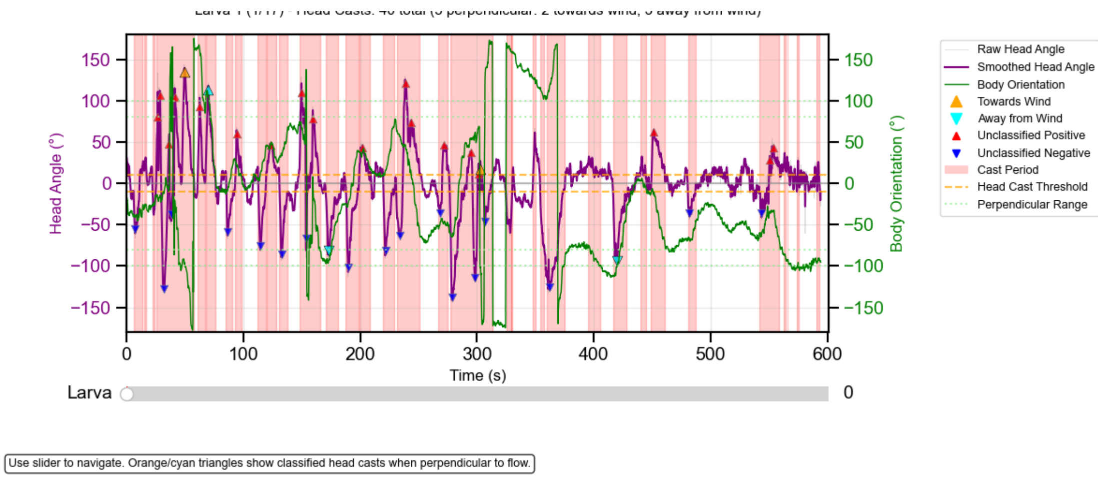


[15]:
```python
# Detect head casts with new method
cast_events_data = data_processor.detect_head_casts_in_casts(
    trx_filtered_by_merging,
    peak_threshold=10.0,
    peak_prominence=10.0,
    smooth_sigma=10,
    print_summary=True
)
```

```python
# Plot with individual subplots
fig = plot_data.plot_cast_detection_results(
    trx_filtered_by_merging,
    cast_events_data,
    figsize=(12,5),
    save_path=os.path.join(output_dir, 'cast_detection_all_larvae.pdf'),
    time_range=None  # Full time range
)
```

```
 Head Cast Detection Summary (with Turn Detection)
================================================================================
Larva  1: 34 cast periods (12 turns),  40 head casts ( 5 perpendicular:  2
towards [40.0%],  3 away [60.0%])
Larva  2: 21 cast periods ( 5 turns),  34 head casts ( 4 perpendicular:  0
towards [0.0%],  4 away [100.0%])
Larva  4: 23 cast periods ( 3 turns),  32 head casts ( 3 perpendicular:  0
towards [0.0%],  3 away [100.0%])
Larva  7: 28 cast periods ( 3 turns),  46 head casts (11 perpendicular:  5
towards [45.5%],  6 away [54.5%])
Larva  9: 40 cast periods ( 3 turns),  27 head casts ( 4 perpendicular:  2
towards [50.0%],  2 away [50.0%])
Larva 14: 24 cast periods ( 3 turns),  20 head casts ( 2 perpendicular:  0
towards [0.0%],  2 away [100.0%])
Larva 16: 27 cast periods ( 3 turns),  32 head casts ( 7 perpendicular:  1
towards [14.3%],  6 away [85.7%])
Larva 18: 30 cast periods ( 5 turns),  36 head casts ( 5 perpendicular:  2
towards [40.0%],  3 away [60.0%])
Larva 22: 39 cast periods ( 5 turns),  12 head casts ( 4 perpendicular:  2
towards [50.0%],  2 away [50.0%])
Larva 25: 38 cast periods ( 3 turns),  31 head casts ( 3 perpendicular:  3
towards [100.0%],  0 away [0.0%])
Larva 26: 11 cast periods ( 4 turns),  24 head casts ( 3 perpendicular:  2
towards [66.7%],  1 away [33.3%])
Larva 80: 19 cast periods ( 3 turns),  17 head casts ( 1 perpendicular:  0
towards [0.0%],  1 away [100.0%])
Larva 86: 26 cast periods ( 1 turns),  24 head casts ( 3 perpendicular:  1
towards [33.3%],  2 away [66.7%])
Larva 96: 27 cast periods ( 4 turns),  31 head casts ( 5 perpendicular:  3
towards [60.0%],  2 away [40.0%])
Larva 116: 26 cast periods ( 2 turns),  17 head casts ( 4 perpendicular:  2
towards [50.0%],  2 away [50.0%])
Larva 117: 10 cast periods ( 6 turns),  19 head casts ( 9 perpendicular:  4
towards [44.4%],  5 away [55.6%])
Larva 126: 20 cast periods ( 4 turns),  17 head casts ( 3 perpendicular:  0
towards [0.0%],  3 away [100.0%])
--------------------------------------------------------------------------------
TOTAL:     443 cast periods (69 turns), 459 head casts (76 perpendicular)
```

```
Overall:   29 towards [38.2%], 47 away [61.8%]
Mean across larvae: 35.0% ± 7.0% towards, 65.0% ± 7.0% away (n=17 larvae)
Average head casts per larva: 27.0
Average head casts per cast period: 1.0
Turn rate: 15.6% (69/443 casts)

 Saved: /Users/sharbat/Projects/anemotaxis/data/FCF_attP2-
40@UAS_TNT_2_0003/p_5gradient2_2s1x600s0s#n#n#n/20240223_112627/analyses/cast_de
tection_all_larvae.pdf
```



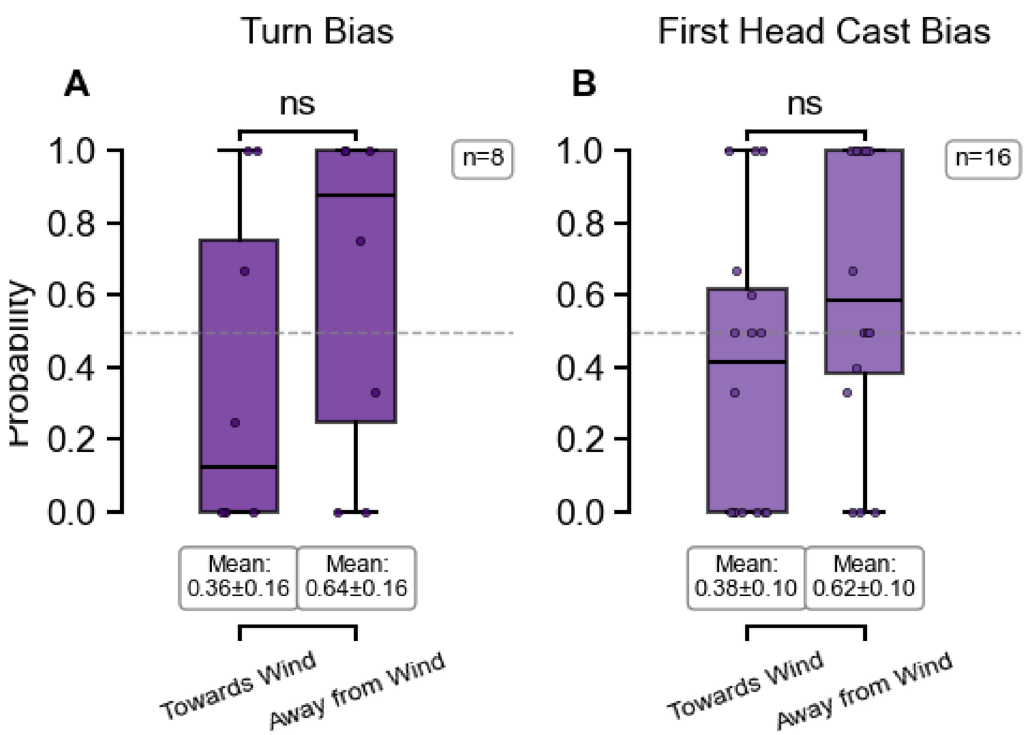
[16]:
```python
# Analyze first head cast bias
bias_results_first = data_processor.analyze_head_cast_bias(
    cast_events_data,
    analysis_type='first'
)

# NEW: Analyze turn bias from perpendicular orientations
bias_results_turn = data_processor.analyze_head_cast_bias(
    cast_events_data,
    analysis_type='turn'
)

# Create 1x2 figure layout for first head cast bias and turn bias only
fig_bias = plt.figure(figsize=(6, 4))  # Reduced width for 2 plots
gs_bias = GridSpec(1, 2, figure=fig_bias,
                   left=0.10, right=0.90,  # Adjusted margins
                   top=0.85, bottom=0.15,
                   wspace=0.3)  # Spacing for 2 plots

# Plot turn bias (first panel)
ax_bias1 = fig_bias.add_subplot(gs_bias[0, 0])
plot_data.plot_head_cast_bias_perpendicular(
```

```
    bias_results_turn,
    ax=ax_bias1,
    title='Turn Bias',
    plot_type='violn'
)
ax_bias1.text(-0.15, 1.05, 'A', transform=ax_bias1.transAxes,
              fontsize=14, fontweight='bold', va='top', ha='left')

# Plot first head cast bias (second panel)
ax_bias2 = fig_bias.add_subplot(gs_bias[0, 1])
plot_data.plot_head_cast_bias_perpendicular(
    bias_results_first,
    ax=ax_bias2,
    title='First Head Cast Bias',
    plot_type='violn'
)
ax_bias2.text(-0.15, 1.05, 'B', transform=ax_bias2.transAxes,
              fontsize=14, fontweight='bold', va='top', ha='left')
ax_bias2.set_ylabel('')  # Remove y-label for second plot

# Save the combined figure
fig_bias.savefig(os.path.join(output_dir, 'head_cast_bias_first_and_turn.pdf'),
                bbox_inches='tight',
                dpi=300,
                transparent=True,
                facecolor='none')
print(f"First head cast bias and turn bias figure saved to: {os.path.
 ↪join(output_dir, 'head_cast_bias_first_and_turn.pdf')}")

plt.show()
```

```
 First Head Cast Bias Analysis
============================================================
Larva  1:  3 first perpendicular head casts ( 0 towards [0.0%],  3 away
[100.0%])
Larva  2:  3 first perpendicular head casts ( 0 towards [0.0%],  3 away
[100.0%])
Larva  4:  3 first perpendicular head casts ( 0 towards [0.0%],  3 away
[100.0%])
Larva  7:  5 first perpendicular head casts ( 3 towards [60.0%],  2 away
[40.0%])
Larva  9:  1 first perpendicular head casts ( 0 towards [0.0%],  1 away
[100.0%])
Larva 14:  2 first perpendicular head casts ( 0 towards [0.0%],  2 away
[100.0%])
Larva 16:  2 first perpendicular head casts ( 0 towards [0.0%],  2 away
[100.0%])
```

```
Larva 18:  1 first perpendicular head casts ( 1 towards [100.0%],  0 away
[0.0%])
Larva 22:  4 first perpendicular head casts ( 2 towards [50.0%],  2 away
[50.0%])
Larva 25:  3 first perpendicular head casts ( 3 towards [100.0%],  0 away
[0.0%])
Larva 26:  1 first perpendicular head casts ( 1 towards [100.0%],  0 away
[0.0%])
Larva 80:  1 first perpendicular head casts ( 0 towards [0.0%],  1 away
[100.0%])
Larva 86:  2 first perpendicular head casts ( 1 towards [50.0%],  1 away
[50.0%])
Larva 96:  3 first perpendicular head casts ( 2 towards [66.7%],  1 away
[33.3%])
Larva 116:  2 first perpendicular head casts ( 1 towards [50.0%],  1 away
[50.0%])
Larva 117:  3 first perpendicular head casts ( 1 towards [33.3%],  2 away
[66.7%])

  Statistical Tests (n=12 larvae with  2 events):
    Wilcoxon signed-rank test: p=0.1484
      No significant bias detected (Wilcoxon p  0.05)
------------------------------------------------------------
TOTAL: 39 first perpendicular head casts
Overall: 15 towards [38.5%], 24 away [61.5%]
Mean across larvae: 38.1% ± 9.9% towards, 61.9% ± 9.9% away (n=16 larvae)

  Turn Head Cast Bias Analysis
============================================================
Larva  1:  4 turns ( 1 towards [25.0%],  3 away [75.0%])
Larva  7:  1 turns ( 1 towards [100.0%],  0 away [0.0%])
Larva 18:  1 turns ( 1 towards [100.0%],  0 away [0.0%])
Larva 22:  3 turns ( 2 towards [66.7%],  1 away [33.3%])
Larva 26:  1 turns ( 0 towards [0.0%],  1 away [100.0%])
Larva 96:  1 turns ( 0 towards [0.0%],  1 away [100.0%])
Larva 116:  1 turns ( 0 towards [0.0%],  1 away [100.0%])
Larva 117:  2 turns ( 0 towards [0.0%],  2 away [100.0%])

  Statistical Tests (n=3 larvae with  2 events):
    Wilcoxon signed-rank test: p=0.5000
      No significant bias detected (Wilcoxon p  0.05)
------------------------------------------------------------
TOTAL: 14 perpendicular turns
Overall: 5 towards [35.7%], 9 away [64.3%]
Mean across larvae: 36.5% ± 16.1% towards, 63.5% ± 16.1% away (n=8 larvae)

=== MEDIANS AND QUARTILES ===
```

```
Towards Wind - Median: 0.125, Q1: 0.000, Q3: 0.750
Away from Wind - Median: 0.875, Q1: 0.250, Q3: 1.000

=== MEDIANS AND QUARTILES ===
Towards Wind - Median: 0.417, Q1: 0.000, Q3: 0.617
Away from Wind - Median: 0.583, Q1: 0.383, Q3: 1.000
First head cast bias and turn bias figure saved to: /Users/sharbat/Projects/anem
otaxis/data/FCF_attP2-
40@UAS_TNT_2_0003/p_5gradient2_2s1x600s0s#n#n#n/20240223_112627/analyses/head_ca
st_bias_first_and_turn.pdf
```



[17]:
```python
# Analyze head casts by cast start orientation - separated by turn success
head_cast_orientation_results = data_processor.
↪analyze_head_casts_by_orientation(
    trx_filtered_by_merging,
    bin_width=20,
    peak_threshold=10.0,
    peak_prominence=10.0,
    smooth_sigma=10,
    large_casts_only=True,
    separate_by_turn_success=True,  # NEW PARAMETER
    min_turn_amplitude=45
)
```

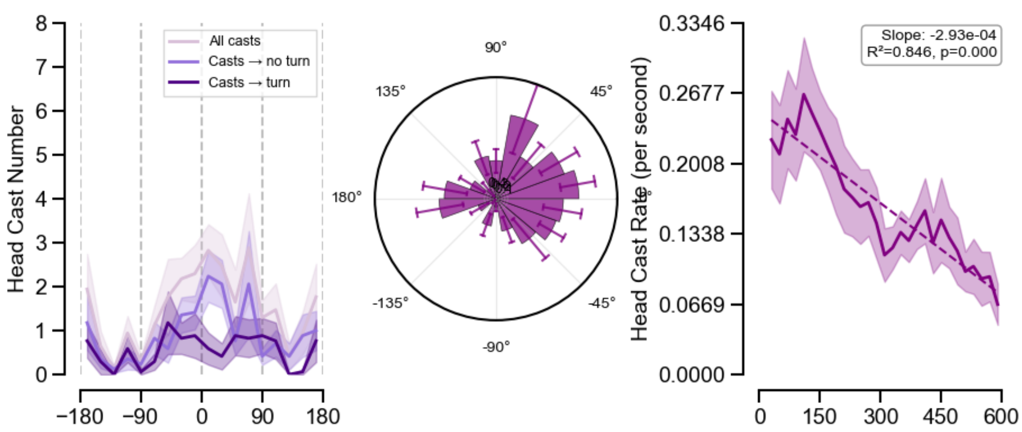
```
# Create combined figure for head cast analysis
fig_head_casts = plt.figure(figsize=(10, 4))
gs_head_casts = GridSpec(1, 3, figure=fig_head_casts,
                        left=0.08, right=0.90,
                        top=0.93, bottom=0.15,
                        wspace=0.4,
                        width_ratios=[0.6, 0.6, 0.6])

# Row 1: Head Cast Analysis
ax_hc1 = fig_head_casts.add_subplot(gs_head_casts[0, 0])
ax_hc2 = fig_head_casts.add_subplot(gs_head_casts[0, 1], projection='polar')
ax_hc3 = fig_head_casts.add_subplot(gs_head_casts[0, 2])

# Linear plot with turn success separation
plot_data.plot_head_cast_orientation_by_turn_success(
    head_cast_orientation_results,
    ax=ax_hc1,
    show_xlabel=True,
    ylabel='Head Cast Number',
    ylim=[0,8]
)

# Polar plot (use all casts for polar representation)
plot_data.plot_orientation_histogram_polar(head_cast_orientation_results,
                                        ax=ax_hc2,
                                        plot_type='head_cast',
                                        bar_style=True,
                                        tick_fontsize=10)
ax_hc2_pos = ax_hc2.get_position()
ax_hc2.set_position([ax_hc2_pos.x0 - 0.04, ax_hc2_pos.y0, ax_hc2_pos.width,
 ↪ax_hc2_pos.height])

# Time series plot (analyze head casts over time - this uses a different
 ↪function)
head_cast_time_results = data_processor.analyze_head_casts_over_time(
    trx_filtered_by_merging,
    window=60,
    step=20,
    peak_threshold=20.0,
    peak_prominence=3.0,
    smooth_sigma=4.0,
    large_casts_only=True
)

plot_data.plot_metric_over_time(
```

```
    head_cast_time_results, plot_type='head_cast', ylabel='Head Cast Rate (per␣
↪second)',
    show_individuals=False, show_error=True, ax=ax_hc3, show_xlabel=False
)

# Save the head cast analysis figure
fig_head_casts.savefig(os.path.join(output_dir,␣
↪'head_cast_analysis_by_turn_success.pdf'),
                      bbox_inches='tight',
                      dpi=300,
                      transparent=True,
                      facecolor='none')
print(f"Head cast analysis figure saved to: {os.path.join(output_dir,␣
↪'head_cast_analysis_by_turn_success.pdf')}")

plt.show()
```

```
 Head Casts by Turn Success Analysis (Min turn: 45°)
================================================================================
Larva  1: 34 casts (12 turns, 22 non-turns, 35.3%)
           Head casts: 27 in successful turns, 13 in unsuccessful, 40 total
Larva  2: 21 casts ( 5 turns, 16 non-turns, 23.8%)
           Head casts: 17 in successful turns, 17 in unsuccessful, 34 total
Larva  4: 23 casts ( 3 turns, 20 non-turns, 13.0%)
           Head casts:  8 in successful turns, 24 in unsuccessful, 32 total
Larva  7: 28 casts ( 3 turns, 25 non-turns, 10.7%)
           Head casts:  6 in successful turns, 40 in unsuccessful, 46 total
Larva  9: 40 casts ( 3 turns, 37 non-turns,  7.5%)
           Head casts:  9 in successful turns, 18 in unsuccessful, 27 total
Larva 14: 24 casts ( 3 turns, 21 non-turns, 12.5%)
           Head casts: 10 in successful turns, 10 in unsuccessful, 20 total
Larva 16: 27 casts ( 3 turns, 24 non-turns, 11.1%)
           Head casts: 12 in successful turns, 20 in unsuccessful, 32 total
Larva 18: 30 casts ( 5 turns, 25 non-turns, 16.7%)
           Head casts: 15 in successful turns, 21 in unsuccessful, 36 total
Larva 22: 39 casts ( 5 turns, 34 non-turns, 12.8%)
           Head casts:  5 in successful turns,  7 in unsuccessful, 12 total
Larva 25: 38 casts ( 3 turns, 35 non-turns,  7.9%)
           Head casts:  4 in successful turns, 27 in unsuccessful, 31 total
Larva 26: 11 casts ( 4 turns,  7 non-turns, 36.4%)
           Head casts: 10 in successful turns, 14 in unsuccessful, 24 total
Larva 80: 19 casts ( 3 turns, 16 non-turns, 15.8%)
           Head casts:  8 in successful turns,  9 in unsuccessful, 17 total
Larva 86: 26 casts ( 1 turns, 25 non-turns,  3.8%)
           Head casts:  2 in successful turns, 22 in unsuccessful, 24 total
Larva 96: 27 casts ( 4 turns, 23 non-turns, 14.8%)
```

```
           Head casts:  7 in successful turns, 24 in unsuccessful, 31 total
Larva 116: 26 casts ( 2 turns, 24 non-turns,  7.7%)
           Head casts:  9 in successful turns,  8 in unsuccessful, 17 total
Larva 117: 10 casts ( 6 turns,  4 non-turns, 60.0%)
           Head casts: 12 in successful turns,  7 in unsuccessful, 19 total
Larva 126: 20 casts ( 4 turns, 16 non-turns, 20.0%)
           Head casts: 10 in successful turns,  7 in unsuccessful, 17 total
--------------------------------------------------------------------------------
SUMMARY:
  Total cast events: 443
  Successful turns: 69 (15.6%)
  Unsuccessful casts: 374 (84.4%)
  Head casts in successful turns: 171
  Head casts in unsuccessful casts: 288
  Total head casts: 459
  Mean head casts per successful turn: 2.5
  Mean head casts per unsuccessful cast: 0.8
```

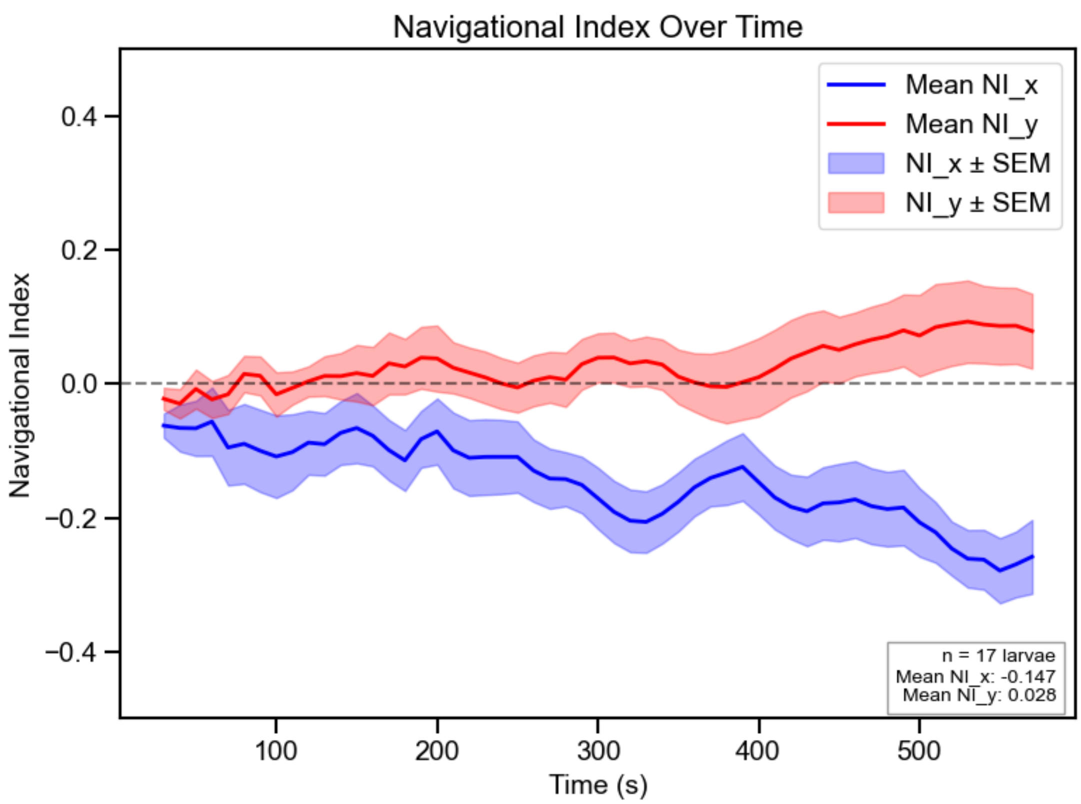
```
Head cast analysis figure saved to: /Users/sharbat/Projects/anemotaxis/data/FCF_
attP2-
40@UAS_TNT_2_0003/p_5gradient2_2s1x600s0s#n#n#n/20240223_112627/analyses/head_ca
st_analysis_by_turn_success.pdf
```



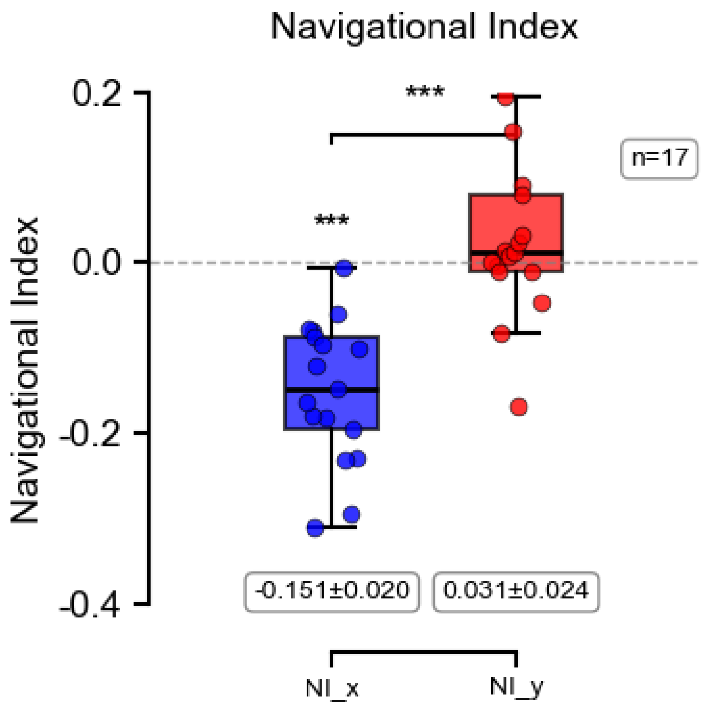

```python
[18]: # 1. Analyze NI over time
ni_time_results = data_processor.analyze_navigational_index_over_time(
    trx_filtered_by_merging, window=60, step=10, t_max=600
)

# 2. Analyze single NI values per larva
ni_single_results = data_processor.analyze_navigational_index_single_values(
    trx_filtered_by_merging, window=60, step=10, t_max=600
)
```

```python
# 3. Plot time series
fig_time = plot_data.plot_navigational_index_over_time(
    ni_time_results,
    save_path=os.path.join(output_dir, 'ni_over_time.pdf')
)

# 4. Plot box plots
fig_box = plot_data.plot_navigational_index_boxplot(
    ni_single_results,
    save_path=os.path.join(output_dir, 'ni_boxplot.pdf')
)
```

```
Figure saved to /Users/sharbat/Projects/anemotaxis/data/FCF_attP2-
40@UAS_TNT_2_0003/p_5gradient2_2s1x600s0s#n#n#n/20240223_112627/analyses/ni_over
_time.pdf
```




```
Figure saved to /Users/sharbat/Projects/anemotaxis/data/FCF_attP2-
40@UAS_TNT_2_0003/p_5gradient2_2s1x600s0s#n#n#n/20240223_112627/analyses/ni_boxp
lot.pdf
```




```
=== NAVIGATIONAL INDEX ANALYSIS ===
Number of larvae: 17
Mean NI_x: -0.151 (p=0.0000, ***)
Mean NI_y: 0.031 (p=0.2105, ns)
Paired comparison NI_x vs NI_y: p=0.0002
RESULT: NI_x and NI_y are significantly different from each other
```

[19]:

```python
# In analyze_single_anemotaxis.ipynb, replace the save_analysis_results call␣
↪with:
saved_file = data_loader.save_analysis_results(
    output_dir,
    single_path,
    trx_filtered_by_merging,

    # Orientation-based analyses (consistent naming)
    run_prob_results=run_prob_results,
    turn_prob_results=turn_prob_results,
    turn_amp_results=turn_amp_results,
    backup_prob_results=backup_prob_results,
    velocity_results=velocity_results,

    # Time-based analyses (consistent naming)
```

```
    run_prob_time_results=run_prob_time_results,
    turn_prob_time_results=turn_prob_time_results,
    turn_amp_time_results=turn_amp_time_results,
    backup_prob_time_results=backup_prob_time_results,
    velocity_time_results=velocity_time_results,

    # Head cast analyses
    # cast_events_data=cast_events_data,
    bias_results_first=bias_results_first,
    # bias_results_last=bias_results_last,
    # bias_results_all=bias_results_all,
    bias_results_turn=bias_results_turn,
    head_cast_orientation_results=head_cast_orientation_results,
    head_cast_time_results=head_cast_time_results,

    # NI results
    ni_time_results=ni_time_results,
    ni_single_results=ni_single_results
)
```

```
Saving run_prob_results…
Saving turn_prob_results…

Saving turn_amp_results…
Saving backup_prob_results…
Saving velocity_results…

Saving run_prob_time_results…
Saving turn_prob_time_results…
Saving turn_amp_time_results…
Saving backup_prob_time_results…
Saving velocity_time_results…
Saving bias_results_first…
Saving bias_results_turn…
Saving head_cast_orientation_results…
Saving head_cast_time_results…

Saving ni_time_results…
Saving ni_single_results…
Analysis results saved to: /Users/sharbat/Projects/anemotaxis/data/FCF_attP2-
40@UAS_TNT_2_0003/p_5gradient2_2s1x600s0s#n#n#n/20240223_112627/analyses/analysi
s_results_20251120_162026.h5
```