Saccade Analysis for Childhood Hemispherectomy Patients

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Background & Introduction

Children with hemispherectomy, i.e. half their brains removed, during childhood typically to prevent otherwise intractable epilepsy.

Sinusoidal Pursuit

- Saccades are rapid, jerky movements of the eyes that abruptly change the point of fixation.
- Ipsilesional (ipsi) movements are those towards the same side of hemispherectomy, while contralesional (contra) movements are towards the opposite side of surgery.

Research Question

- What is the impact of hemispherectomy on saccadic eye movements?
- How does the observed differences vary across individual subjects?

Data

- Data consist of 4494 saccades from 25 subjects (14 controls, 11 patients).
- Key Variables:
  - Saccade Amplitude: Absolute value of the horizontal deviations from the screen center of each individual saccade (in degree of visual angle).
  - Saccade Velocity: Absolute value of the normalized change in amplitude per millisecond of each individual saccade (in degree/millisecond).
  - Log-transformed saccade amplitudes and velocities.

Exploratory Data Analysis

- Figure 1 shows that controls have similar distributions of log velocity between ipsi and contra; patients have a right-shifted distribution with higher variance in ipsi.
- Figure 2 shows distributions of log amplitude, with similar observation as in Figure 1 comparing patients and controls.
- In general, higher log velocities & amplitudes in ipsi than contra among patients.
- Quadrant Analysis

  - Figure 3 shows split scatter plot in four quadrants.
  - More data concentrates in Q2.
  - Patients in Q2: ipsi have higher log Velocity & amplitude than contra.
  - Linear trend between log velocity and log amplitude in Q2.

Methods

- Mixed Effects Models:
  - Focus on Q2 since it has more data than other quadrants.
  - Linear trend between velocity and amplitude is more obvious.
  - Predict log velocities with predictors: log amplitudes (slope), Participant Type (indicator), Saccade Direction (indicator).
  - Used Mixed Effects model because they repeated measures of each participant from multiple trials.
  - Model Formula:
    - Model 0: OLS linear regression model, with all interactions including 3-way and fixed effects (BIC = 3325).
    - Model 1: model 0 + random intercept (BIC = 2877).
    - Model 2a: model 0 + random intercept + random slope (BIC = 2702).
    - Model 2b: model 0 + random intercept + random slope, minus 3-way interaction (BIC = 2694).

Results

- Model Comparison: Goodness of Fit BIC
  - Models with random effects fit better.
  - Model 2b produces better fit.

Coeficient Estimates

- Figure 4 shows regression lines in Model 2b for each subgroup (e.g. patient-ipsi).
- Slopes across groups tend to be similar.
- Intercepts systematically different between control and patient.

- Quadrant Analysis

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Conclusions

- Observed significantly higher intercept for patients than controls in mixed effects model, which confirms and characterizes impact of childhood hemispherectomy.
- Among patients, observed significantly higher intercept in ipsi than contra movements in mixed effects models.
- Future work might involve 1) further investigating influential subjects in variability of surgery impact and 2) explore objective thresholds for quadrant division.

References