Saccade Analysis for Childhood Hemispherectomy Patients

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Background & Introduction

Childhood Hemispherectomy
- Patients had 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 this impact differ between ipsi and contra movements?
- How does the observed differences vary across individual subject?

Data

Data & Data Preprocessing
- Data consist of 4494 saccades from 25 subjects (14 controls, 11 patients)
- Key Variables:
  - Saccade Amplitude: Absolute value of the horizontal deviations from 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 / ms)
- 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.
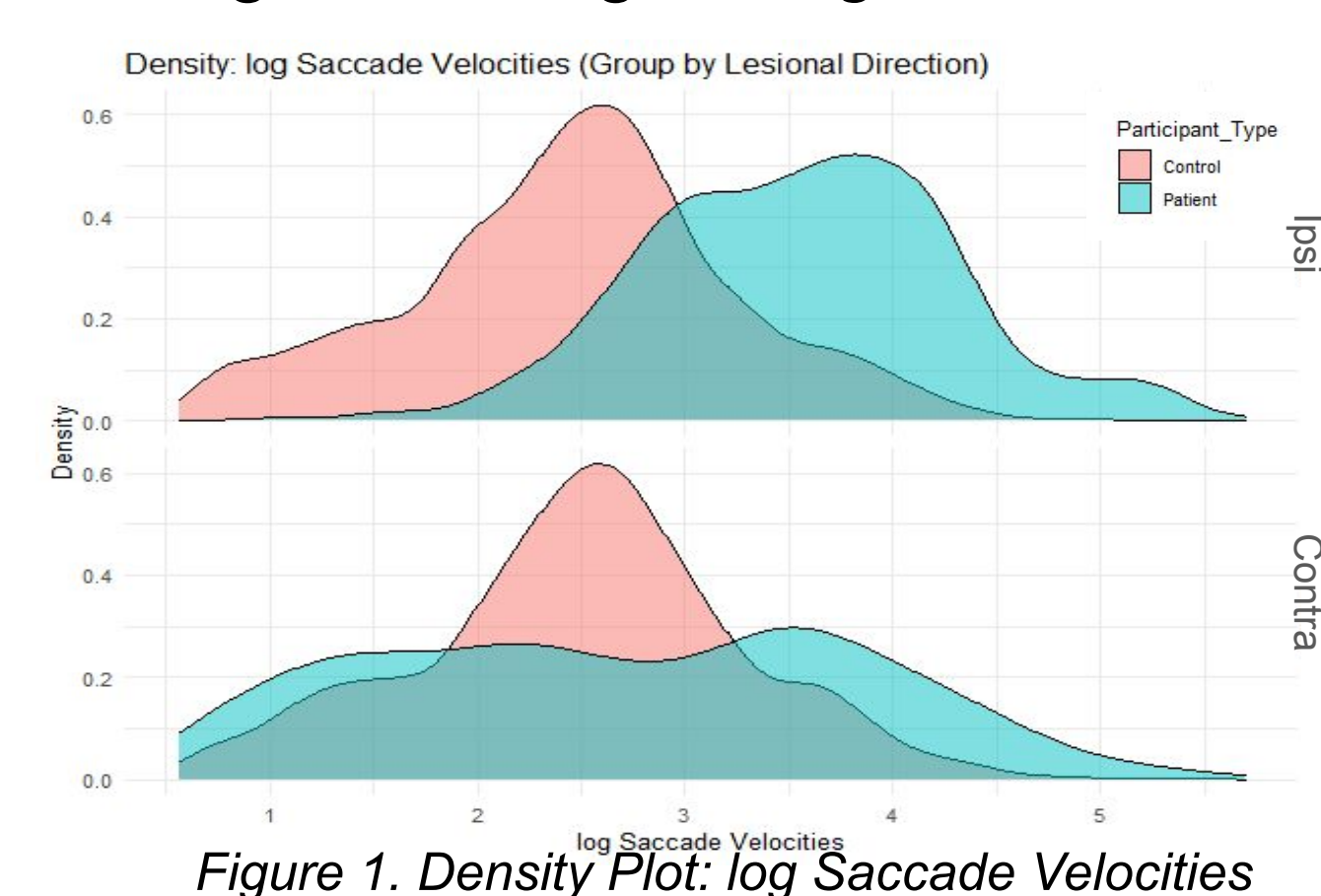- In general, higher *log velocities* & *amplitudes* in ipsi than contra among patients

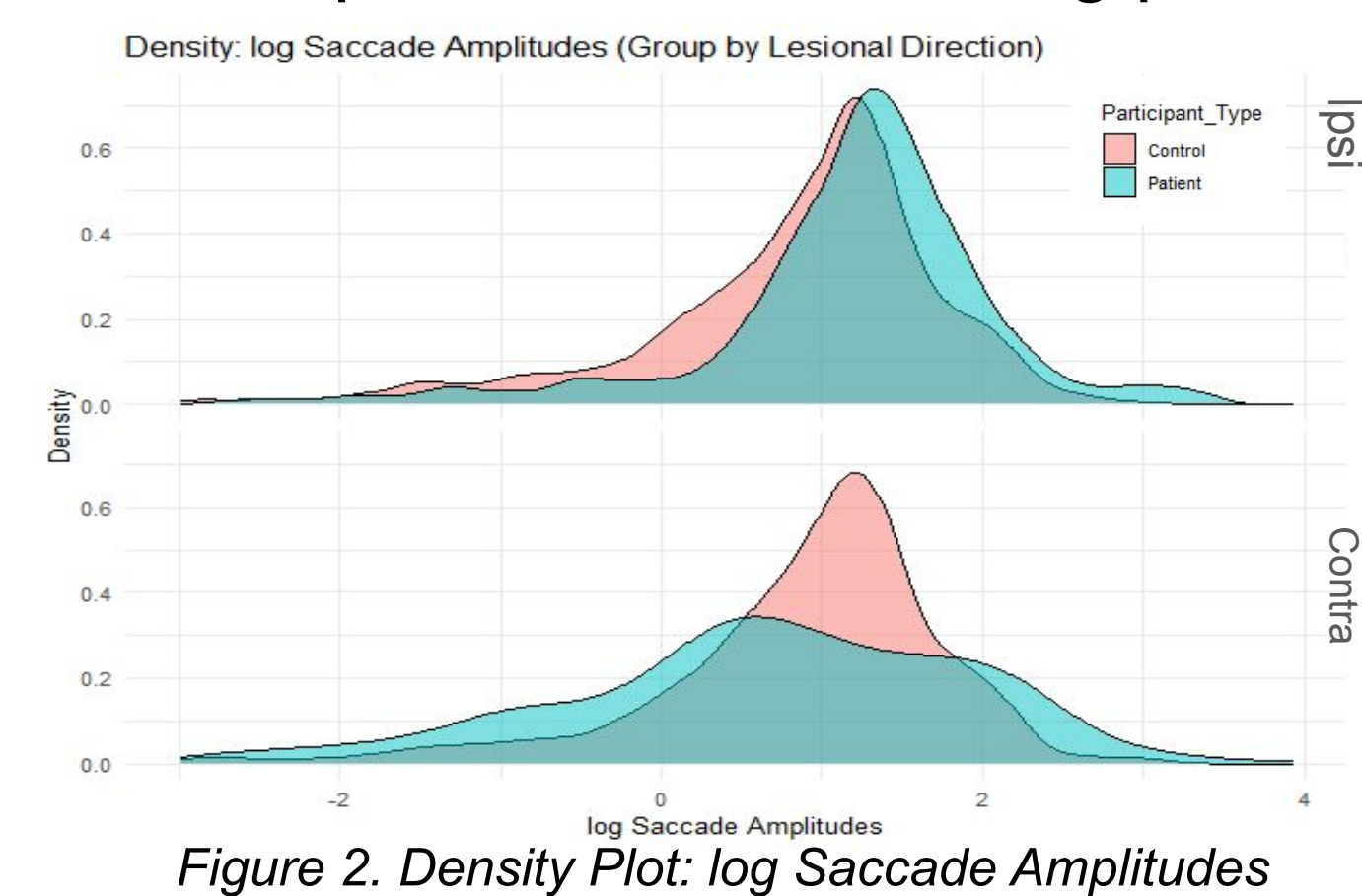*Figure 1. Density Plot: log Saccade Velocities*

Figure 2. Density Plot: log Saccade Amplitudes

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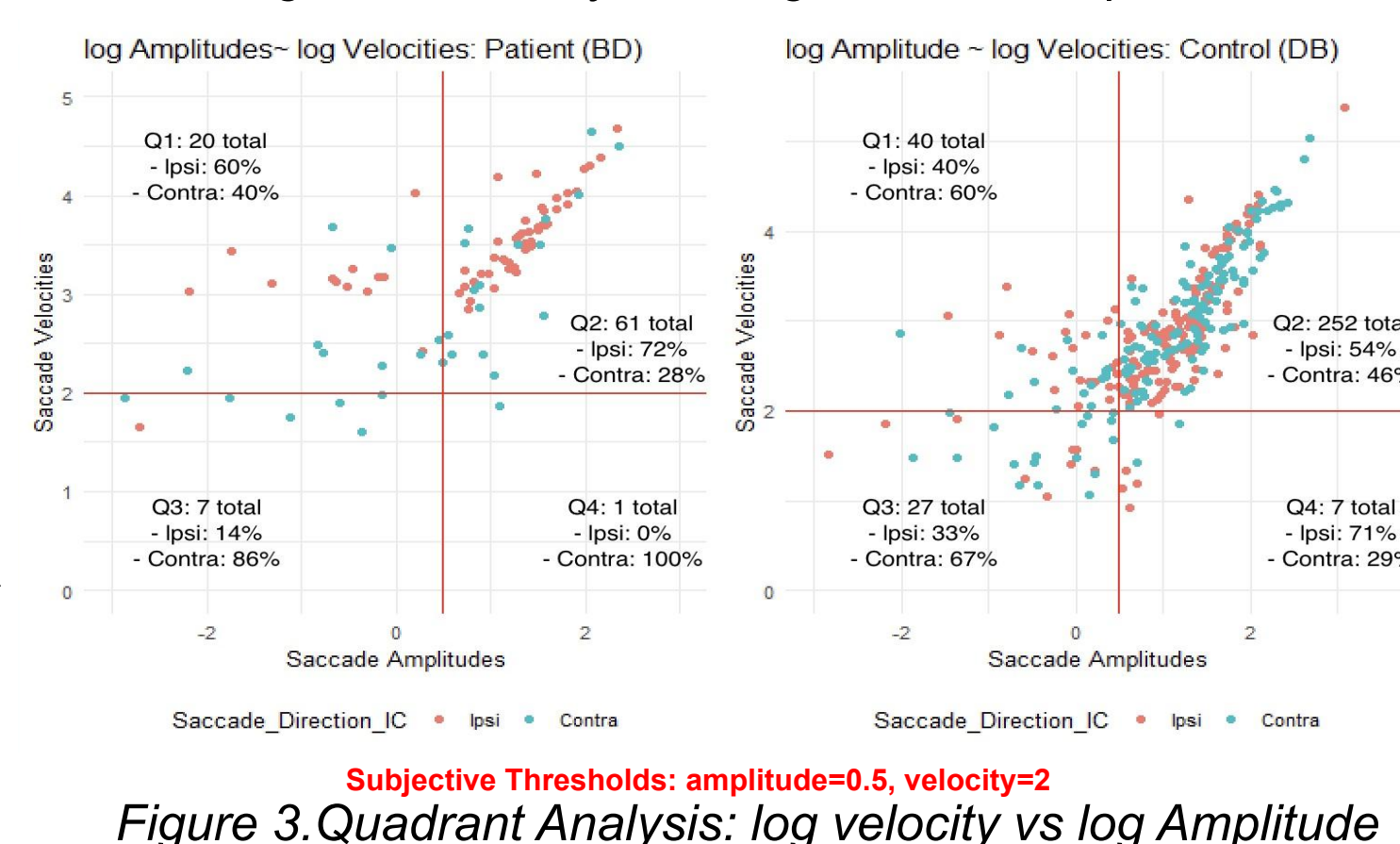- Linear trend between log velocity and log amplitude in Q2

Figure 3.Quadrant Analysis: log velocity vs log Amplitude

Methods

Mixed Effects Models
- Focus on Q2 since 1) it has more data than other quadrants 2) its 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

Fixed effects:	Estimate	Std. Error	t value
(Intercept)	1.72883	0.13637	12.677
log(Saccade_Amplitudes)	0.84233	0.07092	11.878
Participant_TypePatient	0.68380	0.18196	3.758
Saccade_Direction_ICContra	0.04121	0.04127	0.998
log(Saccade_Amplitudes):Participant_TypePatient	0.07786	0.09387	0.829
log(Saccade_Amplitudes):Saccade_Direction_ICContra	-0.02289	0.02833	-0.808
Participant_TypePatient:Saccade_Direction_ICContra	-0.35378	0.03286	-10.765

Table 1. Model 2b Regression Coefficients

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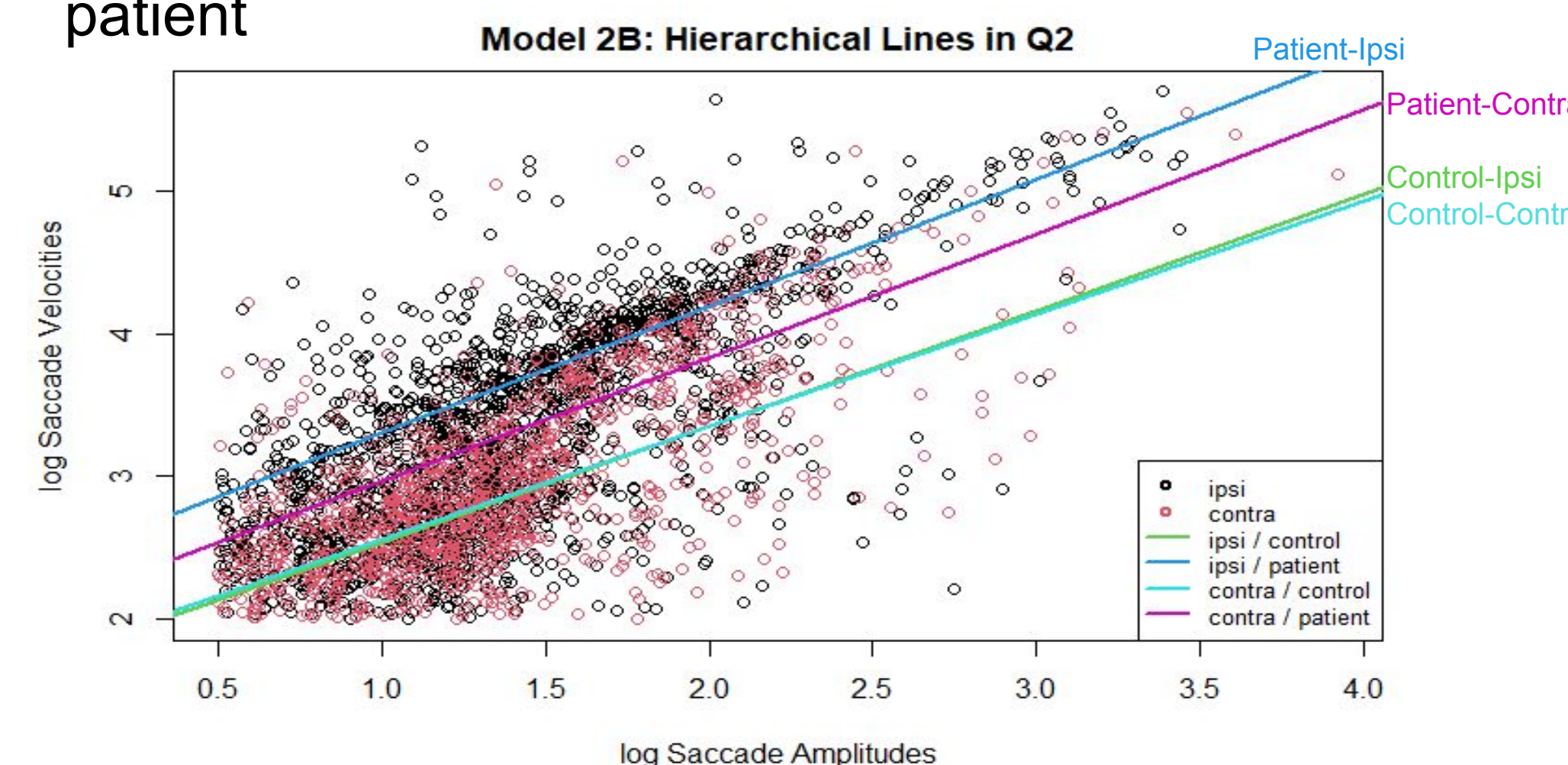- Intercepts systematically different between control and patient

Figure 4. Model 2b Hierarchical Regression Lines

Model Inference
- Linear relationship between log Amplitudes vs log Velocities
- Patients significantly higher than controls on intercepts
- Significant difference between ipsi/contra among patients means that the surgery impact on patients differ significantly between ipsi and contra saccades
- No difference among slopes across four subgroups(ipsi-patient, contra-patient, etc.)
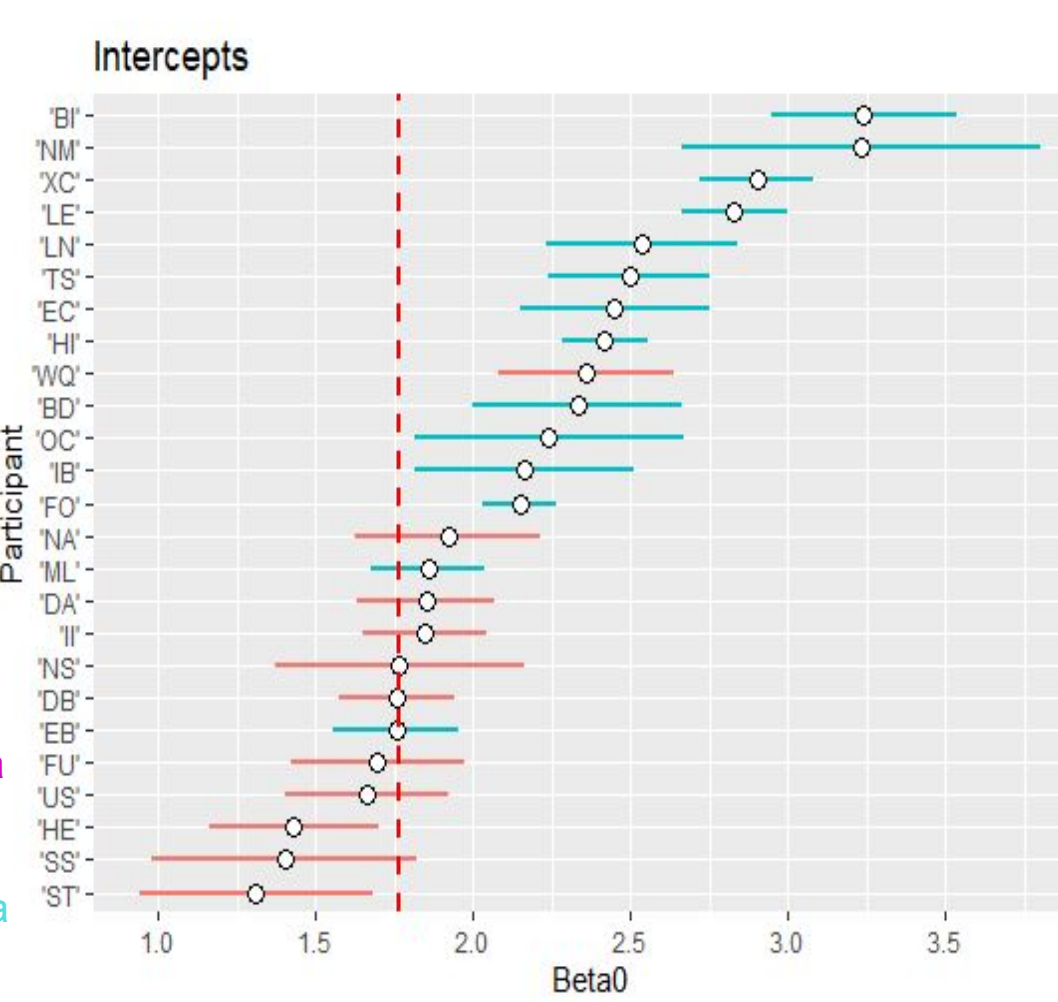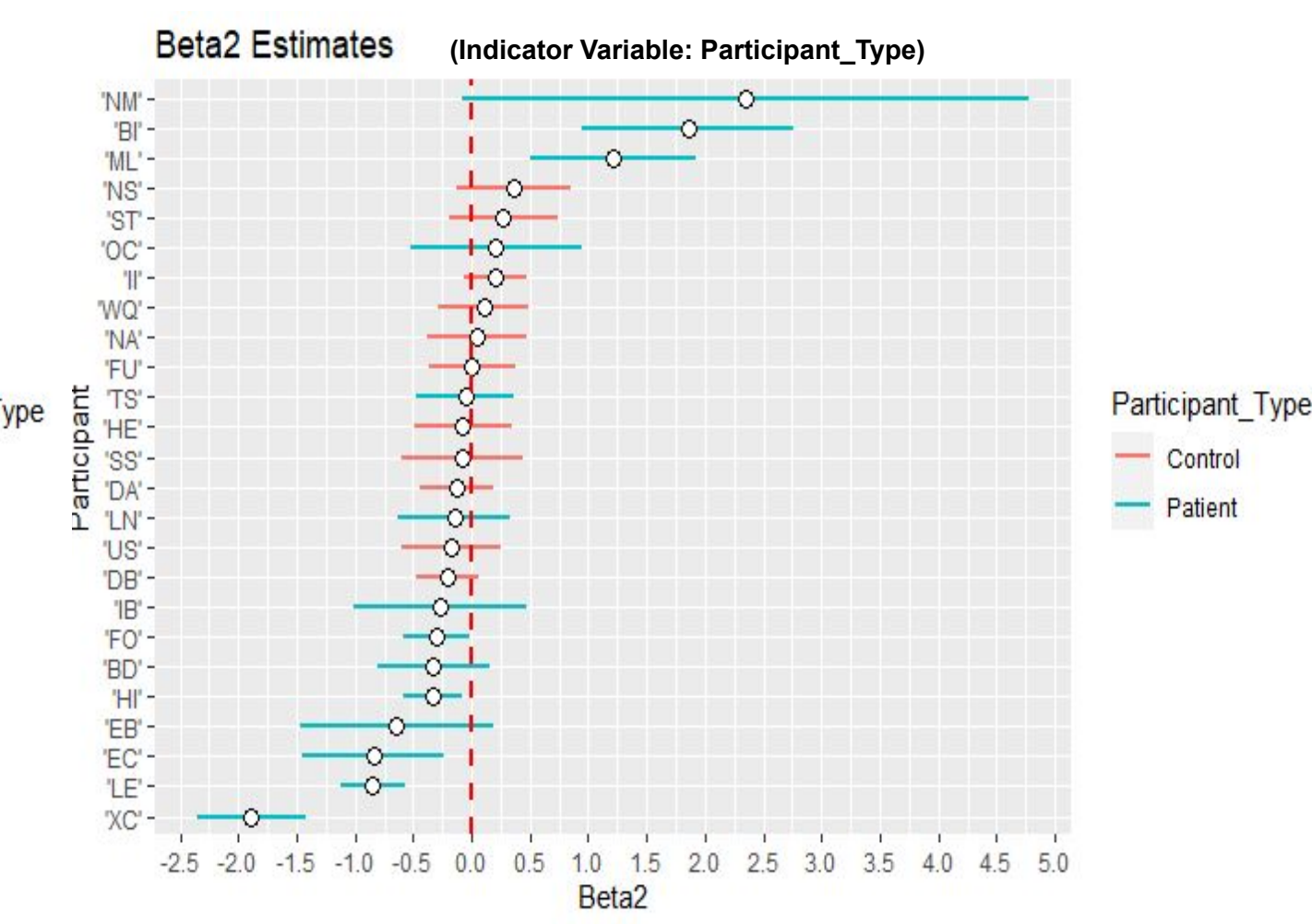

Figure 5. Individual Effects on Intercept

Figure 6. Individual Effects on Participant_Type

Individual Effects
- Figure 5. Shows that:
  - Patients have larger intercept than controls
  - All intercepts are higher than 0
- Figure 5. and 6. show that patients tend to have higher variability than controls.

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

- Troost, B Todd. Darrof, Robert B. Weber, and Ronald B. Dell'Osso, Louis F. *Hemispheric Control of Eye Movements*. Arch Neurol, Vol. 27, 1972.