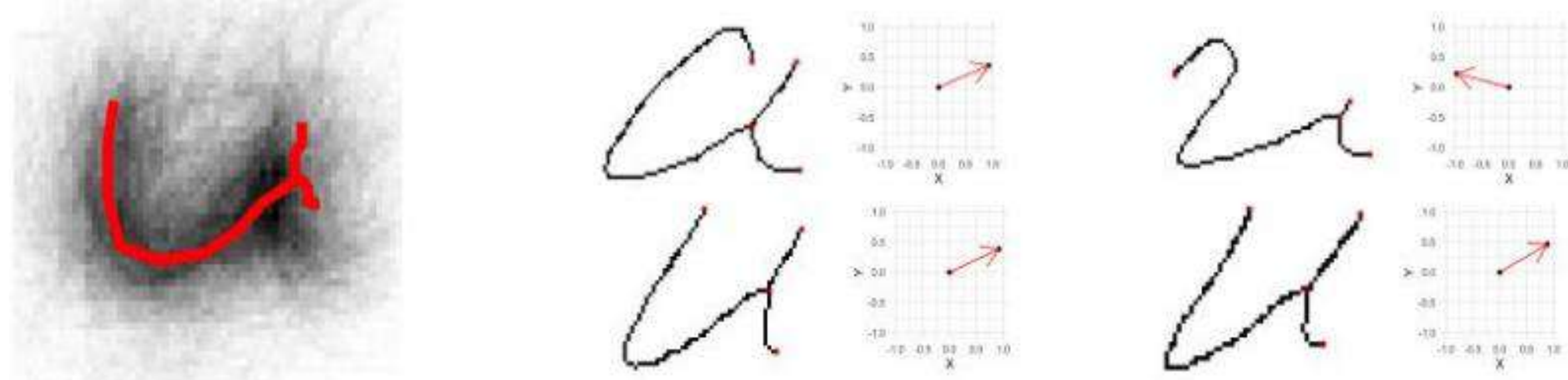


Project Rationale & Goals

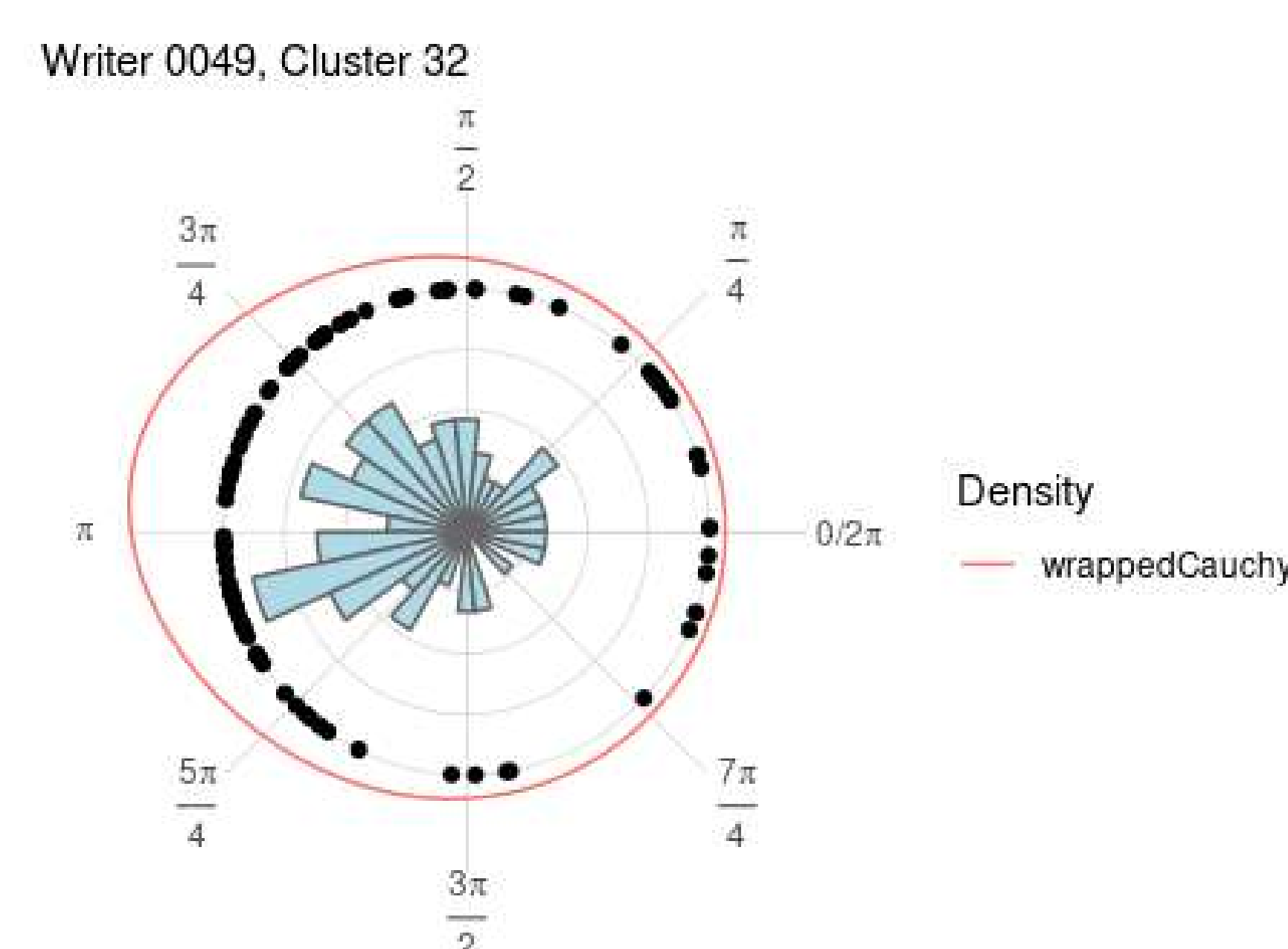
This study aims to provide statistical support for the relationship between demographic variables and the slant in a person's handwriting. Data of handwriting samples were collected and then broken into smaller segments of writing that we call "graphs" by the *handwriter* R package. They were then grouped into 40 clusters of similar graphs. For each graph, a quantitative measure of slant called the rotation angle is computed. An example graph with possible rotation angles is shown below. We then fit a regression with the demographic information as explanatory variables and the rotation angles as the response. As rotation angles live on a circle, the regression model is based on the *projected normal* probability model, appropriate for this type of circular data.



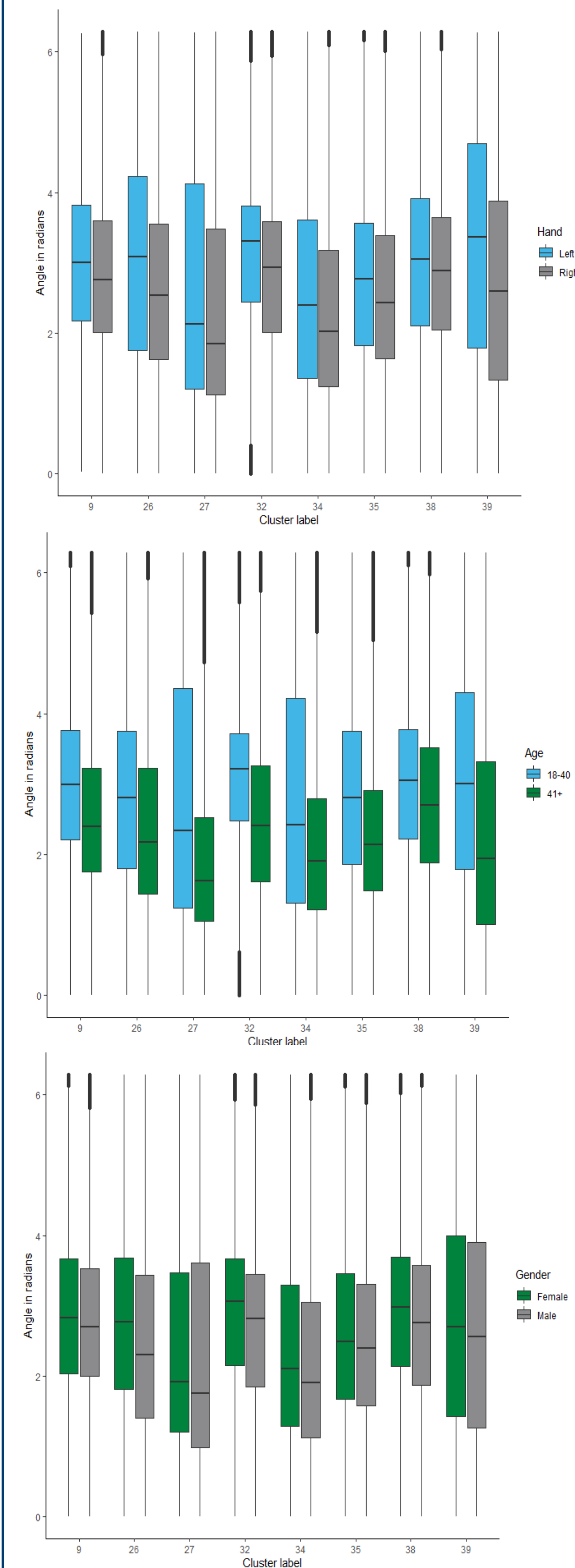
Data

- Handwritten samples were collected by CSAFE.
- We include data from 140 adults with three data collection sessions, each at least three weeks apart.
- At each session, participants provided information about the participant's handedness, age group, gender, and region of third-grade education.
- Due to sample size, we did not include region in the models, and we combined age groups of 18-40 and all ages above 41+ for analysis.

The slant of a writer is determined by calculating the direction of greatest variability in a graph using principal component decomposition and the angle of rotation corresponding to that direction. Below is an image of all the rotation angles from writer 49 cluster 32 plotted on the unit circle, in radians.

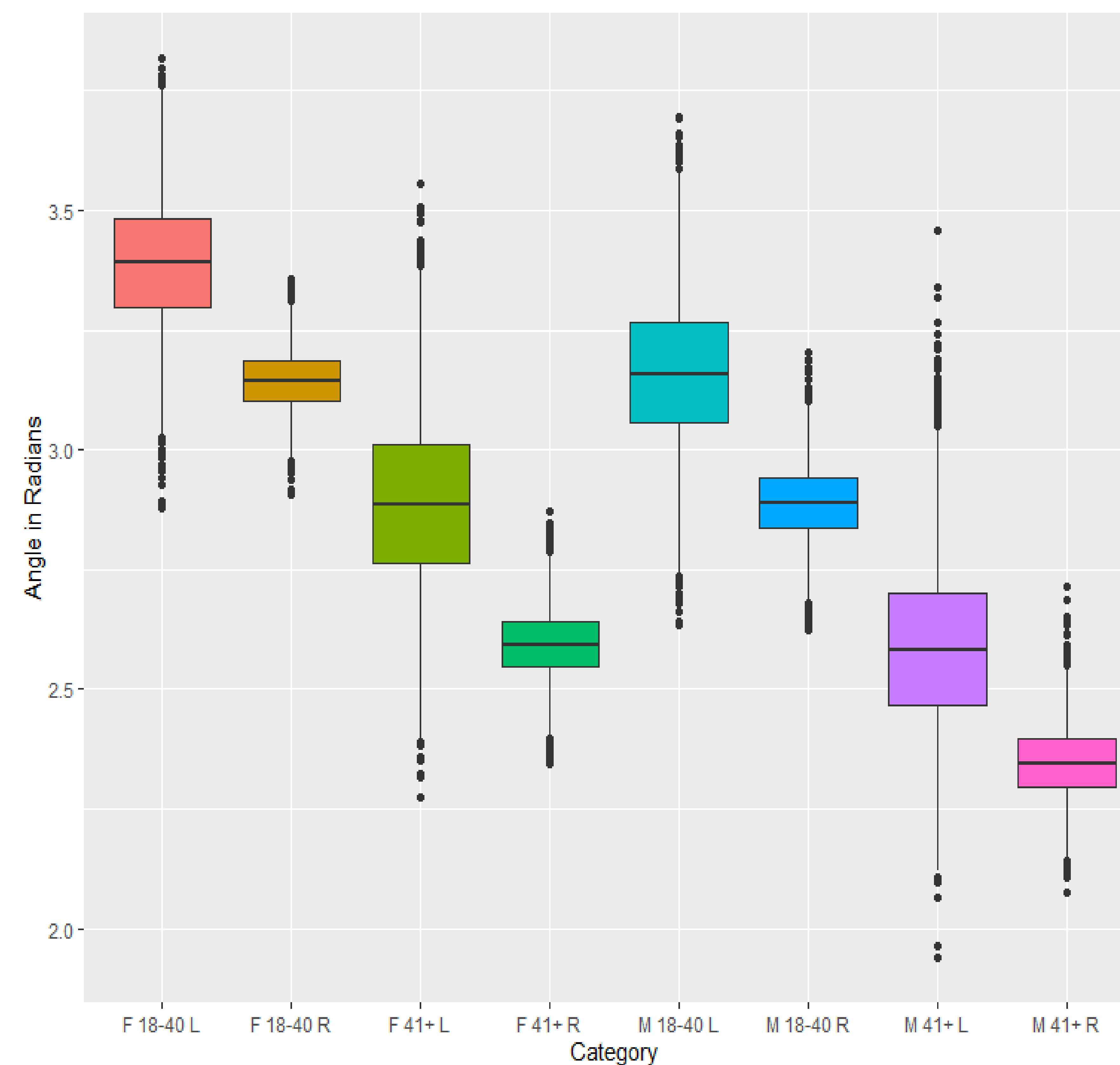


Methods and Results



We fit models using the *bpnreg* package in R. We fit multiple Bayesian Projected Normal Regression and Mixed Effect models using Age Group, Handedness, and Gender as the explanatory variables and Rotation Angle as the response. We only show results for the model that includes a random person effect. Mixed Effects are useful where there are repeated measurements on the same statistical units. Here we have multiple rotation angles for writer, therefore, we fit a model with writer as the mixed effect to account for the correlation between samples from each person. Some observed data summaries are shown to the left for angles in the 8 most populated clusters of graphs.

Predicted Values



Category	Mean	2.5%	97.5%
Female 18-40 Left	3.39	3.11	3.64
Female 18-40 Right	3.14	3.02	3.26
Female 41+ Left	2.89	2.55	3.26
Female 41+ Right	2.6	2.46	2.74
Male 18-40 Left	3.16	2.86	3.46
Male 18-40 Right	2.89	2.74	3.05
Male 41+ Left	2.59	2.28	2.95
Male 41+ Right	2.35	2.21	2.51

Conclusions

In the boxplot and from the above table, we can see the predicted means for each category. We can see that there is a difference in slant associated with demographic characteristics especially across ages. Older people have less of a slant than younger people. There also seems to be a difference in females who are younger and males who are older, as well as younger left-handed writers to older right-handed writers. While we would expect the most notable differences to be with gender or handedness, clearly slant varies most among different ages. We will continue to collect samples from additional participants and will update these results when more data becomes available.

References

- [1] Crawford, A.M.; Ray, A.; and Carriquiry, A. L., "A database of handwriting samples for applications in forensic statistics" (2020). CSAFE Publications
- [2] Berry, N. (2019). *handwriter: A forensic handwriting analysis pipeline in R*. <https://github.com/CSAFE-ISU/handwriter>. Developmental R package
- [3] Crawford, A.M., Berry, N.S., Carriquiry, A.L. "A clustering method for graphical handwriting components and statistical writership analysis." (2020) Statistical Analysis and Data Mining. In press.
- [4] Crawford, Amy, "Bayesian hierarchical modeling for the forensic evaluation of handwritten documents" (2020). Graduate Theses and Dissertations. 18078.