

# ABCD Study CT and Demographic Data Exploratory Data Analysis

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## What is Exploratory Data Analysis?

Exploratory Data Analysis (EDA) is a structured approach for understanding your data that can be used for research question and hypothesis development. EDA's overall objective is to get insights to make better decisions. Sub-objectives include:

- Identify correlated variables.
- Identify and deal with outliers.
- Identify trends across time.
- Identify trends across space.
- Uncover patterns related to the response variable of interest.
- Create research questions to explore or hypotheses to test.
- Identify possible new data sources.

## Set-Up Environment

The .RDS file loaded below was generated using the script “code/0\_get\_data.R”.

```
## -- Attaching packages ----- tidyverse 1.3.2 --
## v ggplot2 3.4.0      v purrr 0.3.5
## v tibble 3.1.8       v dplyr 1.0.10
## v tidyr 1.2.1        v stringr 1.4.1
## v readr 2.1.3        v forcats 0.5.2
## -- Conflicts ----- tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()     masks stats::lag()
```

## About the Variables

- subjectkey is the subject's unique identifier.
- eventname is the data collection point for an observation (row of data). Note, interview\_age is also available in months.
- Brain structure metrics cortical thickness (thick) and surface area (area) are included. For more on the meaning of these metrics, see <https://doi-org.ezp2.lib.umn.edu/10.1007%2Fs00429-015-1177-6>

First, we will split our data by eventname to study it cross-sectionally for now.

```
table(tidy_data$eventname)
```

```
##
##      baseline_year_1_arm_1 2_year_follow_up_y_arm_1
##                11760                7827

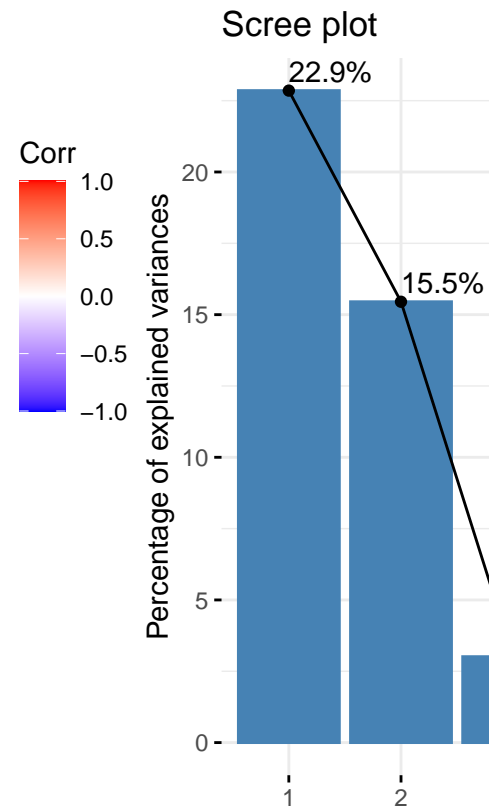
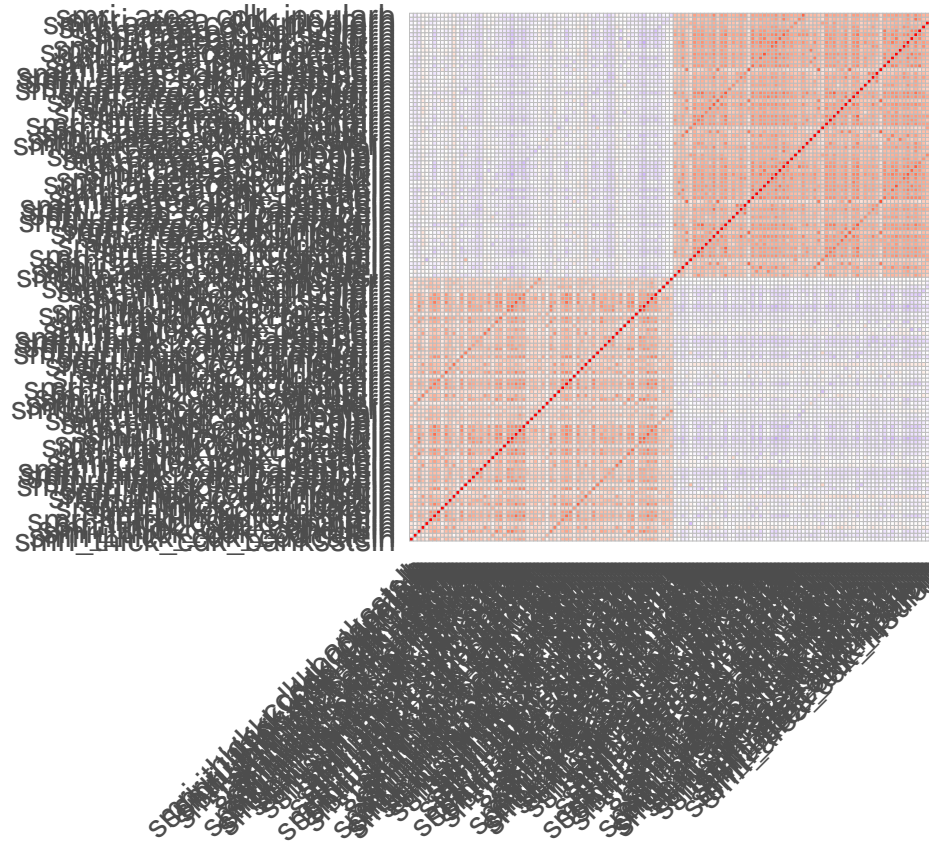
split_data = split(tidy_data, f = tidy_data$eventname)
baseline_data = split_data$baseline_year_1_arm_1 %>% ungroup
baseline_smri = select(baseline_data, starts_with("smri"))
```

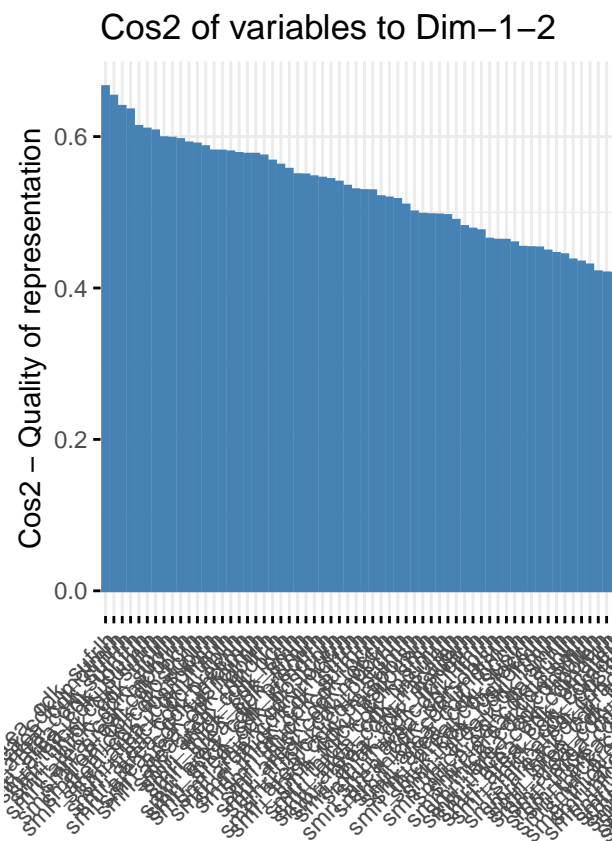
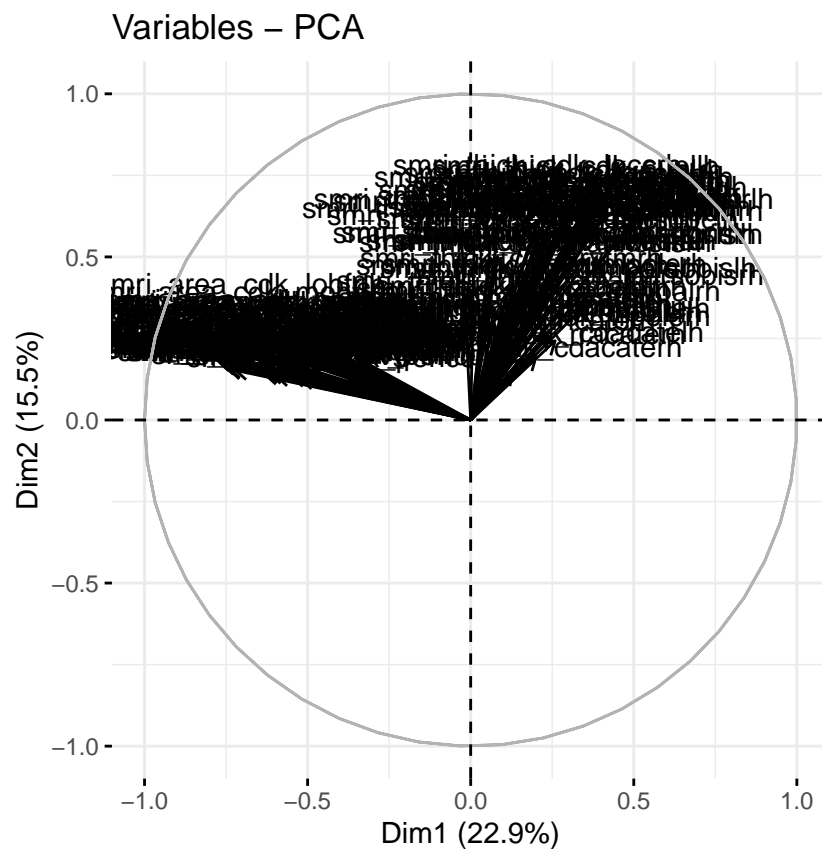
## Principal Components Analysis (PCA)

For Principal Components Analysis (PCA), the R function `prcomp()` is preferred. Note, the loadings are accessible in the resulting object's rotation feature.

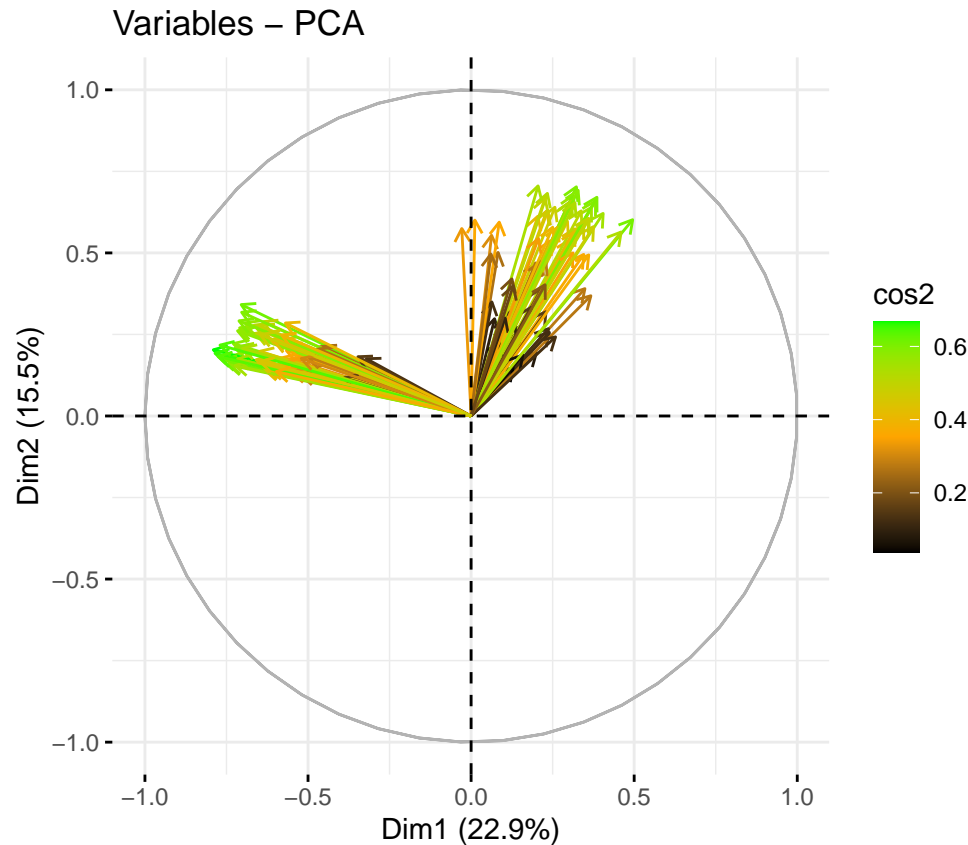
```
## Welcome! Want to learn more? See two factoextra-related books at https://goo.gl/ve3WBa
```

```
## [1] 0
```





```
## Warning: ggrepel: 136 unlabeled data points (too many overlaps). Consider
## increasing max.overlaps
```



### Principal Components Regression (PCR)

Next we perform regression and classification against a clinical severity score and a binary clinical outcome respectively using principal components identified in the PCA above and covariates.

Note, in fits, I'm receiving "Warning: Model failed to converge with max|grad| = 0.00427516 (tol = 0.002, component 1)".

```
# TODO: use lmer to account for fixed/ random effects, control for site effect and family within site
library(lme4)
```

```
## Loading required package: Matrix
```

```
##
```

```
## Attaching package: 'Matrix'
```

```
## The following objects are masked from 'package:tidyr':
```

```
##
```

```
## expand, pack, unpack
```

```
outcome_of_interest <- "outcome_internalizing_score"
```

```
outcome_names <- c("outcome_si", "outcome_internalizing_score")
```

```
outcome_to_remove <- subset(outcome_names, outcome_names!=outcome_of_interest)
```

```
base_model_data <- baseline_data %>%
```

```
  select(-starts_with("smri")) %>%
```

```
  # choose and rename outcome of interest
```

```
  select(-c("subjectkey", "eventname", all_of(outcome_to_remove))) %>%
```

```
  rename(outcome = starts_with("outcome"))
```

```

var_names <- colnames(base_model_data)

random_effect_index <- which(var_names %in% c("abcd_site", "rel_family_id"))
outcome_index <- which(var_names == "outcome")

base_fixed_effects <- var_names[-c(random_effect_index, outcome_index)] %>% paste(collapse = "+")
base_formula <- paste0("outcome~", base_fixed_effects, "+(1|abcd_site/rel_family_id)")

# TODO: https://stats.stackexchange.com/questions/22988/how-to-obtain-the-p-value-check-significance-of

# compute a model where the effect of PC is not estimated
restricted_fit = lmer(
  data = base_model_data,
  formula = base_formula,
  REML = F #because we want to compare models on likelihood
)

fits <- list(restricted_fit)

for (i in 1:10) {
  print(paste("Model",i-1,"fitting"))
  pc_index <- seq(1, i)
  if (i==1) {
    model_data <- base_model_data %>%
      cbind(PC1=pca$x[,pc_index]) # TODO: Find a substitute for this if else
  } else {
    model_data <- base_model_data %>%
      cbind(pca$x[,pc_index])
  }
  pc_names <- paste0("PC", pc_index, collapse = "+")
  model_formula <- paste(base_formula, pc_names, sep = "+")
  # compute a model where the effect of an additional PC is estimated
  fits[[i+1]] = lmer(
    data = model_data,
    formula = model_formula,
    REML = F #because we want to compare models on likelihood
  )
}

## [1] "Model 0 fitting"
## [1] "Model 1 fitting"
## [1] "Model 2 fitting"
## [1] "Model 3 fitting"
## [1] "Model 4 fitting"
## [1] "Model 5 fitting"

## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control$checkConv, :
## Model failed to converge with max|grad| = 0.00427516 (tol = 0.002, component 1)

## [1] "Model 6 fitting"
## [1] "Model 7 fitting"
## [1] "Model 8 fitting"
## [1] "Model 9 fitting"

```

```
lapply(fits, summary)
```

```
## [[1]]
## Linear mixed model fit by maximum likelihood ['lmerMod']
## Formula: outcome ~ sex + interview_age + demo_comb_income_v2 + demo_ethn_v2 +
##      demo_prnt_marital_v2 + race_white + race_black + race_native +
##      race_pacific_islander + race_asian + race_other + demo_prnt_highest_ed +
##      (1 | abcd_site/rel_family_id)
## Data: base_model_data
##
##      AIC      BIC    logLik deviance df.resid
## 64517.8 64844.2 -32213.9 64427.8    10389
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -3.1173 -0.4935 -0.2069  0.2994  5.9601
##
## Random effects:
## Groups              Name              Variance Std.Dev.
## rel_family_id:abcd_site (Intercept) 13.4093  3.6619
## abcd_site              (Intercept)  0.3937  0.6274
## Residual                15.7539  3.9691
## Number of obs: 10434, groups:  rel_family_id:abcd_site, 8708; abcd_site, 23
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)   -0.008922   3.272285  -0.003
## sexM           -0.047732   0.106079  -0.450
## interview_age    0.026461   0.006863   3.855
## demo_comb_income_v22 -0.123681  0.411415  -0.301
## demo_comb_income_v23 -0.243382  0.464543  -0.524
## demo_comb_income_v24 -0.299139  0.402241  -0.744
## demo_comb_income_v25 -0.440258  0.387988  -1.135
## demo_comb_income_v26 -0.920333  0.376399  -2.445
## demo_comb_income_v27 -1.191655  0.373236  -3.193
## demo_comb_income_v28 -1.609261  0.383529  -4.196
## demo_comb_income_v29 -1.933929  0.380868  -5.078
## demo_comb_income_v210 -2.440873  0.414993  -5.882
## demo_ethn_v22      0.117483  0.182339   0.644
## demo_prnt_marital_v22 0.536205  0.640637   0.837
## demo_prnt_marital_v23 0.449181  0.205737   2.183
## demo_prnt_marital_v24 0.707815  0.311342   2.273
## demo_prnt_marital_v25 0.405820  0.224562   1.807
## demo_prnt_marital_v26 0.590390  0.263247   2.243
## race_white        1.463996  0.211347   6.927
## race_black        0.151137  0.217508   0.695
## race_native       0.191699  0.313555   0.611
## race_pacific_islander -0.212590  0.696572  -0.305
## race_asian        0.201198  0.242922   0.828
## race_other        1.158736  0.283800   4.083
## demo_prnt_highest_ed4 0.354527  3.954786   0.090
## demo_prnt_highest_ed5 10.292837  6.261828   1.644
## demo_prnt_highest_ed6 1.933913  3.331507   0.580
## demo_prnt_highest_ed7 2.209281  3.738355   0.591
```

```

## demo_prnt_highest_ed8    3.582343    3.370414    1.063
## demo_prnt_highest_ed9    1.822192    3.217992    0.566
## demo_prnt_highest_ed10   1.085629    3.205464    0.339
## demo_prnt_highest_ed11   1.533785    3.179475    0.482
## demo_prnt_highest_ed12   0.866210    3.171405    0.273
## demo_prnt_highest_ed13   0.957606    3.133979    0.306
## demo_prnt_highest_ed14   1.029849    3.145591    0.327
## demo_prnt_highest_ed15   2.050418    3.129757    0.655
## demo_prnt_highest_ed16   2.162748    3.133023    0.690
## demo_prnt_highest_ed17   2.192227    3.135228    0.699
## demo_prnt_highest_ed18   1.912363    3.130368    0.611
## demo_prnt_highest_ed19   1.862431    3.131292    0.595
## demo_prnt_highest_ed20   1.468954    3.140630    0.468
## demo_prnt_highest_ed21   1.961833    3.138684    0.625

##
## Correlation matrix not shown by default, as p = 42 > 12.
## Use print(x, correlation=TRUE) or
##     vcov(x)           if you need it

##
## [[2]]
## Linear mixed model fit by maximum likelihood ['lmerMod']
## Formula: outcome ~ sex + interview_age + demo_comb_income_v2 + demo_ethn_v2 +
##     demo_prnt_marital_v2 + race_white + race_black + race_native +
##     race_pacific_islander + race_asian + race_other + demo_prnt_highest_ed +
##     (1 | abcd_site/rel_family_id) + PC1
## Data: model_data
##
##      AIC      BIC    logLik deviance df.resid
## 64507.5 64841.2 -32207.8 64415.5    10388
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -3.1022 -0.4954 -0.2034  0.2977  6.0078
##
## Random effects:
## Groups              Name              Variance Std.Dev.
## rel_family_id:abcd_site (Intercept) 13.3449  3.6531
## abcd_site              (Intercept)  0.4043  0.6358
## Residual                  15.7741  3.9717
## Number of obs: 10434, groups:  rel_family_id:abcd_site, 8708; abcd_site, 23
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)  -0.310492   3.271154  -0.095
## sexM          0.146740   0.119675   1.226
## interview_age  0.027151   0.006864   3.956
## demo_comb_income_v22 -0.083980  0.411248  -0.204
## demo_comb_income_v23 -0.196239  0.464364  -0.423
## demo_comb_income_v24 -0.258458  0.402075  -0.643
## demo_comb_income_v25 -0.404072  0.387804  -1.042
## demo_comb_income_v26 -0.861388  0.376461  -2.288
## demo_comb_income_v27 -1.142613  0.373184  -3.062
## demo_comb_income_v28 -1.546988  0.383620  -4.033

```

```

## demo_comb_income_v29 -1.868231 0.381003 -4.903
## demo_comb_income_v210 -2.362339 0.415251 -5.689
## demo_ethn_v22 0.137169 0.182354 0.752
## demo_prnt_marital_v22 0.522642 0.640085 0.817
## demo_prnt_marital_v23 0.453518 0.205564 2.206
## demo_prnt_marital_v24 0.707645 0.311084 2.275
## demo_prnt_marital_v25 0.410002 0.224378 1.827
## demo_prnt_marital_v26 0.574404 0.263073 2.183
## race_white 1.504974 0.211504 7.116
## race_black 0.115322 0.217576 0.530
## race_native 0.184759 0.313338 0.590
## race_pacific_islander -0.180063 0.696078 -0.259
## race_asian 0.207670 0.242759 0.855
## race_other 1.182239 0.283667 4.168
## demo_prnt_highest_ed4 0.348387 3.951800 0.088
## demo_prnt_highest_ed5 10.150136 6.257265 1.622
## demo_prnt_highest_ed6 2.008519 3.329054 0.603
## demo_prnt_highest_ed7 2.145388 3.735586 0.574
## demo_prnt_highest_ed8 3.542194 3.367821 1.052
## demo_prnt_highest_ed9 1.872564 3.215595 0.582
## demo_prnt_highest_ed10 1.080995 3.203044 0.337
## demo_prnt_highest_ed11 1.561769 3.177073 0.492
## demo_prnt_highest_ed12 0.855678 3.169013 0.270
## demo_prnt_highest_ed13 0.968884 3.131616 0.309
## demo_prnt_highest_ed14 1.031011 3.143218 0.328
## demo_prnt_highest_ed15 2.059361 3.127397 0.658
## demo_prnt_highest_ed16 2.165198 3.130658 0.692
## demo_prnt_highest_ed17 2.208516 3.132864 0.705
## demo_prnt_highest_ed18 1.938674 3.128014 0.620
## demo_prnt_highest_ed19 1.899800 3.128946 0.607
## demo_prnt_highest_ed20 1.514667 3.138283 0.483
## demo_prnt_highest_ed21 1.999824 3.136331 0.638
## PC1 0.039383 0.011251 3.500

##
## Correlation matrix not shown by default, as p = 43 > 12.
## Use print(x, correlation=TRUE) or
##     vcov(x)         if you need it

##
## [[3]]
## Linear mixed model fit by maximum likelihood ['lmerMod']
## Formula: outcome ~ sex + interview_age + demo_comb_income_v2 + demo_ethn_v2 +
##     demo_prnt_marital_v2 + race_white + race_black + race_native +
##     race_pacific_islander + race_asian + race_other + demo_prnt_highest_ed +
##     (1 | abcd_site/rel_family_id) + PC1 + PC2
## Data: model_data
##
##      AIC      BIC    logLik deviance df.resid
## 64503.4 64844.3 -32204.7 64409.4    10387
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -3.1142 -0.4956 -0.2046  0.2999  6.0184
##

```



```

## Random effects:
##      Groups              Name              Variance Std.Dev.
## rel_family_id:abcd_site (Intercept) 13.3162  3.6491
## abcd_site              (Intercept)  0.4115  0.6414
## Residual                      15.7810  3.9725
## Number of obs: 10434, groups:  rel_family_id:abcd_site, 8708; abcd_site, 23
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)   -0.132193   3.270827  -0.040
## sexM           0.199040   0.121465   1.639
## interview_age  0.025425   0.006897   3.686
## demo_comb_income_v22 -0.084009   0.411089  -0.204
## demo_comb_income_v23 -0.181074   0.464223  -0.390
## demo_comb_income_v24 -0.240127   0.401980  -0.597
## demo_comb_income_v25 -0.382857   0.387741  -0.987
## demo_comb_income_v26 -0.837775   0.376428  -2.226
## demo_comb_income_v27 -1.109794   0.373263  -2.973
## demo_comb_income_v28 -1.505990   0.383815  -3.924
## demo_comb_income_v29 -1.823914   0.381256  -4.784
## demo_comb_income_v210 -2.311709   0.415578  -5.563
## demo_ethn_v22      0.167370   0.182736   0.916
## demo_prnt_marital_v22 0.530543   0.639819   0.829
## demo_prnt_marital_v23 0.460582   0.205498   2.241
## demo_prnt_marital_v24 0.705942   0.310960   2.270
## demo_prnt_marital_v25 0.409931   0.224288   1.828
## demo_prnt_marital_v26 0.560150   0.263032   2.130
## race_white        1.556322   0.212430   7.326
## race_black        0.071554   0.218204   0.328
## race_native       0.194669   0.313260   0.621
## race_pacific_islander -0.206014   0.695883  -0.296
## race_asian        0.177895   0.242975   0.732
## race_other        1.202699   0.283682   4.240
## demo_prnt_highest_ed4 0.138977   3.951233   0.035
## demo_prnt_highest_ed5 10.325358   6.255333   1.651
## demo_prnt_highest_ed6 1.895269   3.328138   0.569
## demo_prnt_highest_ed7 2.034420   3.734470   0.545
## demo_prnt_highest_ed8 3.451850   3.366739   1.025
## demo_prnt_highest_ed9 1.751343   3.214781   0.545
## demo_prnt_highest_ed10 1.007844   3.201991   0.315
## demo_prnt_highest_ed11 1.464852   3.176131   0.461
## demo_prnt_highest_ed12 0.757836   3.168086   0.239
## demo_prnt_highest_ed13 0.861884   3.130751   0.275
## demo_prnt_highest_ed14 0.934316   3.142293   0.297
## demo_prnt_highest_ed15 1.968089   3.126453   0.629
## demo_prnt_highest_ed16 2.068054   3.129742   0.661
## demo_prnt_highest_ed17 2.112888   3.131938   0.675
## demo_prnt_highest_ed18 1.848235   3.127065   0.591
## demo_prnt_highest_ed19 1.820394   3.127947   0.582
## demo_prnt_highest_ed20 1.445359   3.137240   0.461
## demo_prnt_highest_ed21 1.925179   3.135309   0.614
## PC1              0.042918   0.011337   3.786
## PC2             -0.031554   0.012694  -2.486

```

```

##
## Correlation matrix not shown by default, as p = 44 > 12.
## Use print(x, correlation=TRUE) or
##     vcov(x)         if you need it
##
## [[4]]
## Linear mixed model fit by maximum likelihood ['lmerMod']
## Formula: outcome ~ sex + interview_age + demo_comb_income_v2 + demo_ethn_v2 +
##     demo_prnt_marital_v2 + race_white + race_black + race_native +
##     race_pacific_islander + race_asian + race_other + demo_prnt_highest_ed +
##     (1 | abcd_site/rel_family_id) + PC1 + PC2 + PC3
## Data: model_data
##
##      AIC      BIC    logLik deviance df.resid
## 64501.4 64849.5 -32202.7 64405.4    10386
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -3.0863 -0.4948 -0.2056  0.2991  5.9900
##
## Random effects:
##      Groups              Name      Variance Std.Dev.
## rel_family_id:abcd_site (Intercept) 13.3141  3.6488
## abcd_site                (Intercept)  0.4222  0.6498
## Residual                      15.7713  3.9713
## Number of obs: 10434, groups:  rel_family_id:abcd_site, 8708; abcd_site, 23
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)   -0.052317   3.270539  -0.016
## sexM           0.198630   0.121441   1.636
## interview_age  0.025082   0.006898   3.636
## demo_comb_income_v22 -0.084713  0.411009  -0.206
## demo_comb_income_v23 -0.180798  0.464134  -0.390
## demo_comb_income_v24 -0.220607  0.402020  -0.549
## demo_comb_income_v25 -0.385288  0.387668  -0.994
## demo_comb_income_v26 -0.834299  0.376359  -2.217
## demo_comb_income_v27 -1.104617  0.373201  -2.960
## demo_comb_income_v28 -1.502797  0.383747  -3.916
## demo_comb_income_v29 -1.818805  0.381196  -4.771
## demo_comb_income_v210 -2.305288  0.415528  -5.548
## demo_ethn_v22      0.170534   0.182778   0.933
## demo_prnt_marital_v22 0.512937   0.639761   0.802
## demo_prnt_marital_v23 0.462526   0.205462   2.251
## demo_prnt_marital_v24 0.703564   0.310904   2.263
## demo_prnt_marital_v25 0.414409   0.224257   1.848
## demo_prnt_marital_v26 0.563422   0.262988   2.142
## race_white        1.551874   0.212404   7.306
## race_black         0.073881   0.218177   0.339
## race_native        0.198518   0.313233   0.634
## race_pacific_islander -0.218897  0.695781  -0.315
## race_asian         0.181605   0.242961   0.747
## race_other         1.193661   0.283676   4.208

```

```

## demo_prnt_highest_ed4    0.110973    3.950468    0.028
## demo_prnt_highest_ed5   10.418854    6.254260    1.666
## demo_prnt_highest_ed6    1.872263    3.327507    0.563
## demo_prnt_highest_ed7    2.038657    3.733729    0.546
## demo_prnt_highest_ed8    3.350645    3.366468    0.995
## demo_prnt_highest_ed9    1.710617    3.214218    0.532
## demo_prnt_highest_ed10   0.967580    3.201422    0.302
## demo_prnt_highest_ed11   1.420126    3.175583    0.447
## demo_prnt_highest_ed12   0.707214    3.167567    0.223
## demo_prnt_highest_ed13   0.821162    3.130197    0.262
## demo_prnt_highest_ed14   0.891024    3.141746    0.284
## demo_prnt_highest_ed15   1.925632    3.125905    0.616
## demo_prnt_highest_ed16   2.023178    3.129202    0.647
## demo_prnt_highest_ed17   2.070081    3.131389    0.661
## demo_prnt_highest_ed18   1.802493    3.126527    0.577
## demo_prnt_highest_ed19   1.777937    3.127398    0.569
## demo_prnt_highest_ed20   1.408715    3.136668    0.449
## demo_prnt_highest_ed21   1.879161    3.134770    0.599
## PC1                      0.043842    0.011344    3.865
## PC2                      -0.030900    0.012697   -2.434
## PC3                      0.054705    0.027371    1.999

##
## Correlation matrix not shown by default, as p = 45 > 12.
## Use print(x, correlation=TRUE) or
##     vcov(x)           if you need it

##
## [[5]]
## Linear mixed model fit by maximum likelihood ['lmerMod']
## Formula: outcome ~ sex + interview_age + demo_comb_income_v2 + demo_ethn_v2 +
##     demo_prnt_marital_v2 + race_white + race_black + race_native +
##     race_pacific_islander + race_asian + race_other + demo_prnt_highest_ed +
##     (1 | abcd_site/rel_family_id) + PC1 + PC2 + PC3 + PC4
## Data: model_data
##
##      AIC      BIC   logLik deviance df.resid
## 64501.8 64857.2 -32201.9 64403.8    10385
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -3.0937 -0.4948 -0.2049  0.2974  5.9964
##
## Random effects:
##  Groups                Name             Variance Std.Dev.
## rel_family_id:abcd_site (Intercept) 13.2881  3.6453
## abcd_site                (Intercept)  0.4201  0.6481
## Residual                    15.7889  3.9735
## Number of obs: 10434, groups:  rel_family_id:abcd_site, 8708; abcd_site, 23
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)  -0.249601   3.273922  -0.076
## sexM          0.190015   0.121626   1.562
## interview_age  0.026075   0.006946   3.754

```

```

## demo_comb_income_v22 -0.087573 0.410947 -0.213
## demo_comb_income_v23 -0.171268 0.464112 -0.369
## demo_comb_income_v24 -0.223380 0.401954 -0.556
## demo_comb_income_v25 -0.388176 0.387605 -1.001
## demo_comb_income_v26 -0.832559 0.376293 -2.213
## demo_comb_income_v27 -1.103438 0.373131 -2.957
## demo_comb_income_v28 -1.498575 0.383690 -3.906
## demo_comb_income_v29 -1.816856 0.381125 -4.767
## demo_comb_income_v210 -2.300865 0.415459 -5.538
## demo_ethn_v22 0.174239 0.182754 0.953
## demo_prnt_marital_v22 0.526794 0.639709 0.823
## demo_prnt_marital_v23 0.459705 0.205432 2.238
## demo_prnt_marital_v24 0.705542 0.310848 2.270
## demo_prnt_marital_v25 0.411140 0.224229 1.834
## demo_prnt_marital_v26 0.564341 0.262942 2.146
## race_white 1.555331 0.212382 7.323
## race_black 0.076393 0.218141 0.350
## race_native 0.188648 0.313279 0.602
## race_pacific_islander -0.211614 0.695684 -0.304
## race_asian 0.169116 0.243108 0.696
## race_other 1.187414 0.283673 4.186
## demo_prnt_highest_ed4 0.226433 3.950950 0.057
## demo_prnt_highest_ed5 10.384627 6.253394 1.661
## demo_prnt_highest_ed6 1.957645 3.327707 0.588
## demo_prnt_highest_ed7 2.160181 3.734423 0.578
## demo_prnt_highest_ed8 3.439435 3.366678 1.022
## demo_prnt_highest_ed9 1.778697 3.214197 0.553
## demo_prnt_highest_ed10 1.050133 3.201617 0.328
## demo_prnt_highest_ed11 1.504678 3.175825 0.474
## demo_prnt_highest_ed12 0.798999 3.167937 0.252
## demo_prnt_highest_ed13 0.906460 3.130470 0.290
## demo_prnt_highest_ed14 0.974208 3.141975 0.310
## demo_prnt_highest_ed15 2.007606 3.126124 0.642
## demo_prnt_highest_ed16 2.101859 3.129365 0.672
## demo_prnt_highest_ed17 2.145171 3.131495 0.685
## demo_prnt_highest_ed18 1.881261 3.126693 0.602
## demo_prnt_highest_ed19 1.856695 3.127563 0.594
## demo_prnt_highest_ed20 1.487093 3.136822 0.474
## demo_prnt_highest_ed21 1.953329 3.134861 0.623
## PC1 0.042472 0.011395 3.727
## PC2 -0.031651 0.012709 -2.490
## PC3 0.050493 0.027567 1.832
## PC4 -0.039146 0.030899 -1.267

##
## Correlation matrix not shown by default, as p = 46 > 12.
## Use print(x, correlation=TRUE) or
##     vcov(x)         if you need it

##
## [[6]]
## Linear mixed model fit by maximum likelihood ['lmerMod']
## Formula: outcome ~ sex + interview_age + demo_comb_income_v2 + demo_ethn_v2 +
##     demo_prnt_marital_v2 + race_white + race_black + race_native +
##     race_pacific_islander + race_asian + race_other + demo_prnt_highest_ed +

```

```

##      (1 | abcd_site/rel_family_id) + PC1 + PC2 + PC3 + PC4 + PC5
##      Data: model_data
##
##      AIC      BIC    logLik deviance df.resid
## 64503.8 64866.4 -32201.9 64403.8    10384
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -3.0938 -0.4954 -0.2046  0.2981  5.9963
##
## Random effects:
##      Groups                Name      Variance Std.Dev.
## rel_family_id:abcd_site (Intercept) 13.2872  3.6452
## abcd_site                (Intercept)  0.4208  0.6487
## Residual                      15.7894  3.9736
## Number of obs: 10434, groups:  rel_family_id:abcd_site, 8708; abcd_site, 23
##
## Fixed effects:
##
##              Estimate Std. Error t value
## (Intercept)    -0.242972   3.274263  -0.074
## sexM              0.189239   0.121752   1.554
## interview_age     0.026011   0.006960   3.737
## demo_comb_income_v22 -0.087384   0.410947  -0.213
## demo_comb_income_v23 -0.171508   0.464114  -0.370
## demo_comb_income_v24 -0.222253   0.402028  -0.553
## demo_comb_income_v25 -0.387963   0.387606  -1.001
## demo_comb_income_v26 -0.831162   0.376415  -2.208
## demo_comb_income_v27 -1.102335   0.373205  -2.954
## demo_comb_income_v28 -1.497018   0.383837  -3.900
## demo_comb_income_v29 -1.815744   0.381194  -4.763
## demo_comb_income_v210 -2.299564   0.415547  -5.534
## demo_ethn_v22        0.174855   0.182811   0.956
## demo_prnt_marital_v22 0.526490   0.639709   0.823
## demo_prnt_marital_v23 0.459982   0.205439   2.239
## demo_prnt_marital_v24 0.705668   0.310848   2.270
## demo_prnt_marital_v25 0.411112   0.224228   1.833
## demo_prnt_marital_v26 0.564085   0.262947   2.145
## race_white          1.557556   0.212963   7.314
## race_black           0.073484   0.219099   0.335
## race_native          0.188326   0.313286   0.601
## race_pacific_islander -0.212375   0.695701  -0.305
## race_asian           0.167286   0.243451   0.687
## race_other           1.187794   0.283683   4.187
## demo_prnt_highest_ed4 0.229610   3.950992   0.058
## demo_prnt_highest_ed5 10.390034   6.253469   1.661
## demo_prnt_highest_ed6 1.958010   3.327692   0.588
## demo_prnt_highest_ed7 2.156426   3.734504   0.577
## demo_prnt_highest_ed8 3.437409   3.366695   1.021
## demo_prnt_highest_ed9 1.776914   3.214211   0.553
## demo_prnt_highest_ed10 1.048526   3.201624   0.327
## demo_prnt_highest_ed11 1.502912   3.175837   0.473
## demo_prnt_highest_ed12 0.798477   3.167926   0.252
## demo_prnt_highest_ed13 0.904869   3.130477   0.289
## demo_prnt_highest_ed14 0.973712   3.141963   0.310

```

```

## demo_prnt_highest_ed15 2.006443 3.126121 0.642
## demo_prnt_highest_ed16 2.100842 3.129360 0.671
## demo_prnt_highest_ed17 2.143825 3.131496 0.685
## demo_prnt_highest_ed18 1.879976 3.126693 0.601
## demo_prnt_highest_ed19 1.855402 3.127563 0.593
## demo_prnt_highest_ed20 1.486120 3.136816 0.474
## demo_prnt_highest_ed21 1.952481 3.134852 0.623
## PC1 0.042546 0.011406 3.730
## PC2 -0.031824 0.012767 -2.493
## PC3 0.050587 0.027575 1.835
## PC4 -0.038993 0.030919 -1.261
## PC5 -0.004708 0.033232 -0.142

##
## Correlation matrix not shown by default, as p = 47 > 12.
## Use print(x, correlation=TRUE) or
## vcov(x) if you need it

##
## [[7]]
## Linear mixed model fit by maximum likelihood ['lmerMod']
## Formula: outcome ~ sex + interview_age + demo_comb_income_v2 + demo_ethn_v2 +
## demo_prnt_marital_v2 + race_white + race_black + race_native +
## race_pacific_islander + race_asian + race_other + demo_prnt_highest_ed +
## (1 | abcd_site/rel_family_id) + PC1 + PC2 + PC3 + PC4 + PC5 + PC6
## Data: model_data
##
## AIC BIC logLik deviance df.resid
## 64505.2 64875.1 -32201.6 64403.2 10383
##
## Scaled residuals:
## Min 1Q Median 3Q Max
## -3.0990 -0.4949 -0.2055 0.2981 5.9979
##
## Random effects:
## Groups Name Variance Std.Dev.
## rel_family_id:abcd_site (Intercept) 13.2807 3.6443
## abcd_site (Intercept) 0.4249 0.6519
## Residual 15.7929 3.9740
## Number of obs: 10434, groups: rel_family_id:abcd_site, 8708; abcd_site, 23
##
## Fixed effects:
## Estimate Std. Error t value
## (Intercept) -0.278912 3.274496 -0.085
## sexM 0.186621 0.121802 1.532
## interview_age 0.026417 0.006982 3.784
## demo_comb_income_v22 -0.095461 0.411069 -0.232
## demo_comb_income_v23 -0.177574 0.464164 -0.383
## demo_comb_income_v24 -0.226851 0.402056 -0.564
## demo_comb_income_v25 -0.391658 0.387617 -1.010
## demo_comb_income_v26 -0.834152 0.376418 -2.216
## demo_comb_income_v27 -1.106484 0.373230 -2.965
## demo_comb_income_v28 -1.499297 0.383831 -3.906
## demo_comb_income_v29 -1.819930 0.381225 -4.774
## demo_comb_income_v210 -2.302413 0.415554 -5.541

```

```

## demo_ethn_v22      0.172530    0.182853    0.944
## demo_prnt_marital_v22 0.526809    0.639667    0.824
## demo_prnt_marital_v23 0.458687    0.205435    2.233
## demo_prnt_marital_v24 0.703266    0.310847    2.262
## demo_prnt_marital_v25 0.414254    0.224255    1.847
## demo_prnt_marital_v26 0.570752    0.263088    2.169
## race_white        1.552707    0.213054    7.288
## race_black        0.079087    0.219225    0.361
## race_native       0.190355    0.313291    0.608
## race_pacific_islander -0.209169    0.695677   -0.301
## race_asian        0.171022    0.243500    0.702
## race_other        1.189878    0.283682    4.194
## demo_prnt_highest_ed4 0.216469    3.950834    0.055
## demo_prnt_highest_ed5 10.392929    6.253160    1.662
## demo_prnt_highest_ed6 1.943311    3.327594    0.584
## demo_prnt_highest_ed7 2.159330    3.734318    0.578
## demo_prnt_highest_ed8 3.444151    3.366527    1.023
## demo_prnt_highest_ed9 1.772492    3.214058    0.551
## demo_prnt_highest_ed10 1.057149    3.201482    0.330
## demo_prnt_highest_ed11 1.495179    3.175695    0.471
## demo_prnt_highest_ed12 0.796432    3.167769    0.251
## demo_prnt_highest_ed13 0.899883    3.130328    0.287
## demo_prnt_highest_ed14 0.969094    3.141811    0.308
## demo_prnt_highest_ed15 2.003015    3.125967    0.641
## demo_prnt_highest_ed16 2.096060    3.129209    0.670
## demo_prnt_highest_ed17 2.139467    3.131344    0.683
## demo_prnt_highest_ed18 1.875896    3.126540    0.600
## demo_prnt_highest_ed19 1.852094    3.127408    0.592
## demo_prnt_highest_ed20 1.480156    3.136668    0.472
## demo_prnt_highest_ed21 1.948800    3.134698    0.622
## PC1               0.042497    0.011406    3.726
## PC2              -0.031338    0.012785   -2.451
## PC3               0.051554    0.027605    1.868
## PC4              -0.038174    0.030943   -1.234
## PC5              -0.004715    0.033232   -0.142
## PC6              -0.024518    0.033187   -0.739

##
## Correlation matrix not shown by default, as p = 48 > 12.
## Use print(x, correlation=TRUE) or
##     vcov(x)           if you need it

## optimizer (nloptwrap) convergence code: 0 (OK)
## Model failed to converge with max|grad| = 0.00427516 (tol = 0.002, component 1)
##
##
## [[8]]
## Linear mixed model fit by maximum likelihood ['lmerMod']
## Formula: outcome ~ sex + interview_age + demo_comb_income_v2 + demo_ethn_v2 +
##     demo_prnt_marital_v2 + race_white + race_black + race_native +
##     race_pacific_islander + race_asian + race_other + demo_prnt_highest_ed +
##     (1 | abcd_site/rel_family_id) + PC1 + PC2 + PC3 + PC4 + PC5 +
##     PC6 + PC7
## Data: model_data
##

```

```

##      AIC      BIC    logLik deviance df.resid
## 64507.2 64884.3 -32201.6 64403.2    10382
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -3.0970 -0.4946 -0.2057  0.2975  5.9949
##
## Random effects:
##      Groups              Name      Variance Std.Dev.
## rel_family_id:abcd_site (Intercept) 13.2838  3.6447
## abcd_site                (Intercept)  0.4254  0.6522
## Residual                      15.7902  3.9737
## Number of obs: 10434, groups:  rel_family_id:abcd_site, 8708; abcd_site, 23
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)   -0.265837   3.275138  -0.081
## sexM           0.187404   0.121860   1.538
## interview_age  0.026312   0.007001   3.759
## demo_comb_income_v22 -0.095708  0.411074  -0.233
## demo_comb_income_v23 -0.177934  0.464171  -0.383
## demo_comb_income_v24 -0.226221  0.402072  -0.563
## demo_comb_income_v25 -0.390720  0.387647  -1.008
## demo_comb_income_v26 -0.833554  0.376433  -2.214
## demo_comb_income_v27 -1.105508  0.373262  -2.962
## demo_comb_income_v28 -1.498472  0.383854  -3.904
## demo_comb_income_v29 -1.819396  0.381238  -4.772
## demo_comb_income_v210 -2.302172  0.415561  -5.540
## demo_ethn_v22      0.172117   0.182867   0.941
## demo_prnt_marital_v22 0.527474   0.639687   0.825
## demo_prnt_marital_v23 0.459540   0.205476   2.236
## demo_prnt_marital_v24 0.704048   0.310874   2.265
## demo_prnt_marital_v25 0.415285   0.224309   1.851
## demo_prnt_marital_v26 0.571347   0.263105   2.172
## race_white        1.551839   0.213093   7.282
## race_black        0.077319   0.219384   0.352
## race_native       0.190974   0.313312   0.610
## race_pacific_islander -0.207525  0.695726  -0.298
## race_asian        0.173463   0.243770   0.712
## race_other        1.189615   0.283688   4.193
## demo_prnt_highest_ed4 0.211613   3.950928   0.054
## demo_prnt_highest_ed5 10.382752  6.253391   1.660
## demo_prnt_highest_ed6 1.944865   3.327623   0.584
## demo_prnt_highest_ed7 2.150293   3.734588   0.576
## demo_prnt_highest_ed8 3.449385   3.366640   1.025
## demo_prnt_highest_ed9 1.772800   3.214080   0.552
## demo_prnt_highest_ed10 1.059243   3.201518   0.331
## demo_prnt_highest_ed11 1.493084   3.175734   0.470
## demo_prnt_highest_ed12 0.796533   3.167790   0.251
## demo_prnt_highest_ed13 0.899046   3.130351   0.287
## demo_prnt_highest_ed14 0.969055   3.141832   0.308
## demo_prnt_highest_ed15 2.002516   3.125989   0.641
## demo_prnt_highest_ed16 2.095117   3.129233   0.670
## demo_prnt_highest_ed17 2.138829   3.131366   0.683

```



```

## demo_prnt_highest_ed18 1.875003 3.126564 0.600
## demo_prnt_highest_ed19 1.851024 3.127433 0.592
## demo_prnt_highest_ed20 1.479271 3.136691 0.472
## demo_prnt_highest_ed21 1.947506 3.134725 0.621
## PC1 0.042691 0.011443 3.731
## PC2 -0.031234 0.012794 -2.441
## PC3 0.052098 0.027722 1.879
## PC4 -0.037128 0.031327 -1.185
## PC5 -0.004857 0.033238 -0.146
## PC6 -0.024646 0.033192 -0.743
## PC7 -0.007781 0.036542 -0.213

##
## Correlation matrix not shown by default, as p = 49 > 12.
## Use print(x, correlation=TRUE) or
## vcov(x) if you need it

##
## [[9]]
## Linear mixed model fit by maximum likelihood ['lmerMod']
## Formula: outcome ~ sex + interview_age + demo_comb_income_v2 + demo_ethn_v2 +
## demo_prnt_marital_v2 + race_white + race_black + race_native +
## race_pacific_islander + race_asian + race_other + demo_prnt_highest_ed +
## (1 | abcd_site/rel_family_id) + PC1 + PC2 + PC3 + PC4 + PC5 +
## PC6 + PC7 + PC8
## Data: model_data
##
## AIC BIC logLik deviance df.resid
## 64509.0 64893.4 -32201.5 64403.0 10381
##
## Scaled residuals:
## Min 1Q Median 3Q Max
## -3.0940 -0.4948 -0.2057 0.2985 5.9911
##
## Random effects:
## Groups Name Variance Std.Dev.
## rel_family_id:abcd_site (Intercept) 13.286 3.6450
## abcd_site (Intercept) 0.425 0.6519
## Residual 15.788 3.9734
## Number of obs: 10434, groups: rel_family_id:abcd_site, 8708; abcd_site, 23
##
## Fixed effects:
## Estimate Std. Error t value
## (Intercept) -0.273897 3.275178 -0.084
## sexM 0.190668 0.122087 1.562
## interview_age 0.026264 0.007001 3.751
## demo_comb_income_v22 -0.096027 0.411076 -0.234
## demo_comb_income_v23 -0.174306 0.464247 -0.375
## demo_comb_income_v24 -0.226465 0.402073 -0.563
## demo_comb_income_v25 -0.387118 0.387736 -0.998
## demo_comb_income_v26 -0.829681 0.376538 -2.203
## demo_comb_income_v27 -1.102907 0.373311 -2.954
## demo_comb_income_v28 -1.494866 0.383944 -3.893
## demo_comb_income_v29 -1.815255 0.381358 -4.760
## demo_comb_income_v210 -2.297303 0.415713 -5.526

```

```

## demo_ethn_v22      0.173376    0.182888    0.948
## demo_prnt_marital_v22 0.526050    0.639699    0.822
## demo_prnt_marital_v23 0.460894    0.205501    2.243
## demo_prnt_marital_v24 0.704795    0.310880    2.267
## demo_prnt_marital_v25 0.416471    0.224327    1.857
## demo_prnt_marital_v26 0.571998    0.263110    2.174
## race_white         1.552617    0.213101    7.286
## race_black         0.078325    0.219396    0.357
## race_native        0.191809    0.313318    0.612
## race_pacific_islander -0.208970    0.695736   -0.300
## race_asian         0.172736    0.243776    0.709
## race_other         1.190614    0.283697    4.197
## demo_prnt_highest_ed4 0.231640    3.951190    0.059
## demo_prnt_highest_ed5 10.379098    6.253393    1.660
## demo_prnt_highest_ed6 1.951205    3.327655    0.586
## demo_prnt_highest_ed7 2.155907    3.734609    0.577
## demo_prnt_highest_ed8 3.450929    3.366645    1.025
## demo_prnt_highest_ed9 1.775305    3.214085    0.552
## demo_prnt_highest_ed10 1.068355    3.201585    0.334
## demo_prnt_highest_ed11 1.497557    3.175750    0.472
## demo_prnt_highest_ed12 0.802848    3.167823    0.253
## demo_prnt_highest_ed13 0.904868    3.130379    0.289
## demo_prnt_highest_ed14 0.975969    3.141871    0.311
## demo_prnt_highest_ed15 2.008604    3.126019    0.643
## demo_prnt_highest_ed16 2.101992    3.129272    0.672
## demo_prnt_highest_ed17 2.144444    3.131392    0.685
## demo_prnt_highest_ed18 1.882525    3.126610    0.602
## demo_prnt_highest_ed19 1.858503    3.127479    0.594
## demo_prnt_highest_ed20 1.488641    3.136763    0.475
## demo_prnt_highest_ed21 1.955518    3.134777    0.624
## PC1                0.042950    0.011458    3.748
## PC2                -0.031208    0.012794   -2.439
## PC3                0.052425    0.027732    1.890
## PC4                -0.036463    0.031362   -1.163
## PC5                -0.004825    0.033238   -0.145
## PC6                -0.024759    0.033193   -0.746
## PC7                -0.008404    0.036569   -0.230
## PC8                -0.015970    0.036294   -0.440

##
## Correlation matrix not shown by default, as p = 50 > 12.
## Use print(x, correlation=TRUE) or
##     vcov(x)         if you need it
##
## [[10]]
## Linear mixed model fit by maximum likelihood ['lmerMod']
## Formula: outcome ~ sex + interview_age + demo_comb_income_v2 + demo_ethn_v2 +
##     demo_prnt_marital_v2 + race_white + race_black + race_native +
##     race_pacific_islander + race_asian + race_other + demo_prnt_highest_ed +
##     (1 | abcd_site/rel_family_id) + PC1 + PC2 + PC3 + PC4 + PC5 +
##     PC6 + PC7 + PC8 + PC9
## Data: model_data
##
##      AIC      BIC   logLik deviance df.resid

```

```

## 64508.9 64900.6 -32200.5 64400.9 10380
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -3.0777 -0.4951 -0.2069  0.2991  6.0005
##
## Random effects:
##      Groups              Name            Variance Std.Dev.
## rel_family_id:abcd_site (Intercept) 13.3006  3.6470
## abcd_site                (Intercept)  0.4252  0.6521
## Residual                      15.7707  3.9712
## Number of obs: 10434, groups:  rel_family_id:abcd_site, 8708; abcd_site, 23
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)   -0.234707   3.275124  -0.072
## sexM           0.173065   0.122685   1.411
## interview_age  0.026516   0.007002   3.787
## demo_comb_income_v22 -0.089460  0.411087  -0.218
## demo_comb_income_v23 -0.170274  0.464242  -0.367
## demo_comb_income_v24 -0.222290  0.402075  -0.553
## demo_comb_income_v25 -0.388330  0.387728  -1.002
## demo_comb_income_v26 -0.826753  0.376535  -2.196
## demo_comb_income_v27 -1.102136  0.373305  -2.952
## demo_comb_income_v28 -1.493157  0.383939  -3.889
## demo_comb_income_v29 -1.812786  0.381356  -4.754
## demo_comb_income_v210 -2.288895  0.415749  -5.505
## demo_ethn_v22      0.166759  0.182942   0.912
## demo_prnt_marital_v22 0.525350  0.639699   0.821
## demo_prnt_marital_v23 0.460848  0.205500   2.243
## demo_prnt_marital_v24 0.700936  0.310885   2.255
## demo_prnt_marital_v25 0.414301  0.224328   1.847
## demo_prnt_marital_v26 0.570195  0.263107   2.167
## race_white        1.564185  0.213251   7.335
## race_black         0.048525  0.220375   0.220
## race_native        0.192537  0.313310   0.615
## race_pacific_islander -0.212334  0.695721  -0.305
## race_asian         0.182436  0.243862   0.748
## race_other         1.194926  0.283702   4.212
## demo_prnt_highest_ed4 0.132037  3.951617   0.033
## demo_prnt_highest_ed5 10.368184  6.253104   1.658
## demo_prnt_highest_ed6 1.927507  3.327545   0.579
## demo_prnt_highest_ed7 2.102477  3.734620   0.563
## demo_prnt_highest_ed8 3.366775  3.367027   1.000
## demo_prnt_highest_ed9 1.716536  3.214198   0.534
## demo_prnt_highest_ed10 1.023227  3.201591   0.320
## demo_prnt_highest_ed11 1.419475  3.176076   0.447
## demo_prnt_highest_ed12 0.754003  3.167860   0.238
## demo_prnt_highest_ed13 0.852474  3.130447   0.272
## demo_prnt_highest_ed14 0.921141  3.141958   0.293
## demo_prnt_highest_ed15 1.949476  3.126146   0.624
## demo_prnt_highest_ed16 2.048205  3.129351   0.655
## demo_prnt_highest_ed17 2.079082  3.131577   0.664
## demo_prnt_highest_ed18 1.819732  3.126772   0.582

```

```

## demo_prnt_highest_ed19  1.800883  3.127591  0.576
## demo_prnt_highest_ed20  1.429687  3.136887  0.456
## demo_prnt_highest_ed21  1.893376  3.134931  0.604
## PC1                      0.043265  0.011459  3.775
## PC2                     -0.031018  0.012793 -2.425
## PC3                      0.054046  0.027752  1.947
## PC4                     -0.033050  0.031448 -1.051
## PC5                     -0.006857  0.033265 -0.206
## PC6                     -0.024561  0.033189 -0.740
## PC7                     -0.011956  0.036648 -0.326
## PC8                     -0.017186  0.036300 -0.473
## PC9                      0.054163  0.037775  1.434

##
## Correlation matrix not shown by default, as p = 51 > 12.
## Use print(x, correlation=TRUE) or
##     vcov(x)           if you need it

##
## [[11]]
## Linear mixed model fit by maximum likelihood ['lmerMod']
## Formula: outcome ~ sex + interview_age + demo_comb_income_v2 + demo_ethn_v2 +
##     demo_prnt_marital_v2 + race_white + race_black + race_native +
##     race_pacific_islander + race_asian + race_other + demo_prnt_highest_ed +
##     (1 | abcd_site/rel_family_id) + PC1 + PC2 + PC3 + PC4 + PC5 +
##     PC6 + PC7 + PC8 + PC9 + PC10
## Data: model_data
##
##      AIC      BIC   logLik deviance df.resid
## 64510.8 64909.7 -32200.4 64400.8    10379
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -3.0794 -0.4938 -0.2071  0.2993  6.0028
##
## Random effects:
## Groups              Name            Variance Std.Dev.
## rel_family_id:abcd_site (Intercept) 13.2989  3.6468
## abcd_site              (Intercept)  0.4258  0.6525
## Residual                  15.7717  3.9714
## Number of obs: 10434, groups:  rel_family_id:abcd_site, 8708; abcd_site, 23
##
## Fixed effects:
##              Estimate Std. Error t value
## (Intercept)   -0.21421    3.27560  -0.065
## sexM           0.16981    0.12303   1.380
## interview_age   0.02640    0.00701   3.766
## demo_comb_income_v22 -0.08883    0.41109  -0.216
## demo_comb_income_v23 -0.17100    0.46424  -0.368
## demo_comb_income_v24 -0.22324    0.40208  -0.555
## demo_comb_income_v25 -0.38877    0.38772  -1.003
## demo_comb_income_v26 -0.82662    0.37653  -2.195
## demo_comb_income_v27 -1.10251    0.37330  -2.953
## demo_comb_income_v28 -1.49407    0.38394  -3.891
## demo_comb_income_v29 -1.81374    0.38136  -4.756

```

```
## demo_comb_income_v210 -2.28964 0.41575 -5.507
## demo_ethn_v22 0.16731 0.18295 0.915
## demo_prnt_marital_v22 0.52765 0.63972 0.825
## demo_prnt_marital_v23 0.46108 0.20550 2.244
## demo_prnt_marital_v24 0.70045 0.31088 2.253
## demo_prnt_marital_v25 0.41487 0.22433 1.849
## demo_prnt_marital_v26 0.57032 0.26310 2.168
## race_white 1.56300 0.21327 7.329
## race_black 0.04666 0.22043 0.212
## race_native 0.19356 0.31332 0.618
## race_pacific_islander -0.21627 0.69580 -0.311
## race_asian 0.18425 0.24391 0.755
## race_other 1.19493 0.28370 4.212
## demo_prnt_highest_ed4 0.13612 3.95159 0.034
## demo_prnt_highest_ed5 10.35422 6.25316 1.656
## demo_prnt_highest_ed6 1.92419 3.32752 0.578
## demo_prnt_highest_ed7 2.08554 3.73488 0.558
## demo_prnt_highest_ed8 3.37120 3.36701 1.001
## demo_prnt_highest_ed9 1.71191 3.21419 0.533
## demo_prnt_highest_ed10 1.02032 3.20156 0.319
## demo_prnt_highest_ed11 1.41731 3.17604 0.446
## demo_prnt_highest_ed12 0.74876 3.16786 0.236
## demo_prnt_highest_ed13 0.84995 3.13042 0.272
## demo_prnt_highest_ed14 0.91848 3.14193 0.292
## demo_prnt_highest_ed15 1.94647 3.12612 0.623
## demo_prnt_highest_ed16 2.04437 3.12933 0.653
## demo_prnt_highest_ed17 2.07553 3.13156 0.663
## demo_prnt_highest_ed18 1.81639 3.12675 0.581
## demo_prnt_highest_ed19 1.79741 3.12757 0.575
## demo_prnt_highest_ed20 1.42603 3.13687 0.455
## demo_prnt_highest_ed21 1.89094 3.13490 0.603
## PC1 0.04305 0.01148 3.751
## PC2 -0.03098 0.01279 -2.421
## PC3 0.05384 0.02776 1.940
## PC4 -0.03342 0.03147 -1.062
## PC5 -0.00670 0.03327 -0.201
## PC6 -0.02448 0.03319 -0.738
## PC7 -0.01159 0.03666 -0.316
## PC8 -0.01714 0.03630 -0.472
## PC9 0.05415 0.03778 1.433
## PC10 -0.01312 0.03691 -0.355
```

```
##
## Correlation matrix not shown by default, as p = 52 > 12.
## Use print(x, correlation=TRUE) or
##     vcov(x)         if you need it
```

```
likelihood_ratios <- list()
for (i in 1:10) {
  unrestricted_fit <- fits[[i]]
  restricted_fit <- fits[[i+1]]
  # compute the AIC-corrected log-base-2 likelihood ratio (a.k.a. "bits" of evidence)
  likelihood_ratios[[i]] <- (AIC(restricted_fit)-AIC(unrestricted_fit))*log2(exp(1))
}
```

```
likelihood_ratios
```

```
## [[1]]  
## [1] -14.76303  
##  
## [[2]]  
## [1] -6.020721  
##  
## [[3]]  
## [1] -2.868523  
##  
## [[4]]  
## [1] 0.5724099  
##  
## [[5]]  
## [1] 2.856471  
##  
## [[6]]  
## [1] 2.099211  
##  
## [[7]]  
## [1] 2.820005  
##  
## [[8]]  
## [1] 2.606116  
##  
## [[9]]  
## [1] -0.07920071  
##  
## [[10]]  
## [1] 2.703107
```

```
# classification_data <- model_data %>%  
#   select(-c("subjectkey", "eventname", "outcome_internalizing_score")) %>%  
#   rename(outcome = outcome_si)  
# classification_fit <- glmer(model_formula, data = classification_data, family = binomial)  
# summary(classification_fit)
```

## Principal Component Loading Plots

Now, let's make plots of the first ten principal components' thickness loading minus surface area loading. Thus,

- a region with a more positive value is more represented by cortical thickness,
- a region with a near zero value is represented by both cortical thickness and surface area, and
- a region with a more negative value is more represented by surface area.

Consider, Is a given PC representing variance in certain regions? Is a given PC more dominated by thickness or surface area?

```
library(ggseg) # https://drmwinkels.io/blog/2021-03-14-new-ggseg-with-geom/
```

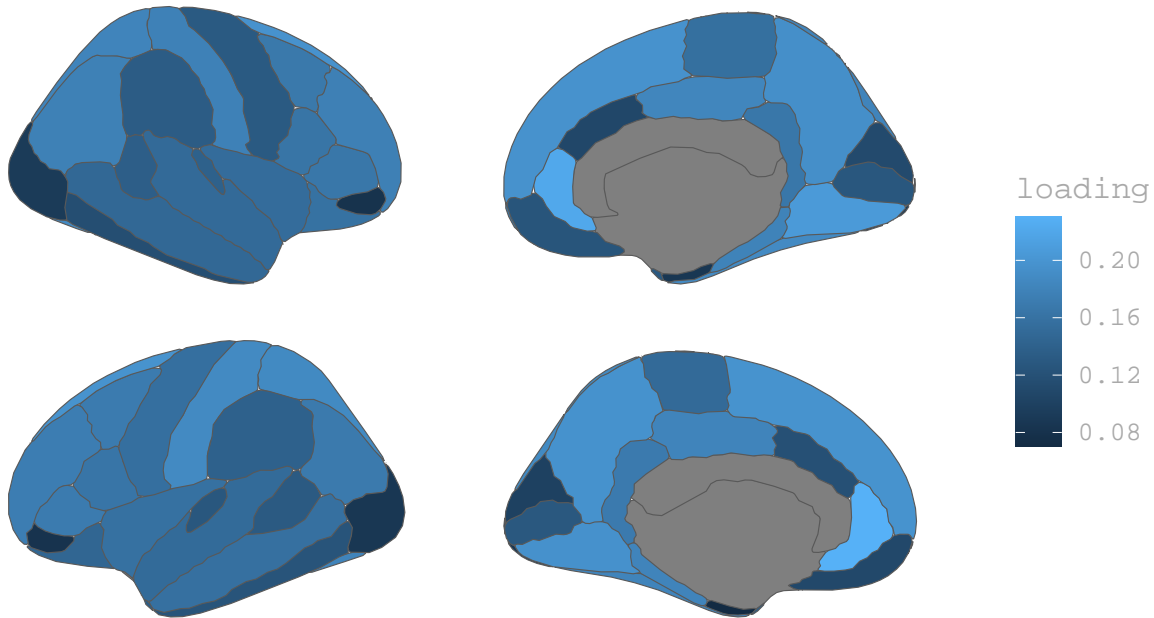
```
plot_pc_relative_loadings <- function(pc) {  
  pc_thick_index <- which(names(pc) %>% str_detect("thick"))  
  pc_thick <- pc[pc_thick_index]  
  pc_area <- pc[-pc_thick_index]
```

```
regions <- dk$data %>%
  filter(region != "corpus callosum") %>%
  pull(region) %>% na.omit %>% unique %>% sort
df <- data.frame(hemi=c(rep("left", length(regions)),
                        rep("right", length(regions))),
                 region=rep(regions, 2),
                 loading=pc_thick-pc_area,
                 row.names = NULL)
ggplot(df) + geom_brain(atlas = dk,
                       position = position_brain(hemi ~ side),
                       aes(fill = loading)) + theme_brain2()
}

pc_plots <- apply(pca$rotation[,1:10], 2, plot_pc_relative_loadings)
pc_plots
```

```
## $PC1
```

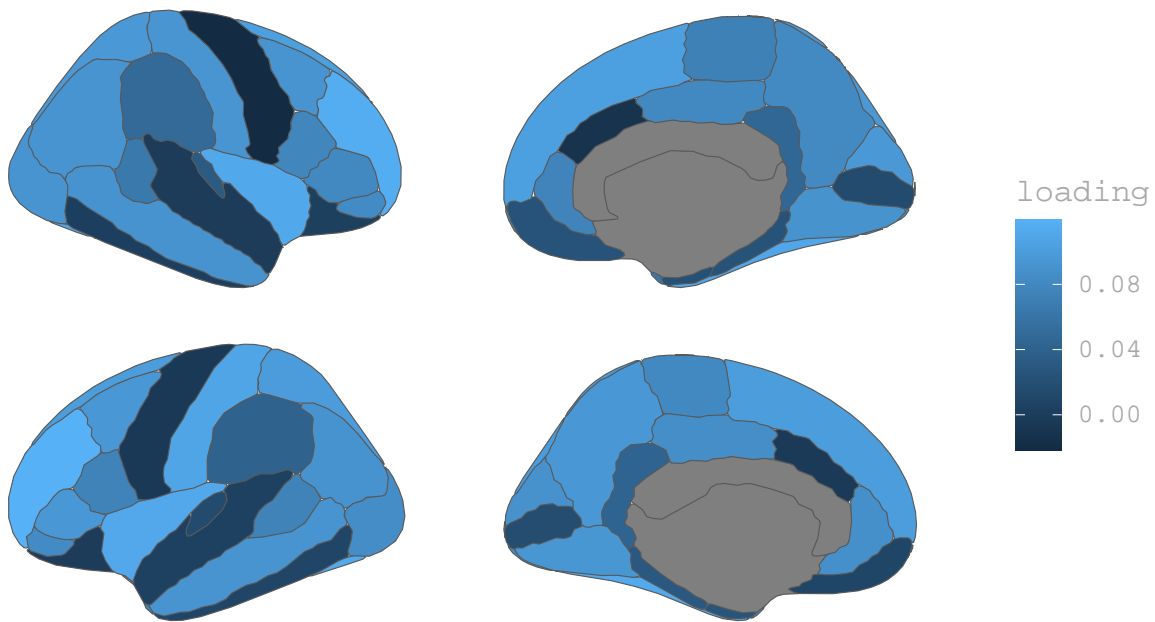
```
## merging atlas and data by 'hemi', 'region'
```



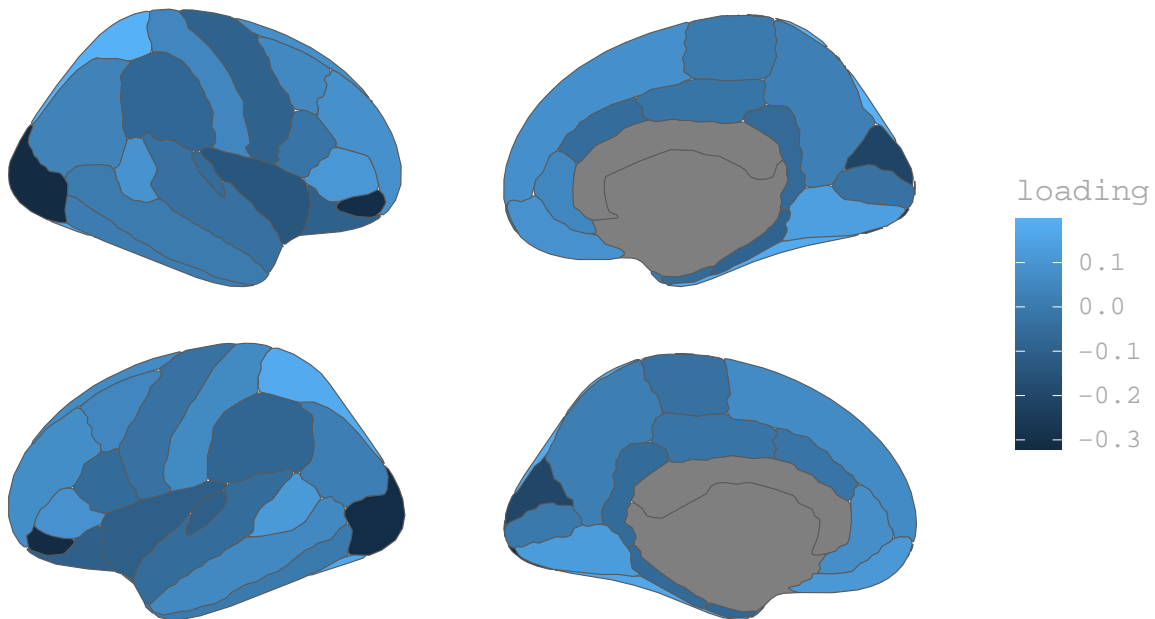
```
##
```

```
## $PC2
```

```
## merging atlas and data by 'hemi', 'region'
```

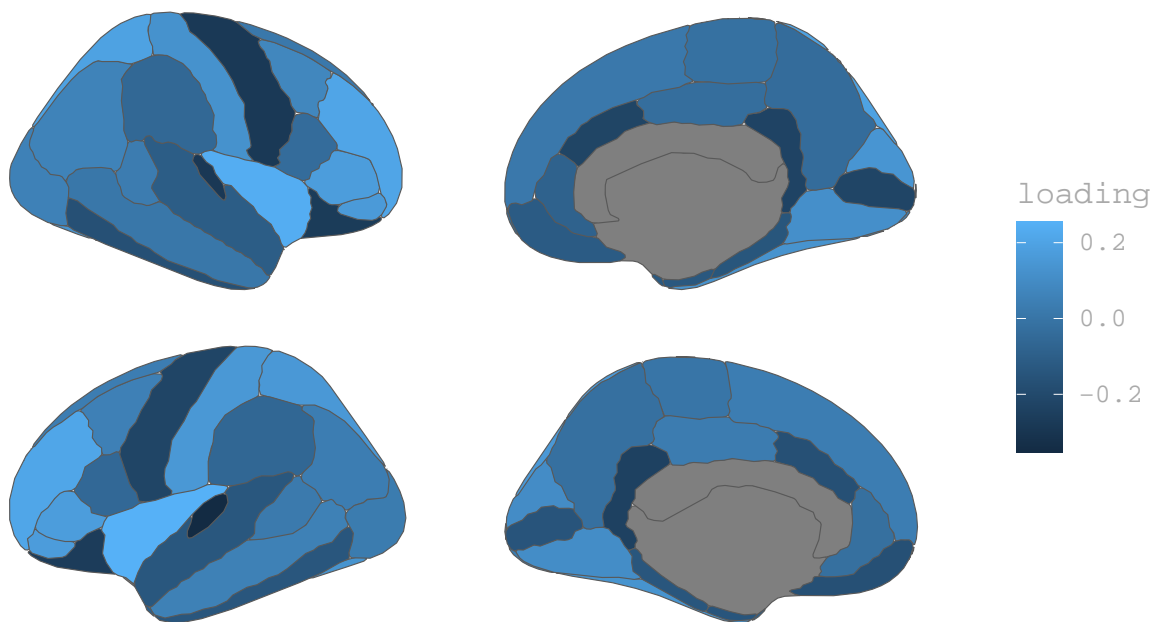


```
##
## $PC3
## merging atlas and data by 'hemi', 'region'
```

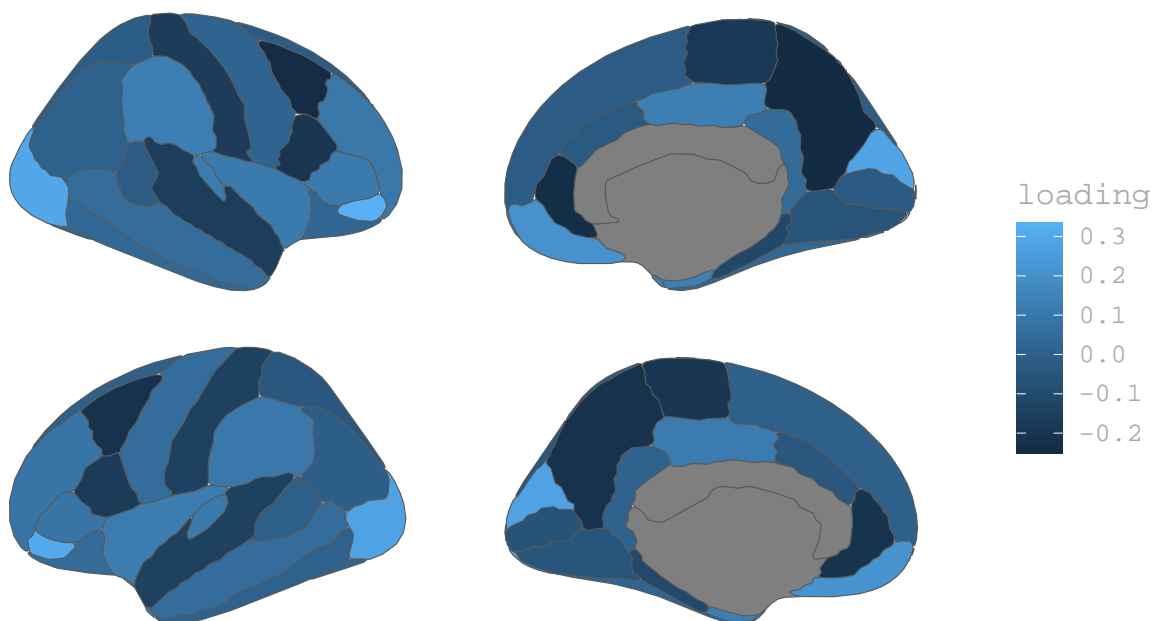


```
##
## $PC4
## merging atlas and data by 'hemi', 'region'
```

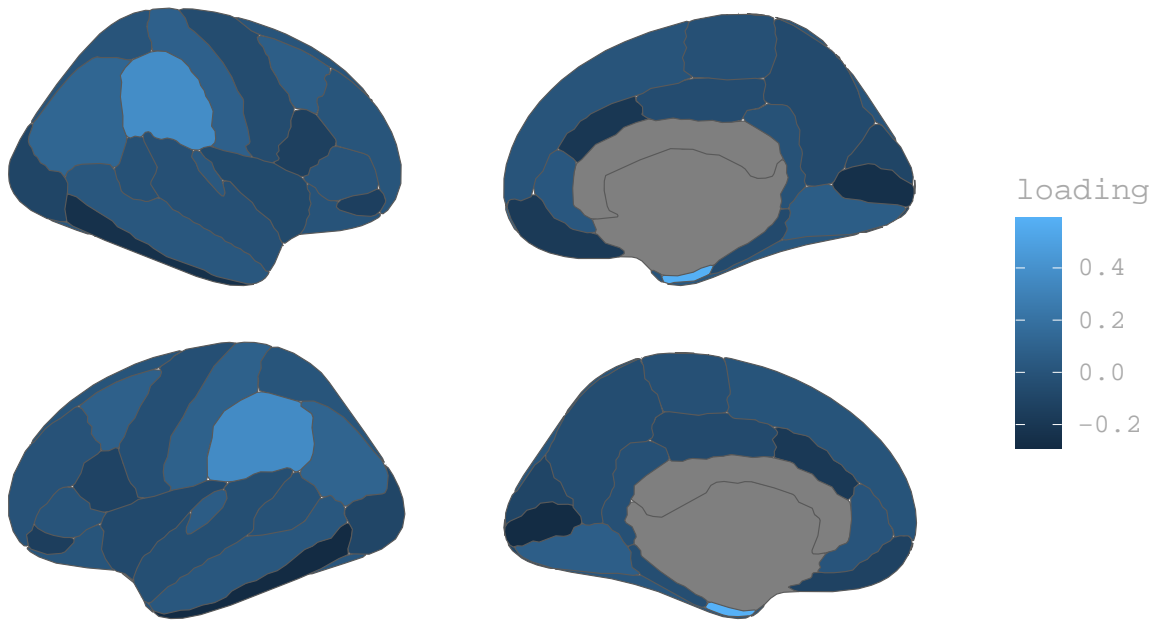




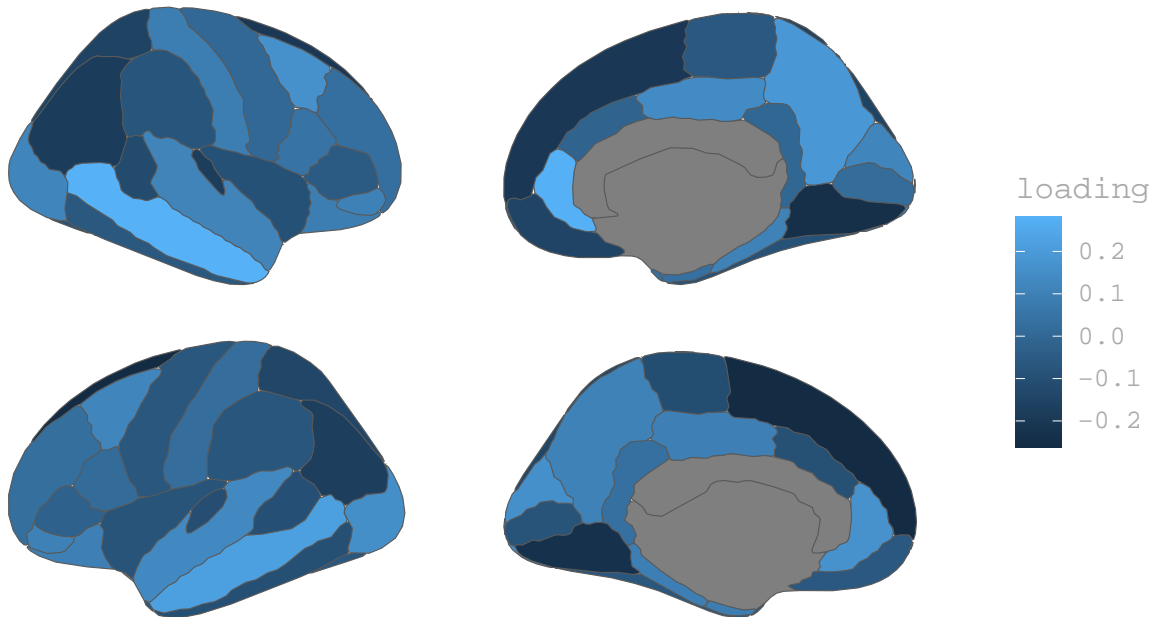
```
##
## $PC5
## merging atlas and data by 'hemi', 'region'
```



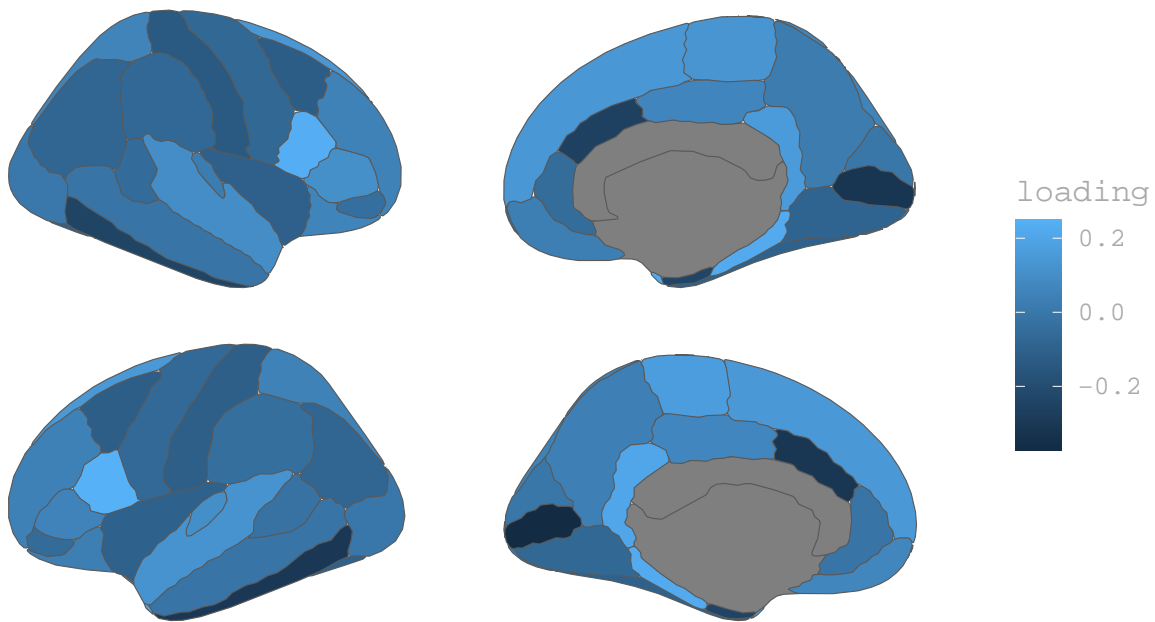
```
##
## $PC6
## merging atlas and data by 'hemi', 'region'
```



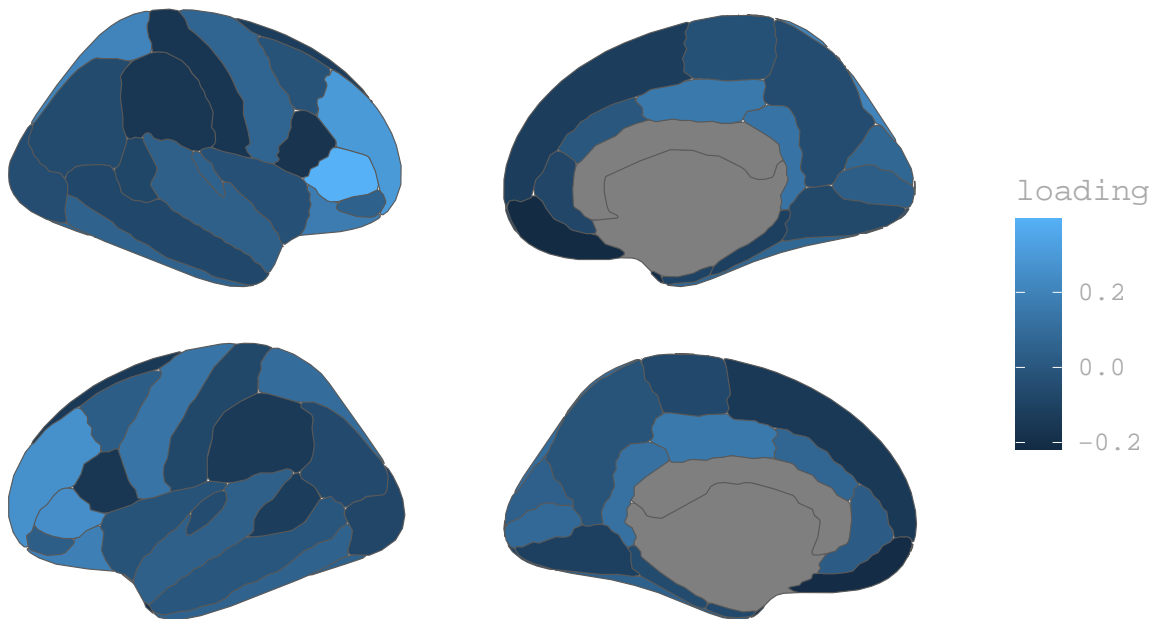
```
##
## $PC7
## merging atlas and data by 'hemi', 'region'
```



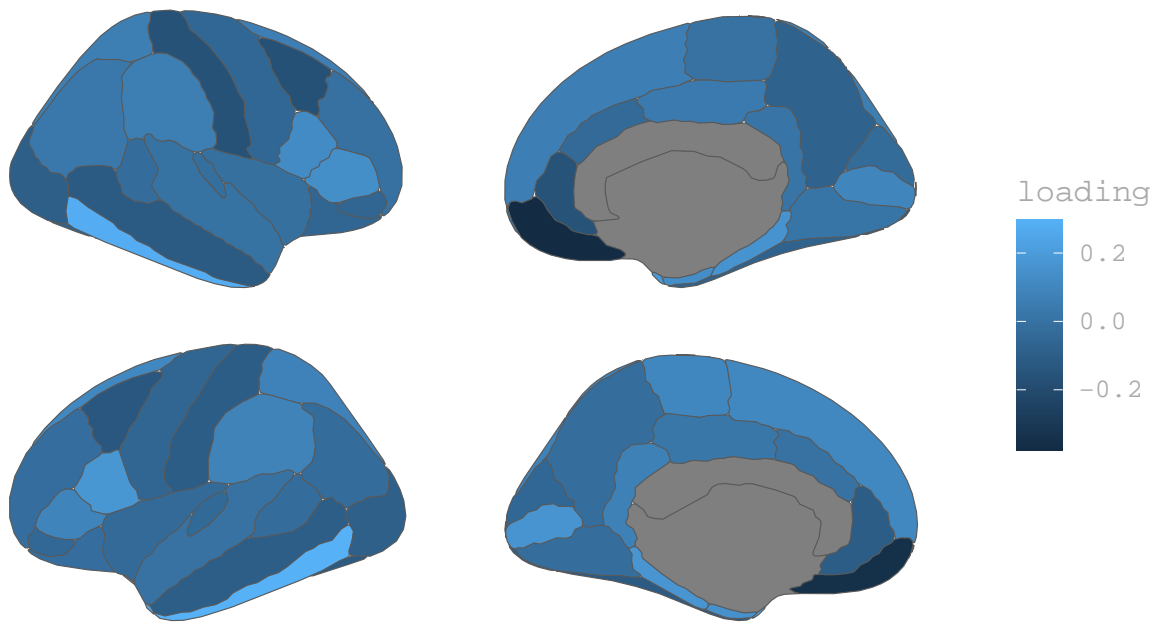
```
##
## $PC8
## merging atlas and data by 'hemi', 'region'
```



```
##
## $PC9
## merging atlas and data by 'hemi', 'region'
```



```
##
## $PC10
## merging atlas and data by 'hemi', 'region'
```



## Questions

- What other covariates are required?
- Do we want to use eventname or interview age for temporal effect?