Hyperparameter Tuning

Team Rho

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```r
#libraries

library(readxl)
library(caret)
library(tidyr)
library(dplyr)
library(corrplot)
library(rvest)
library(glmnet)
library(pls)
```

```r
#reading data

# data_GTrends <- read_excel("C:/data_science/DSE6311OM_/week3_Exploratory Data Analysis/googleTrendsMH
# acs_data <- load("C:\\data_science\\DSE6311OM_\\Week4_Pre-processing and Feature Engineering\\ACS_for
# Replace with this code to allow quick access regardless of download location
data_GTrends <- read_excel("~/GitHub/DSE6311OM_SP2025R2_Data-Science-Capstone/Data/googleTrendsMH.xlsx"
    sheet = "googleTrendsMH")
acs_data <- load("~/GitHub/DSE6311OM_SP2025R2_Data-Science-Capstone/Data/ACS_for_MHGoogleTrends.Rdata")

acs_data <- ACS_data
ACS_data <- NULL
```

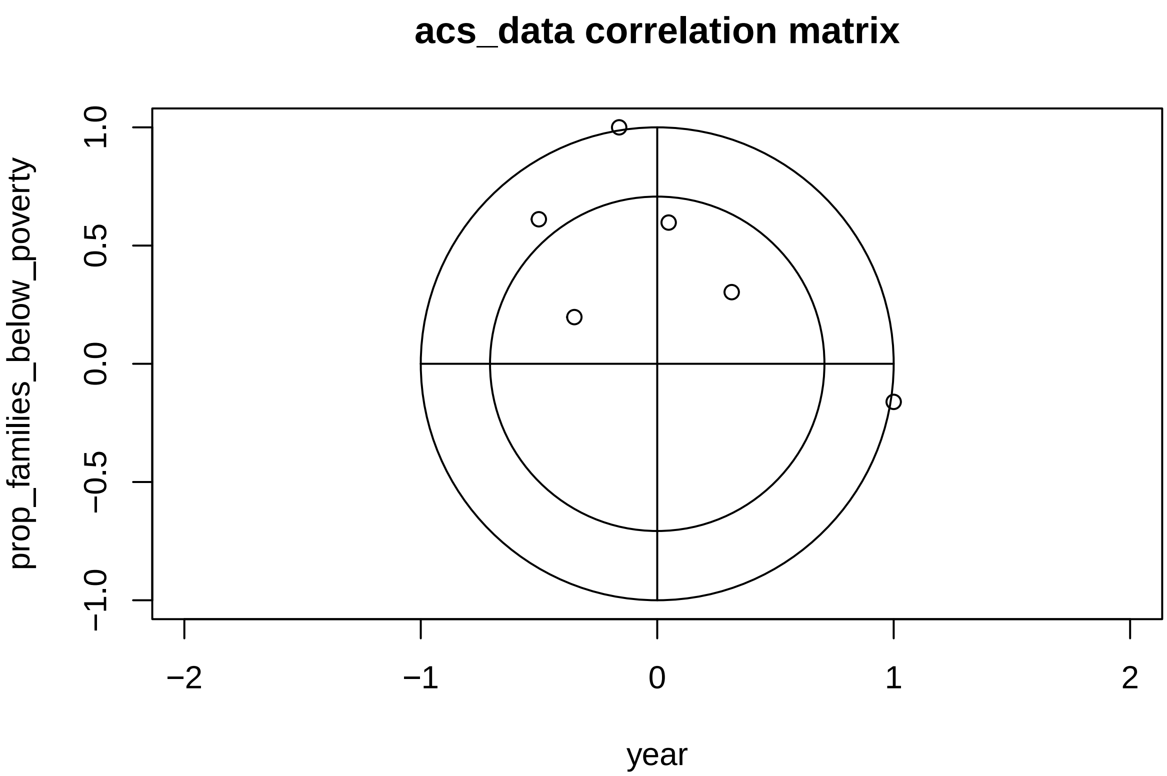
```r
##CORRELATION MATRIX FOR acs_data

acs_correlation_matrix <- acs_data %>%
  select_if(is.numeric) %>%
  select(-prop_persons_below_poverty_threshold, -prop_veterans_disability) %>%
  cor()

print(acs_correlation_matrix)
```

```
##                                           year prop_families_below_poverty
## year                                1.00000000                  -0.1610309
## prop_families_below_poverty        -0.16103094                   1.0000000
## prop_adults_without_health_insurance -0.35051348                 0.1974453
## prop_unemployed_in_labor_force     -0.50071692                   0.6113240
## prop_without_internet_access        0.31496819                   0.3030755
## prop_adult_disability               0.04834553                   0.5972604
##                                    prop_adults_without_health_insurance
## year                                                         -0.3505135
```

```
## prop_families_below_poverty                                  0.1974453
## prop_adults_without_health_insurance                         1.0000000
## prop_unemployed_in_labor_force                               0.2889701
## prop_without_internet_access                                -0.1226758
## prop_adult_disability                                        0.1945398
##                                      prop_unemployed_in_labor_force
## year                                                     -0.5007169
## prop_families_below_poverty                               0.6113240
## prop_adults_without_health_insurance                      0.2889701
## prop_unemployed_in_labor_force                            1.0000000
## prop_without_internet_access                             -0.1705119
## prop_adult_disability                                     0.1723363
##                                      prop_without_internet_access
## year                                                    0.3149682
## prop_families_below_poverty                             0.3030755
## prop_adults_without_health_insurance                   -0.1226758
## prop_unemployed_in_labor_force                         -0.1705119
## prop_without_internet_access                            1.0000000
## prop_adult_disability                                   0.3494365
##                                      prop_adult_disability
## year                                            0.04834553
## prop_families_below_poverty                     0.59726036
## prop_adults_without_health_insurance            0.19453980
## prop_unemployed_in_labor_force                  0.17233629
## prop_without_internet_access                    0.34943653
## prop_adult_disability                           1.00000000
```

updated code

```r
#presenting correlation matrix in graphic format

acs_correlation_matrix <- acs_data %>%
  select_if(is.numeric) %>%
  select(-prop_persons_below_poverty_threshold, -prop_veterans_disability) %>%
  cor() %>%
  corrplot( diag = F,
           tl.cex = 0.7,
           tl.col = "black",
           main = "acs_data correlation matrix",
           mar = c(0,0,1,0))
```




```
#removing correlated features


acs_data_clean <- acs_data %>%
  select(-prop_persons_below_poverty_threshold, -prop_veterans_disability)


# convert state names into abbreviation to match state in data_GTrends

acs_data_clean$state <- toupper(state.abb[match(tolower(acs_data_clean$state), tolower(state.name))])
```

testing GitHub

```
#data transformations ct variables
#creating response variable => state_mentalhealth_utili = state_psych_care / population_est

#state_mentalhealth_utili <- data_GTrends$state_psych_care / data_GTrends$population_est

data_GTrends <- data_GTrends %>%
  mutate(state_mentalhealth_util = state_psych_care/population_est,
         anxiety_prop = anxiety_ct/ population_est,
         trauma_stress_prop = trauma_stress_ct/population_est,
         adhd_prop = adhd_ct/population_est,
         bipolar_prop = bipolar_ct/population_est,
         depression_prop = depression_ct/population_est)

#data_GTrends <- data_GTrends %>%
  #select(-state_psych_care, -anxiety_ct, -trauma_stress_ct, -adhd_ct, -bipolar_ct, -depression_ct) all
```

```r
#joining both datasets acs_data and data_GTrends

GTrends_acs_joined <- inner_join(data_GTrends, acs_data_clean, by = c("year", "state"))
```

```r
#testing correlation


correlation_matrix <- GTrends_acs_joined %>%
  select_if(is.numeric) %>%
  select(-fips, -population_est,-private_psych_care, -total_util, -outpatient_util, -mean_anxiety, -res
         -total_util) %>%
  cor()

print(correlation_matrix)
```

```
##                                             year   anxiety_ct trauma_stress_ct
## year                                  1.00000000  0.230563501       0.13366856
## anxiety_ct                            0.23056350  1.000000000       0.92240079
## trauma_stress_ct                      0.13366856  0.922400795       1.00000000
## adhd_ct                               0.01851770  0.847645702       0.87161036
## bipolar_ct                           -0.13690754  0.653131435       0.75571956
## depression_ct                         0.06120702  0.873780027       0.94087338
## comm_psych_care                       0.05264059  0.793626073       0.89977194
## state_psych_care                      0.05220254  0.800842275       0.90248691
## mean_adhd                             0.75682637  0.192811841       0.08958471
## mean_ptsd                             0.62228218  0.090669189       0.04475684
## mean_bipolar                         -0.09097469 -0.085128361      -0.08423315
## mean_depression                      -0.02390143  0.009319898      -0.02136263
## mean_mental_hospital                  0.27777930  0.319455125       0.28112091
## mean_psychiatrists_near_me            0.18697534  0.063526502       0.09919989
## mean_psychologist_near_me             0.64878930  0.404062943       0.38356349
## anxiety_prop                          0.25256530  0.575638687       0.40794338
## adhd_prop                             0.02582844  0.540119606       0.44884626
## bipolar_prop                         -0.27713846  0.402247684       0.39406527
## prop_families_below_poverty          -0.31411265 -0.065951520      -0.02266406
## prop_adults_without_health_insurance -0.35036488 -0.120820100      -0.08943951
## prop_unemployed_in_labor_force       -0.54031845 -0.047006409       0.07676369
## prop_without_internet_access          0.31423583  0.011777977      -0.03506000
## prop_adult_disability                 0.07154859 -0.089418168      -0.12802032
##                                          adhd_ct   bipolar_ct depression_ct
## year                                  0.018517704 -0.13690754    0.06120702
## anxiety_ct                            0.847645702  0.65313144    0.87378003
## trauma_stress_ct                      0.871610355  0.75571956    0.94087338
## adhd_ct                               1.000000000  0.83440163    0.90823233
## bipolar_ct                            0.834401629  1.00000000    0.88673220
## depression_ct                         0.908232333  0.88673220    1.00000000
## comm_psych_care                       0.874225711  0.87090215    0.95667411
## state_psych_care                      0.884006979  0.87166405    0.95701158
## mean_adhd                            -0.007745775 -0.10866030    0.02253769
## mean_ptsd                            -0.124707857 -0.22821302   -0.08131642
## mean_bipolar                         -0.082850695 -0.03030126   -0.08659302
## mean_depression                      -0.026389005 -0.09361394   -0.02884011
## mean_mental_hospital                  0.220054198  0.21655455    0.28147786
```

```
## mean_psychiatrists_near_me            0.086212620  0.06521304    0.09221333
## mean_psychologist_near_me             0.316683082  0.20732437    0.35169600
## anxiety_prop                          0.306023903  0.03211950    0.27306557
## adhd_prop                             0.557691198  0.19368296    0.36224924
## bipolar_prop                          0.458390120  0.36562312    0.36378200
## prop_families_below_poverty           0.091452450  0.21421452    0.06093810
## prop_adults_without_health_insurance  0.001121328  0.24369742    0.03448441
## prop_unemployed_in_labor_force        0.124358517  0.28278587    0.13217179
## prop_without_internet_access          0.010097643 -0.11859483   -0.03027184
## prop_adult_disability                -0.041620397 -0.11618594   -0.11834226
##                                      comm_psych_care state_psych_care
## year                                      0.05264059       0.05220254
## anxiety_ct                                0.79362607       0.80084228
## trauma_stress_ct                          0.89977194       0.90248691
## adhd_ct                                   0.87422571       0.88400698
## bipolar_ct                                0.87090215       0.87166405
## depression_ct                             0.95667411       0.95701158
## comm_psych_care                           1.00000000       0.99936080
## state_psych_care                          0.99936080       1.00000000
## mean_adhd                                 0.01154550       0.01301038
## mean_ptsd                                -0.09505592      -0.09409334
## mean_bipolar                             -0.06243299      -0.06269307
## mean_depression                          -0.04094749      -0.04237320
## mean_mental_hospital                      0.24373032       0.24415647
## mean_psychiatrists_near_me                0.13571311       0.13354197
## mean_psychologist_near_me                 0.36100819       0.35825438
## anxiety_prop                              0.18813746       0.20049138
## adhd_prop                                 0.28982510       0.30527377
## bipolar_prop                              0.30483675       0.31814831
## prop_families_below_poverty               0.06341390       0.06303851
## prop_adults_without_health_insurance      0.02920460       0.02820942
## prop_unemployed_in_labor_force            0.16815934       0.16554652
## prop_without_internet_access             -0.03609294      -0.03484673
## prop_adult_disability                    -0.15530682      -0.14673191
##                                         mean_adhd   mean_ptsd mean_bipolar
## year                                  0.756826372  0.62228218 -0.090974692
## anxiety_ct                            0.192811841  0.09066919 -0.085128361
## trauma_stress_ct                      0.089584712  0.04475684 -0.084233146
## adhd_ct                              -0.007745775 -0.12470786 -0.082850695
## bipolar_ct                           -0.108660303 -0.22821302 -0.030301260
## depression_ct                         0.022537693 -0.08131642 -0.086593022
## comm_psych_care                       0.011545502 -0.09505592 -0.062432992
## state_psych_care                      0.013010379 -0.09409334 -0.062693072
## mean_adhd                             1.000000000  0.42495384  0.179510680
## mean_ptsd                             0.424953840  1.00000000  0.193509244
## mean_bipolar                          0.179510680  0.19350924  1.000000000
## mean_depression                      -0.245750075  0.41128942  0.308755245
## mean_mental_hospital                  0.287677009  0.09702821  0.232486981
## mean_psychiatrists_near_me            0.042769431  0.05674090 -0.005280538
## mean_psychologist_near_me             0.415735545  0.23433255 -0.080183845
## anxiety_prop                          0.222753634  0.30520691 -0.005956554
## adhd_prop                             0.028590323  0.09085592 -0.010212770
## bipolar_prop                         -0.159049076 -0.04663275  0.157398435
## prop_families_below_poverty          -0.208577621 -0.20391856  0.293106346
```

```
## prop_adults_without_health_insurance -0.186412427 -0.24473889  0.233057761
## prop_unemployed_in_labor_force       -0.327758496 -0.43653037  0.157300589
## prop_without_internet_access         -0.126520915  0.33393361 -0.090016482
## prop_adult_disability                 0.109982033  0.10629585  0.222236769
##                                      mean_depression mean_mental_hospital
## year                                    -0.023901425           0.27777930
## anxiety_ct                               0.009319898           0.31945513
## trauma_stress_ct                        -0.021362629           0.28112091
## adhd_ct                                 -0.026389005           0.22005420
## bipolar_ct                              -0.093613944           0.21655455
## depression_ct                           -0.028840113           0.28147786
## comm_psych_care                         -0.040947486           0.24373032
## state_psych_care                        -0.042373199           0.24415647
## mean_adhd                               -0.245750075           0.28767701
## mean_ptsd                                0.411289416           0.09702821
## mean_bipolar                             0.308755245           0.23248698
## mean_depression                          1.000000000          -0.10548867
## mean_mental_hospital                    -0.105488666           1.00000000
## mean_psychiatrists_near_me               0.001374564           0.15614239
## mean_psychologist_near_me               -0.098056483           0.41633384
## anxiety_prop                             0.050429764           0.02664347
## adhd_prop                                0.069487449          -0.06288825
## bipolar_prop                             0.026384149          -0.09485722
## prop_families_below_poverty             -0.077146712           0.21535926
## prop_adults_without_health_insurance    -0.062380502          -0.02688604
## prop_unemployed_in_labor_force          -0.348426242           0.10886182
## prop_without_internet_access             0.385215253           0.07508085
## prop_adult_disability                   -0.081676556           0.16483923
##                                      mean_psychiatrists_near_me
## year                                                0.186975337
## anxiety_ct                                          0.063526502
## trauma_stress_ct                                    0.099199887
## adhd_ct                                             0.086212620
## bipolar_ct                                          0.065213036
## depression_ct                                       0.092213328
## comm_psych_care                                     0.135713106
## state_psych_care                                    0.133541968
## mean_adhd                                           0.042769431
## mean_ptsd                                           0.056740904
## mean_bipolar                                       -0.005280538
## mean_depression                                     0.001374564
## mean_mental_hospital                                0.156142388
## mean_psychiatrists_near_me                          1.000000000
## mean_psychologist_near_me                           0.466711912
## anxiety_prop                                       -0.104990533
## adhd_prop                                          -0.105489672
## bipolar_prop                                       -0.156142069
## prop_families_below_poverty                        -0.185544042
## prop_adults_without_health_insurance               -0.257450224
## prop_unemployed_in_labor_force                     -0.020698183
## prop_without_internet_access                        0.051130358
## prop_adult_disability                              -0.239770625
##                                      mean_psychologist_near_me anxiety_prop
## year                                                0.64878930  0.252565296
```

```
## anxiety_ct                                      0.40406294  0.575638687
## trauma_stress_ct                                0.38356349  0.407943378
## adhd_ct                                         0.31668308  0.306023903
## bipolar_ct                                      0.20732437  0.032119498
## depression_ct                                   0.35169600  0.273065574
## comm_psych_care                                 0.36100819  0.188137462
## state_psych_care                                0.35825438  0.200491380
## mean_adhd                                       0.41573555  0.222753634
## mean_ptsd                                       0.23433255  0.305206913
## mean_bipolar                                   -0.08018385 -0.005956554
## mean_depression                                -0.09805648  0.050429764
## mean_mental_hospital                            0.41633384  0.026643466
## mean_psychiatrists_near_me                      0.46671191 -0.104990533
## mean_psychologist_near_me                       1.00000000  0.018713136
## anxiety_prop                                    0.01871314  1.000000000
## adhd_prop                                      -0.02192663  0.772593545
## bipolar_prop                                   -0.20102389  0.592973858
## prop_families_below_poverty                    -0.16397365 -0.139411004
## prop_adults_without_health_insurance           -0.20618180 -0.202330161
## prop_unemployed_in_labor_force                 -0.18536934 -0.244392365
## prop_without_internet_access                    0.15990322  0.090420463
## prop_adult_disability                          -0.08569762  0.099264075
##                                         adhd_prop bipolar_prop
## year                                   0.02582844  -0.27713846
## anxiety_ct                             0.54011961   0.40224768
## trauma_stress_ct                       0.44884626   0.39406527
## adhd_ct                                0.55769120   0.45839012
## bipolar_ct                             0.19368296   0.36562312
## depression_ct                          0.36224924   0.36378200
## comm_psych_care                        0.28982510   0.30483675
## state_psych_care                       0.30527377   0.31814831
## mean_adhd                              0.02859032  -0.15904908
## mean_ptsd                              0.09085592  -0.04663275
## mean_bipolar                          -0.01021277   0.15739843
## mean_depression                        0.06948745   0.02638415
## mean_mental_hospital                  -0.06288825  -0.09485722
## mean_psychiatrists_near_me            -0.10548967  -0.15614207
## mean_psychologist_near_me             -0.02192663  -0.20102389
## anxiety_prop                           0.77259354   0.59297386
## adhd_prop                              1.00000000   0.73676449
## bipolar_prop                           0.73676449   1.00000000
## prop_families_below_poverty            0.06474605   0.24288704
## prop_adults_without_health_insurance -0.10333794   0.15947980
## prop_unemployed_in_labor_force        -0.06381305   0.17824936
## prop_without_internet_access           0.10675502  -0.09079816
## prop_adult_disability                  0.20587109   0.24830497
##                                      prop_families_below_poverty
## year                                                 -0.31411265
## anxiety_ct                                           -0.06595152
## trauma_stress_ct                                     -0.02266406
## adhd_ct                                               0.09145245
## bipolar_ct                                            0.21421452
## depression_ct                                         0.06093810
## comm_psych_care                                       0.06341390
```

```
## state_psych_care                                 0.06303851
## mean_adhd                                       -0.20857762
## mean_ptsd                                       -0.20391856
## mean_bipolar                                     0.29310635
## mean_depression                                 -0.07714671
## mean_mental_hospital                             0.21535926
## mean_psychiatrists_near_me                      -0.18554404
## mean_psychologist_near_me                       -0.16397365
## anxiety_prop                                    -0.13941100
## adhd_prop                                        0.06474605
## bipolar_prop                                     0.24288704
## prop_families_below_poverty                      1.00000000
## prop_adults_without_health_insurance             0.60329043
## prop_unemployed_in_labor_force                   0.52364772
## prop_without_internet_access                     0.12312374
## prop_adult_disability                            0.65543780
##                                     prop_adults_without_health_insurance
## year                                                        -0.350364883
## anxiety_ct                                                  -0.120820100
## trauma_stress_ct                                            -0.089439512
## adhd_ct                                                      0.001121328
## bipolar_ct                                                   0.243697423
## depression_ct                                                0.034484408
## comm_psych_care                                              0.029204600
## state_psych_care                                             0.028209419
## mean_adhd                                                   -0.186412427
## mean_ptsd                                                   -0.244738889
## mean_bipolar                                                 0.233057761
## mean_depression                                             -0.062380502
## mean_mental_hospital                                        -0.026886042
## mean_psychiatrists_near_me                                  -0.257450224
## mean_psychologist_near_me                                   -0.206181798
## anxiety_prop                                                -0.202330161
## adhd_prop                                                   -0.103337943
## bipolar_prop                                                 0.159479797
## prop_families_below_poverty                                  0.603290434
## prop_adults_without_health_insurance                         1.000000000
## prop_unemployed_in_labor_force                               0.409465887
## prop_without_internet_access                                -0.106556672
## prop_adult_disability                                        0.289928013
##                                     prop_unemployed_in_labor_force
## year                                                   -0.54031845
## anxiety_ct                                             -0.04700641
## trauma_stress_ct                                        0.07676369
## adhd_ct                                                 0.12435852
## bipolar_ct                                              0.28278587
## depression_ct                                           0.13217179
## comm_psych_care                                         0.16815934
## state_psych_care                                        0.16554652
## mean_adhd                                              -0.32775850
## mean_ptsd                                              -0.43653037
## mean_bipolar                                            0.15730059
## mean_depression                                        -0.34842624
## mean_mental_hospital                                    0.10886182
```

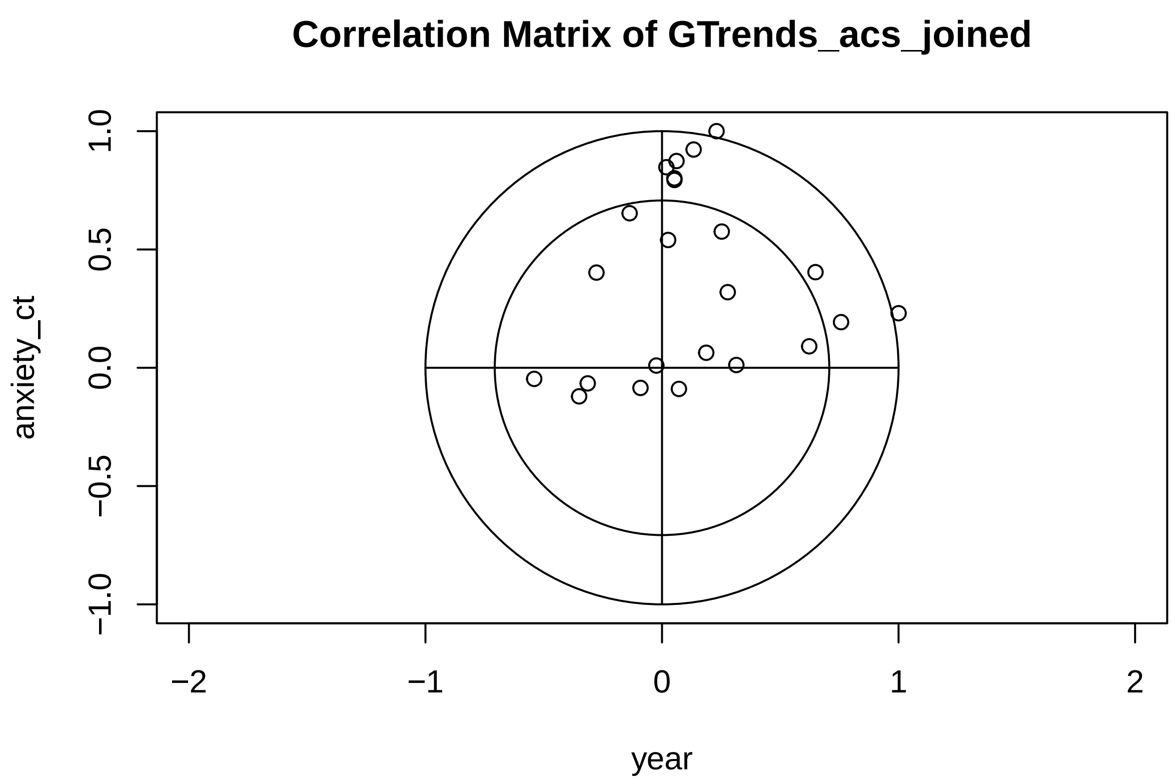
```
## mean_psychiatrists_near_me                               -0.02069818
## mean_psychologist_near_me                                -0.18536934
## anxiety_prop                                             -0.24439237
## adhd_prop                                                -0.06381305
## bipolar_prop                                              0.17824936
## prop_families_below_poverty                               0.52364772
## prop_adults_without_health_insurance                      0.40946589
## prop_unemployed_in_labor_force                            1.00000000
## prop_without_internet_access                             -0.34452758
## prop_adult_disability                                     0.06756309
##                                      prop_without_internet_access
## year                                                   0.31423583
## anxiety_ct                                             0.01177798
## trauma_stress_ct                                      -0.03506000
## adhd_ct                                                0.01009764
## bipolar_ct                                            -0.11859483
## depression_ct                                         -0.03027184
## comm_psych_care                                       -0.03609294
## state_psych_care                                      -0.03484673
## mean_adhd                                             -0.12652092
## mean_ptsd                                              0.33393361
## mean_bipolar                                          -0.09001648
## mean_depression                                        0.38521525
## mean_mental_hospital                                   0.07508085
## mean_psychiatrists_near_me                             0.05113036
## mean_psychologist_near_me                              0.15990322
## anxiety_prop                                           0.09042046
## adhd_prop                                              0.10675502
## bipolar_prop                                          -0.09079816
## prop_families_below_poverty                            0.12312374
## prop_adults_without_health_insurance                  -0.10655667
## prop_unemployed_in_labor_force                        -0.34452758
## prop_without_internet_access                           1.00000000
## prop_adult_disability                                  0.30396009
##                                      prop_adult_disability
## year                                            0.07154859
## anxiety_ct                                     -0.08941817
## trauma_stress_ct                               -0.12802032
## adhd_ct                                        -0.04162040
## bipolar_ct                                     -0.11618594
## depression_ct                                  -0.11834226
## comm_psych_care                                -0.15530682
## state_psych_care                               -0.14673191
## mean_adhd                                       0.10998203
## mean_ptsd                                       0.10629585
## mean_bipolar                                    0.22223677
## mean_depression                                -0.08167656
## mean_mental_hospital                            0.16483923
## mean_psychiatrists_near_me                     -0.23977062
## mean_psychologist_near_me                      -0.08569762
## anxiety_prop                                    0.09926407
## adhd_prop                                       0.20587109
## bipolar_prop                                    0.24830497
## prop_families_below_poverty                     0.65543780
```

```
## prop_adults_without_health_insurance          0.28992801
## prop_unemployed_in_labor_force                0.06756309
## prop_without_internet_access                  0.30396009
## prop_adult_disability                         1.00000000
```

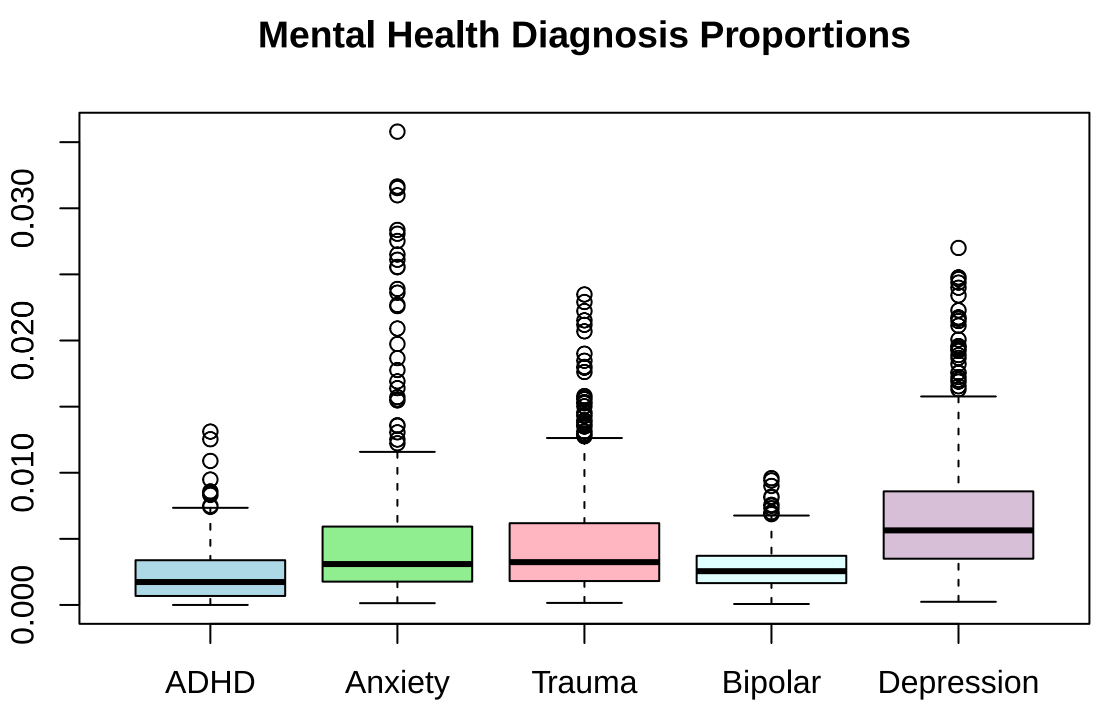
high correlation variables

1. private, reside and comm_psych_care, 2.inpatient_util vs outpatient_util (i already have state_mentalhealth_util) 3.mean_therapist near_me vs mean_psychiatrist and mean_psychologist 4.mean_alltrend vs mean_adhd, mean_ptsd, mean_anxiety, mean_mentalhospital.
2. mean_anxiety vs year, mean_adhd & ptsd 6.outpatient_util vs total_util, adhd, bipolar & depression 7.total_util 8.depression prob vs adhd. ptsd, bipolar and trauma_stress_prop 9.trauma_stress_prop vs adhd, anxiety_prop and state_mentalhealth_util 10.state_mentalhealth_util vs adhd, ptsd, bipolar

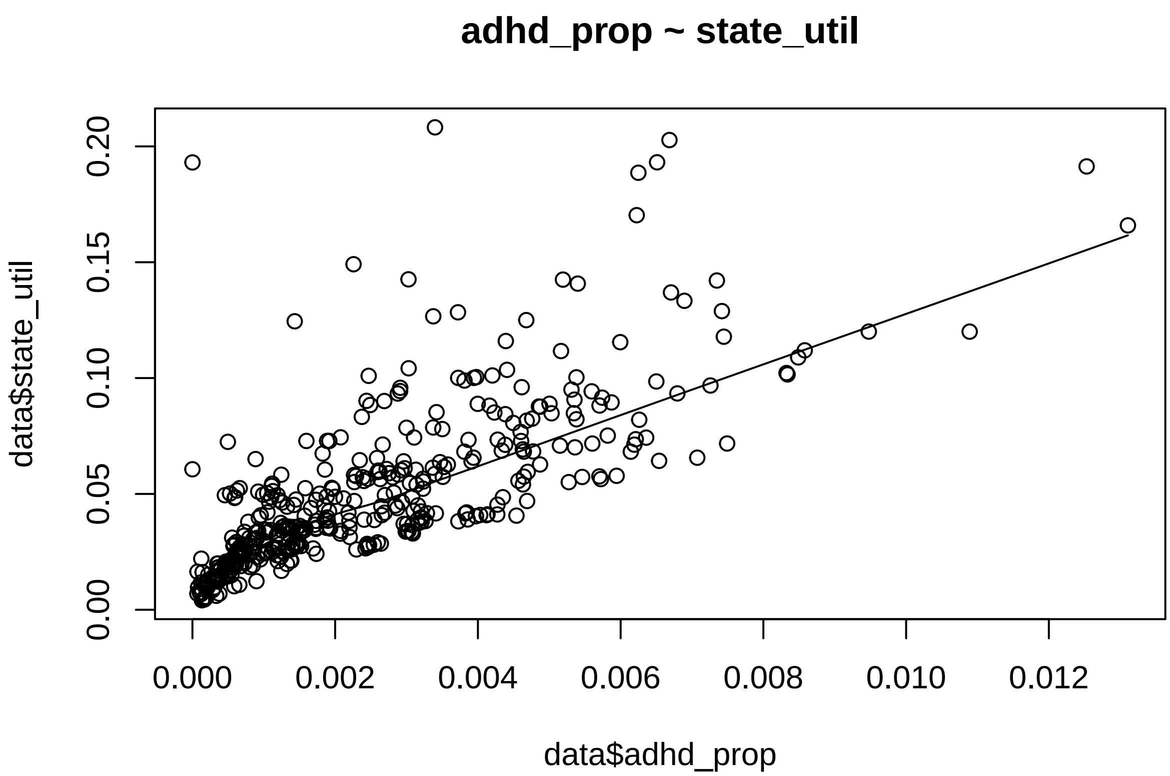
```
#correlation matrix

GTrends_acs_joined %>%
  select_if(is.numeric) %>%
  select(-fips, -population_est,-private_psych_care, -total_util, -outpatient_util, -mean_anxiety, -res
         -total_util) %>%
  cor() %>%

corrplot(diag = F,
         tl.cex = 0.7,
         tl.col = "black",
         main = "Correlation Matrix of GTrends_acs_joined",
         mar = c(0, 0, 1, 0))
```



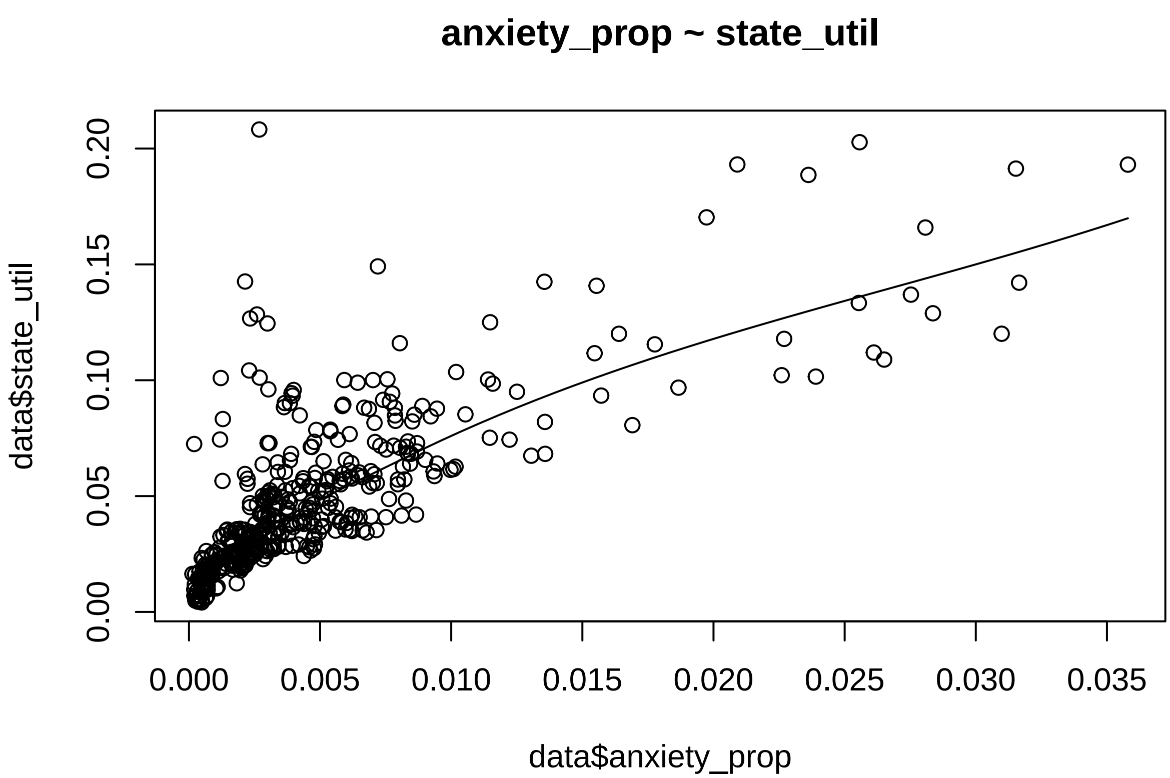
```r
data <- data_GTrends
data$adhd_prop= data$adhd_ct/data$population_est
data$anxiety_prop = data$anxiety_ct/data$population_est
data$bipolar_prop = data$bipolar_ct/data$population_est
data$depression_prop = data$depression_ct/data$population_est
data$trauma_prop = data$trauma_stress_ct/data$population_est
data$state_util = data$state_psych_care/data$population_est
data$private_util = data$private_psych_care/data$population_est
data$diff_util = data$total_util-(data$state_util + data$private_util)

boxplot(data[c("adhd_prop", "anxiety_prop", "trauma_prop", "bipolar_prop",  "depression_prop")],
        main = "Mental Health Diagnosis Proportions",
        names = c("ADHD", "Anxiety", "Trauma", "Bipolar", "Depression"),
        col = c("lightblue", "lightgreen", "lightpink", "lightcyan","thistle" ))
```



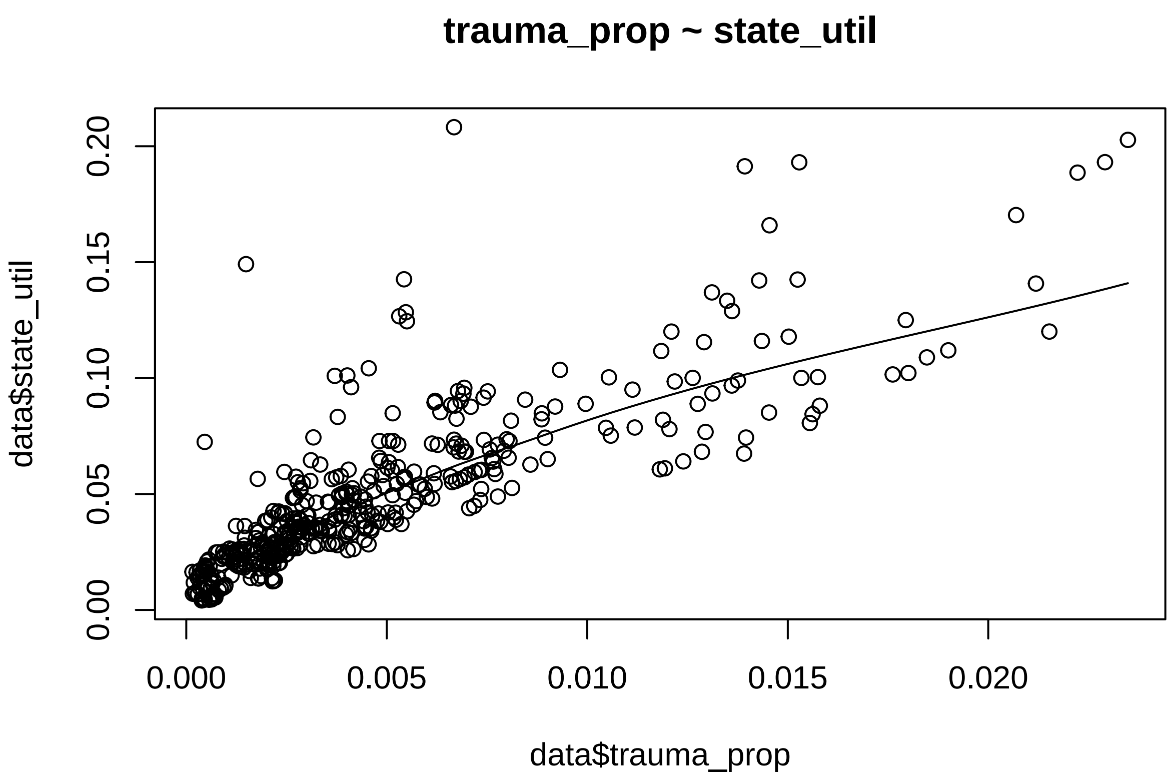

```r
par(mfrow=c(1,1))  # divide graph area in 2 columns
scatter.smooth(x=data$adhd_prop, y=data$state_util, main="adhd_prop ~ state_util")
```



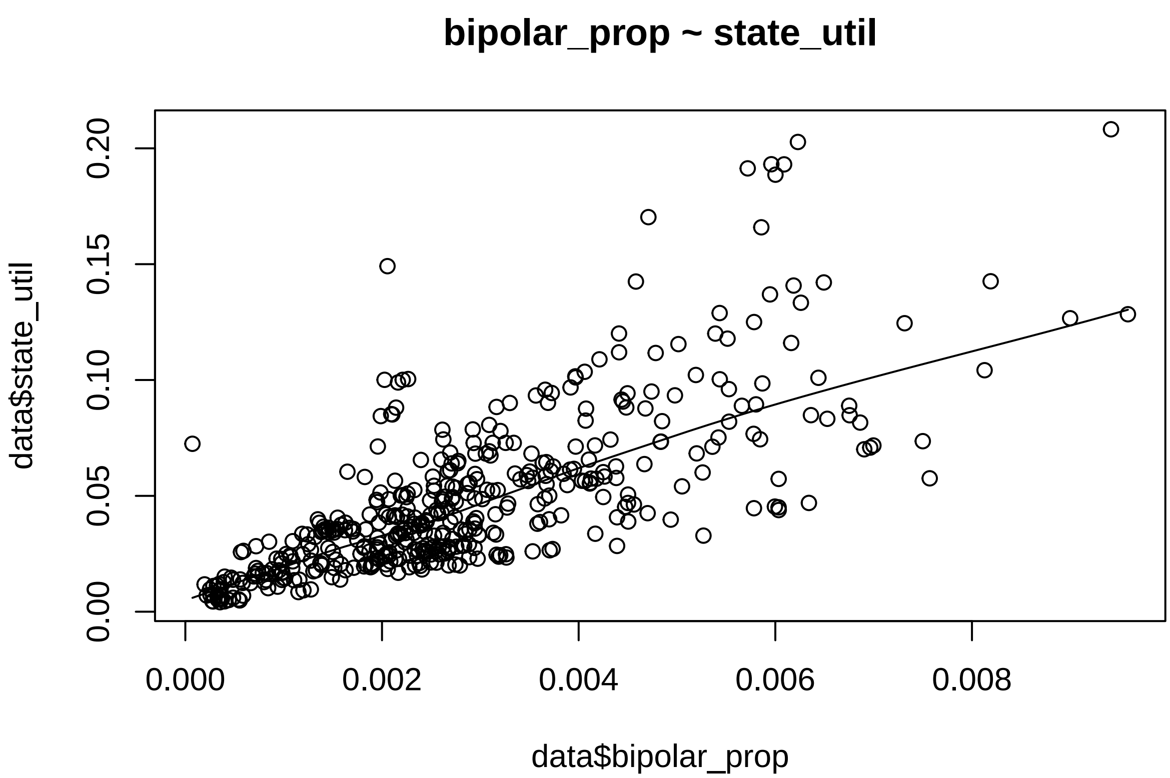

```r
scatter.smooth(x=data$anxiety_prop, y=data$state_util, main="anxiety_prop ~ state_util")
```



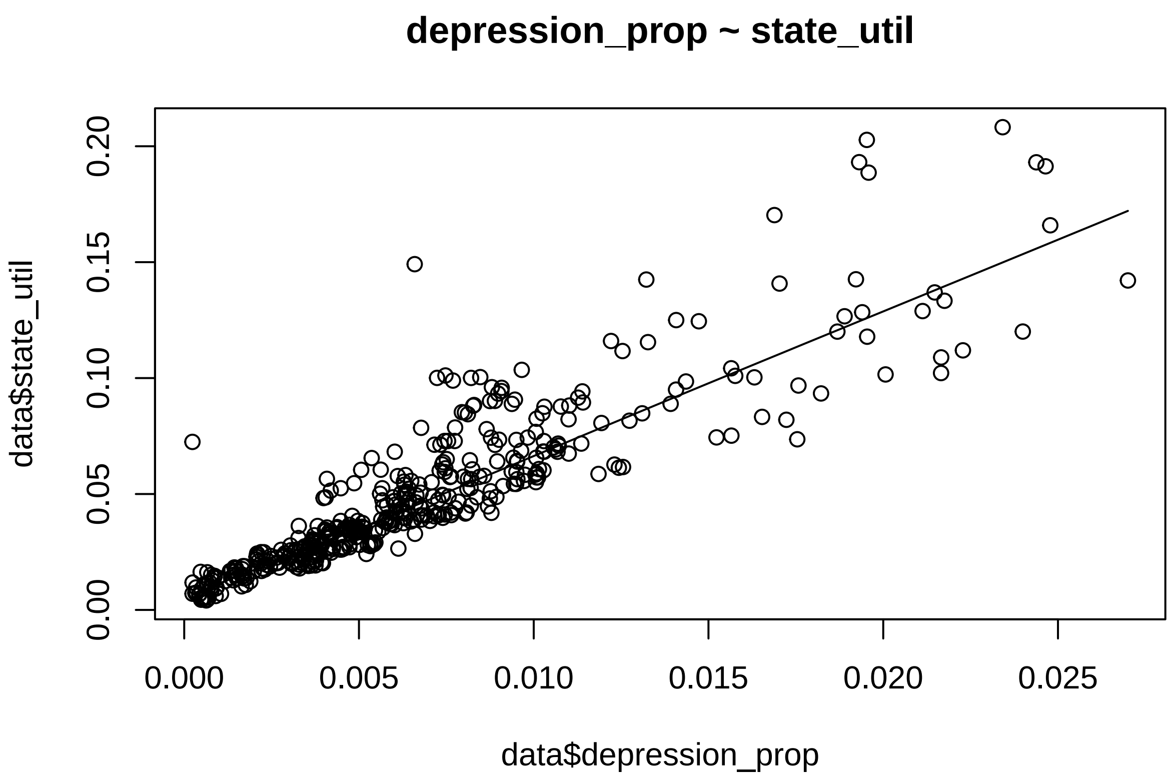
```r
scatter.smooth(x=data$trauma_prop, y=data$state_util, main="trauma_prop ~ state_util")
```




```r
scatter.smooth(x=data$bipolar_prop, y=data$state_util, main="bipolar_prop ~ state_util")
```



```
scatter.smooth(x=data$depression_prop, y=data$state_util, main="depression_prop ~ state_util")
```

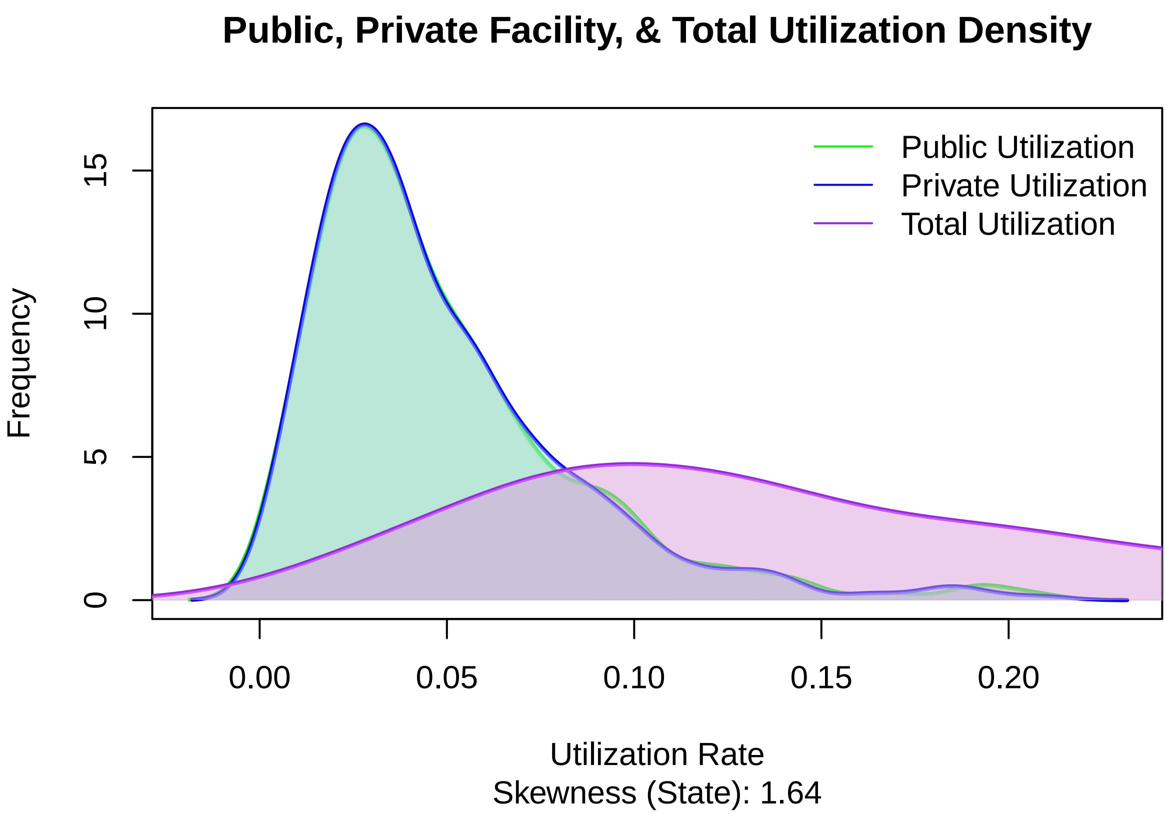



```
library(e1071)
```

```
## Warning: package 'e1071' was built under R version 4.3.3
```

```
par(mfrow=c(1, 1))

# Create a density plot that shows public, private, and total mental healthcare utilization rate
# frequency
plot(density(data$state_util),
     main = "Public, Private Facility, & Total Utilization Density",
     ylab = "Frequency",
     xlab = "Utilization Rate",
     col = "green",
     lwd = 2,
     sub = paste("Skewness (State):", round(e1071::skewness(data$state_util), 2)))

# Fill the first density with polygon
polygon(density(data$state_util), col = adjustcolor("lightgreen", alpha.f = 0.5), border = NA)

# Add second density line
lines(density(data$private_util), col = "blue", lwd = 2)
polygon(density(data$private_util), col = adjustcolor("lightblue", alpha.f = 0.5), border = NA)

# Add third density line
lines(density(data$total_util), col = "purple", lwd = 2)
```

```r
polygon(density(data$total_util), col = adjustcolor("plum", alpha.f = 0.5), border = NA)

# Add legend
legend("topright", legend = c("Public Utilization", "Private Utilization", "Total Utilization "),
       col = c("green", "blue", "purple"), lwd = 1, bty = "n")
```




```r
#data split: train and test dataset

clean_GTrends_acs_joined <- GTrends_acs_joined %>%
  select(-fips, -population_est,-private_psych_care, -total_util,
         -outpatient_util, -region, -mean_anxiety, -resid_psych_care,
         -mean_all_trends, -mean_therapist_near_me, -depression_prop,
         -trauma_stress_prop, -inpatient_util,
         -contains(c("median", "total")), -total_util) #i have added region as part of eliminated featu

test_n <- (1/sqrt(19))*nrow(clean_GTrends_acs_joined)
test_prop <- round((1/sqrt(19))*nrow(clean_GTrends_acs_joined)/nrow(clean_GTrends_acs_joined), 2)
train_prop <- 1-test_prop

paste("The ideal split ratio is", train_prop, ":", test_prop, " training : testing")
```

```
## [1] "The ideal split ratio is 0.77 : 0.23  training : testing"
```

```r
# Show the dimensions of the dataframe and the column names.
dim(clean_GTrends_acs_joined)
```

```
## [1] 433  25
```

```r
names(clean_GTrends_acs_joined)
```

```
##  [1] "year"
##  [2] "state"
##  [3] "anxiety_ct"
##  [4] "trauma_stress_ct"
##  [5] "adhd_ct"
##  [6] "bipolar_ct"
##  [7] "depression_ct"
##  [8] "comm_psych_care"
##  [9] "state_psych_care"
## [10] "mean_adhd"
## [11] "mean_ptsd"
## [12] "mean_bipolar"
## [13] "mean_depression"
## [14] "mean_mental_hospital"
## [15] "mean_psychiatrists_near_me"
## [16] "mean_psychologist_near_me"
## [17] "state_mentalhealth_util"
## [18] "anxiety_prop"
## [19] "adhd_prop"
## [20] "bipolar_prop"
## [21] "prop_families_below_poverty"
## [22] "prop_adults_without_health_insurance"
## [23] "prop_unemployed_in_labor_force"
## [24] "prop_without_internet_access"
## [25] "prop_adult_disability"
```

```r
#write the merged dataframe to a CSV file with a time stamp in the  name.
# This way we don't overwrite the file in case someone else is working on the file.
# TimeStamp <- format(Sys.time(), "%Y%m%d_%H%M%S")
# file_name <- paste("~/GitHub/DSE6311OM_SP2025R2_Data-Science-Capstone/Data/clean_GTrends_acs_joined_"
# write.csv(clean_GTrends_acs_joined, file_name, row.names = FALSE)
```

```r
train <- createDataPartition(clean_GTrends_acs_joined$state_mentalhealth_util,
                             p = 0.77,
                             list = FALSE,
                             times = 1)


GTrend_training_set <- clean_GTrends_acs_joined[train, ]


test_set <- clean_GTrends_acs_joined[-train, ]

dim(GTrend_training_set)
```

```
## [1] 336  25
```

```r
dim(test_set)
```

```
## [1] 97 25
```

TARGET ENCODING OF STATE BY Njagi

```r
unique(clean_GTrends_acs_joined$state)
```

```
##  [1] "AL" "AZ" "AR" "CA" "CO" "CT" "DE" "FL" "HI" "ID" "IL" "IN" "IA" "KS" "KY"
## [16] "LA" "MA" "MS" "MO" "MT" "NE" "NV" "NJ" "NM" "NY" "NC" "ND" "OH" "OK" "OR"
## [31] "PA" "RI" "SC" "SD" "TN" "TX" "UT" "VT" "VA" "WA" "WI" "WY" "MN" "MI" "AK"
## [46] "GA"
```

```r
is.factor(clean_GTrends_acs_joined$state) #checking whether region is a factor = false
```

```
## [1] FALSE
```

```r
GTrend_training_set$state <- factor(GTrend_training_set$state)

     class(GTrend_training_set$state)
```

```
## [1] "factor"
```

```r
     levels(GTrend_training_set$state)
```

```
##  [1] "AK" "AL" "AR" "AZ" "CA" "CO" "CT" "DE" "FL" "GA" "HI" "IA" "ID" "IL" "IN"
## [16] "KS" "KY" "LA" "MA" "MI" "MN" "MO" "MS" "MT" "NC" "ND" "NE" "NJ" "NM" "NV"
## [31] "NY" "OH" "OK" "OR" "PA" "RI" "SC" "SD" "TN" "TX" "UT" "VA" "VT" "WA" "WI"
## [46] "WY"
```

```r
# we are going to apply target encoding (state_mentalhealth_util). To avoid overfitting we are going to
#smoothed version of target encoding

main_mean <- mean( GTrend_training_set$state_mentalhealth_util)

  smoothing_factor <- 10


  #calculating the smoothed state means from the training set
   state_encoded_by_smoothedmean <- GTrend_training_set %>%
     group_by(state) %>%
     summarise(state_encoded = (mean(state_mentalhealth_util) * n() + main_mean * smoothing_factor) / (

   #merging the smoothed encoded state means with the training set

         GTrend_training_set_f <- GTrend_training_set %>%
           left_join(state_encoded_by_smoothedmean, by = "state") %>%
           select(-state)


    #merging smoothed encoded state means with the test_set
```

```r
             test_set$state <- factor(test_set$state)

                test_set_f <- test_set%>%
                  left_join(state_encoded_by_smoothedmean, by = "state") %>%
                  select(-state)
```

```r
dim(test_set_f)
```

```
## [1] 97 25
```

```r
#center and scale

test_set_f[, c(-10)] <- scale(test_set_f[, c(-10)],
                           center = apply(GTrend_training_set_f[, c(-10)], 2, mean),
                           scale = apply(GTrend_training_set_f[, c(-10)], 2, sd))

#(-10) is the state_mentalhealth_util, i want to exclude it from center and scale since its already a p


GTrend_training_set_f[, -10] <- scale(GTrend_training_set_f[, -10])

head(GTrend_training_set_f)
```

```
## # A tibble: 6 x 25
##    year anxiety_ct trauma_stress_ct adhd_ct bipolar_ct depression_ct
##   <dbl>      <dbl>            <dbl>   <dbl>      <dbl>         <dbl>
## 1 -1.56     -0.353           -0.520   0.117     0.0137        -0.172
## 2 -1.56      0.537            0.702   1.54      1.65           0.337
## 3 -1.56     -0.607           -0.570  -0.440    -0.216         -0.486
## 4 -1.56      1.40             2.78    2.44      4.61           3.73
## 5 -1.56     -0.263            0.112  -0.244     0.309         -0.187
## 6 -1.56     -0.412           -0.219  -0.250    -0.117         -0.364
## # i 19 more variables: comm_psych_care <dbl>, state_psych_care <dbl>,
## #   mean_adhd <dbl>, mean_ptsd <dbl>, mean_bipolar <dbl>,
## #   mean_depression <dbl>, mean_mental_hospital <dbl>,
## #   mean_psychiatrists_near_me <dbl>, mean_psychologist_near_me <dbl>,
## #   state_mentalhealth_util <dbl>, anxiety_prop <dbl>, adhd_prop <dbl>,
## #   bipolar_prop <dbl>, prop_families_below_poverty <dbl>,
## #   prop_adults_without_health_insurance <dbl>, ...
```

```r
#generating codebook

library(tibble)

codebook <- tibble(
  variable = names(clean_GTrends_acs_joined),
  class = sapply(clean_GTrends_acs_joined, class),
  "Number of Missing Values" = sapply(clean_GTrends_acs_joined, function(x) sum(is.na(x))),
  "Number of Unique Values" = sapply(clean_GTrends_acs_joined, function(x) length(unique(x)))
)

print(codebook)
```

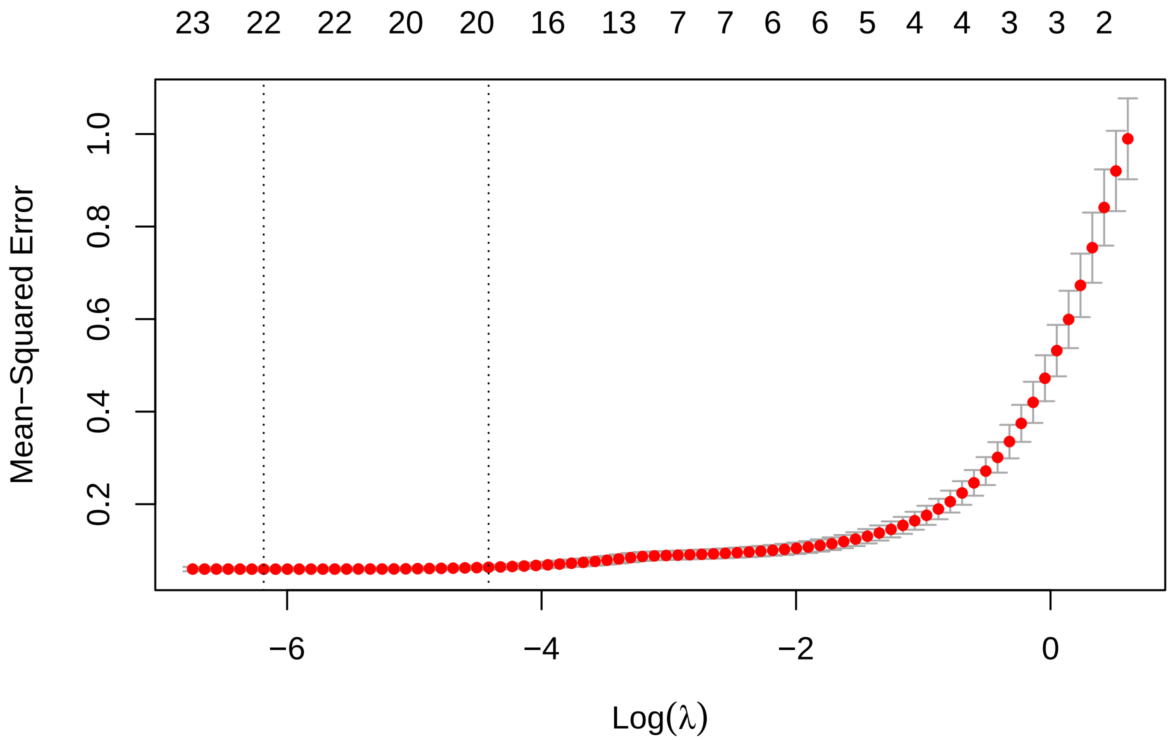
```
## # A tibble: 25 x 4
##    variable         class     `Number of Missing Values` Number of Unique Valu~1
##    <chr>            <chr>                          <int>                   <int>
##  1 year             numeric                            0                      10
##  2 state            character                          0                      46
##  3 anxiety_ct       numeric                            0                     433
##  4 trauma_stress_ct numeric                            0                     431
##  5 adhd_ct          numeric                            0                     423
##  6 bipolar_ct       numeric                            0                     430
##  7 depression_ct    numeric                            0                     432
##  8 comm_psych_care  numeric                            0                     432
##  9 state_psych_care numeric                            0                     433
## 10 mean_adhd        numeric                            0                     205
## # i 15 more rows
## # i abbreviated name: 1: `Number of Unique Values`
```

```r
# Create an empty dataframe with three fields store storing model train and test RMSE values.
rmse_df <- tibble(
  Model = character(),
  Train_RMSE = numeric(),
  Test_RMSE = numeric()
)

# Function to add rows to the rmse_df
add_rmse_row <- function(df, model_name, train_rmse, test_rmse) {
  new_row <- tibble(
    Model = model_name,
    Train_RMSE = train_rmse,
    Test_RMSE = test_rmse
  )
  updated_df <- bind_rows(df, new_row)
  return(updated_df)
}
```

INITIAL MODELS BY Njagi

1. LINEAR REGRESSION (ELASTIC NET REGULARIZATION)

```r
# DEVELOPING THE MODEL (LR. ENR)

x <- model.matrix(state_mentalhealth_util ~ ., data = GTrend_training_set_f, intercept = FALSE)

y <- GTrend_training_set_f$state_mentalhealth_util

    #Performing cross_validation to find the best lambda

   set.seed(123) # for consistent and replicable results

   cv_model <- cv.glmnet(x, y, alpha = 0.5, family = "gaussian", nfolds = 5)

   plot(cv_model) #plotting cross-validation curve
```




```
#getting the best/ optimal lambda

best_lambda <- cv_model$lambda.min
best_lambda_1se <- cv_model$lambda.1se


  #developing the model using the best lambda

model_min <- glmnet(x, y, alpha = 0.5, lambda = best_lambda, family = "gaussian")
model_lambda_1se <- glmnet(x, y, alpha = 0.5, lambda = best_lambda_1se, family = "gaussian")

#preparing the test set into matrx

x_test <- model.matrix(state_mentalhealth_util ~ ., data = test_set_f, intercept = FALSE)
y_test <- test_set_f$state_mentalhealth_util

#ensure x and x_test have the same number of columns. its a good practise after using model.matrix

common_columns <- intersect(colnames(x), colnames(x_test))
x <- x[, common_columns]
x_test <- x_test[, common_columns]

# use test set to make predictions, use lambda min and lambda_1se

y_pred_min <- predict(model_min, newx = x_test)
y_pred_1se <- predict(model_lambda_1se, newx = x_test)

#calculate the mean squared error
```

```r
mse_min <- mean((y_test - y_pred_min)^2)
mse_1se <- mean((y_test - y_pred_1se)^2)


print(paste("MSE (MIN):", mse_min))
```

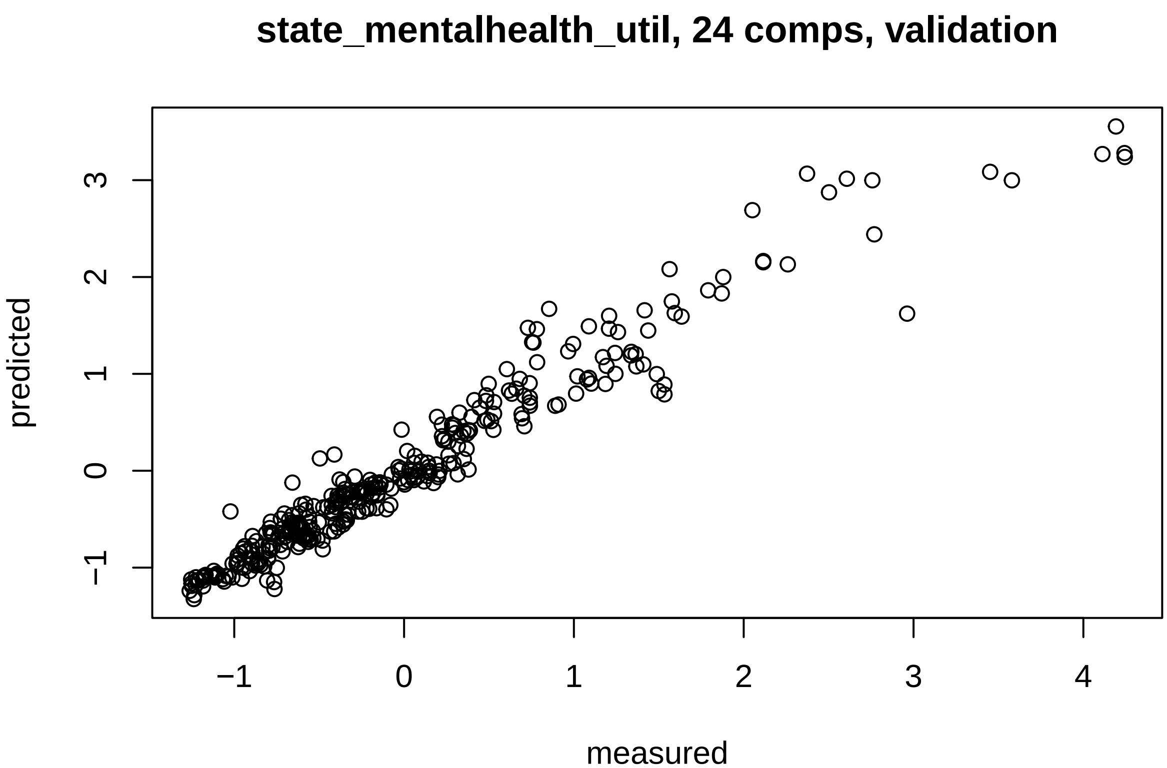
```
## [1] "MSE (MIN): 0.0503121894128666"
```

```r
print(paste("MSE (1SE):", mse_1se))
```

```
## [1] "MSE (1SE): 0.0620688183621769"
```

Principal Component Regression (PCR)

```r
pcr_m_selected <- 1

# Get the PCR fit for the training data set
pcr_fit <- pcr(state_mentalhealth_util ~ ., data =GTrend_training_set_f ,
                scale=TRUE, validation="CV")
# plot the PCR fit
plot(pcr_fit)
```

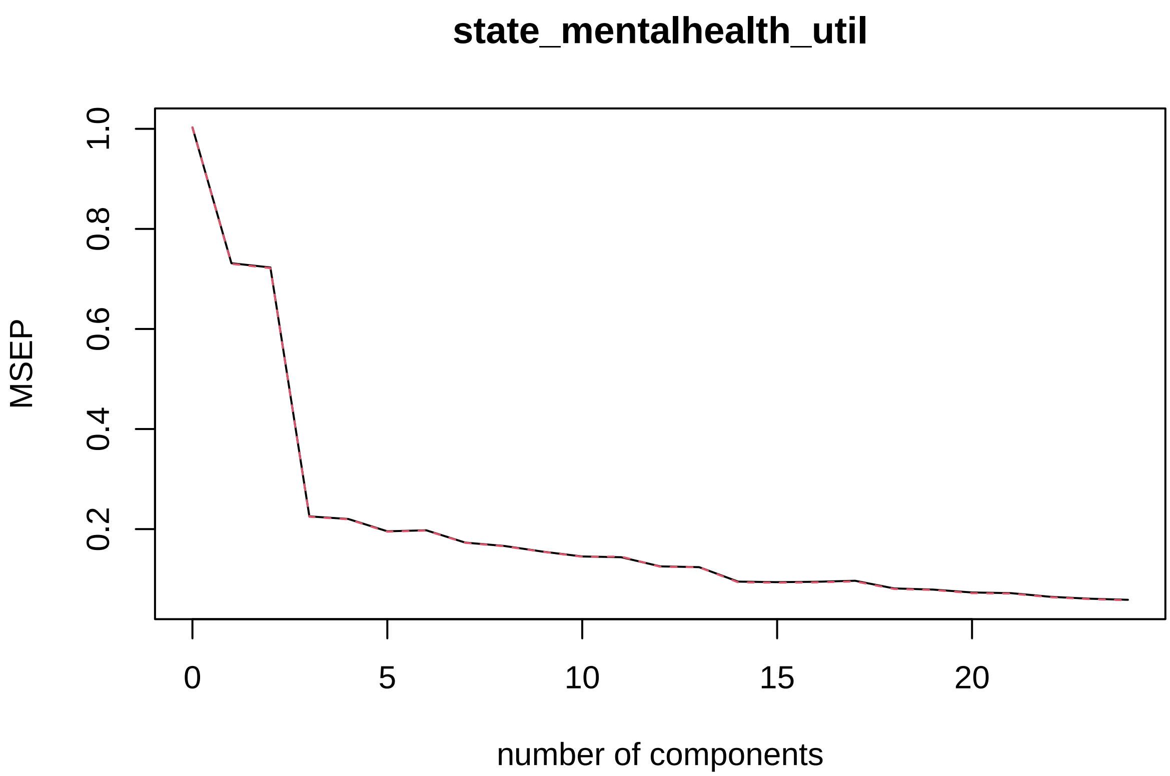



```r
# Show the summary of the PCR fit.
summary(pcr_fit)
```

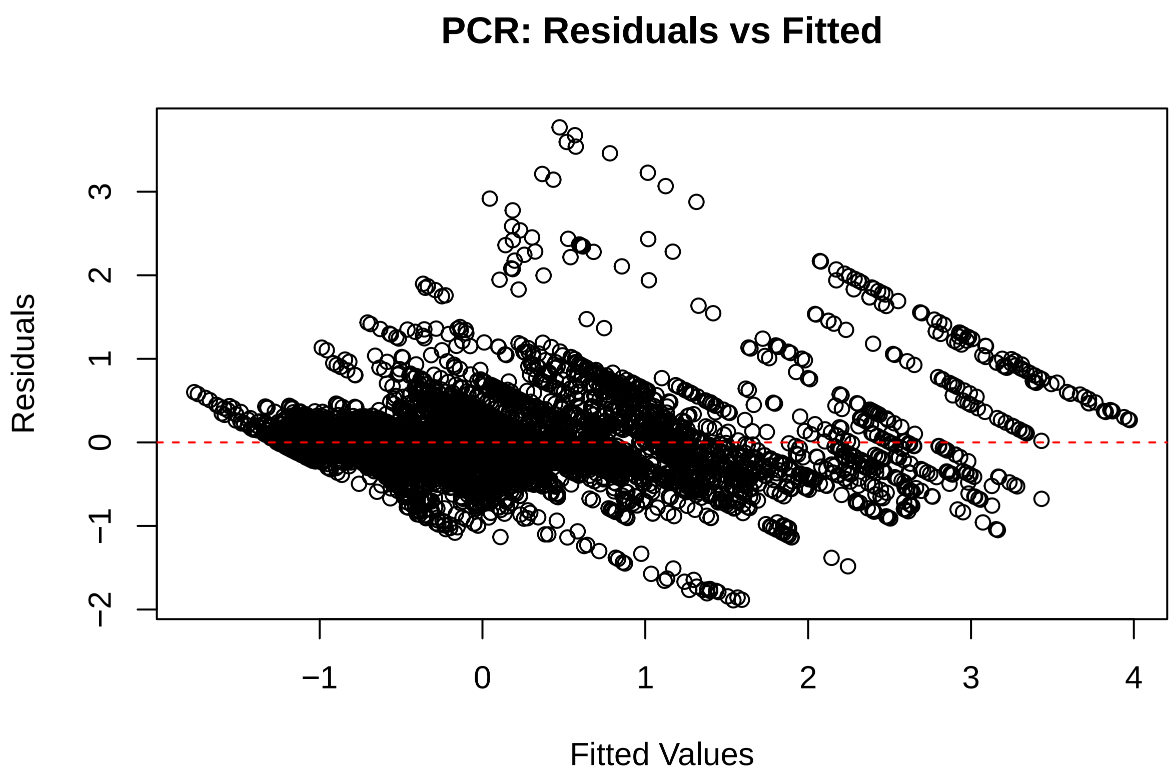
```
## Data:     X dimension: 336 24
```

```
##  Y dimension: 336 1
## Fit method: svdpc
## Number of components considered: 24
##
## VALIDATION: RMSEP
## Cross-validated using 10 random segments.
##        (Intercept)  1 comps  2 comps  3 comps  4 comps  5 comps  6 comps
## CV           1.001   0.8552   0.8503   0.4748   0.4693   0.4423   0.4445
## adjCV        1.001   0.8544   0.8495   0.4739   0.4686   0.4414   0.4439
##        7 comps  8 comps  9 comps  10 comps  11 comps  12 comps  13 comps
## CV      0.4160   0.4078   0.3935    0.3811    0.3792    0.3543    0.3520
## adjCV   0.4154   0.4070   0.3931    0.3805    0.3809    0.3532    0.3518
##        14 comps  15 comps  16 comps  17 comps  18 comps  19 comps  20 comps
## CV       0.3083    0.3065    0.3077    0.3111    0.2854    0.2812    0.2708
## adjCV    0.3060    0.3048    0.3057    0.3089    0.2834    0.2799    0.2682
##        21 comps  22 comps  23 comps  24 comps
## CV       0.2683    0.2545    0.2468    0.2422
## adjCV    0.2666    0.2528    0.2451    0.2404
##
## TRAINING: % variance explained
##                          1 comps  2 comps  3 comps  4 comps  5 comps  6 comps
## X                          29.76    46.62    59.79    69.11    75.72    80.82
## state_mentalhealth_util    28.32    30.48    78.32    78.84    81.55    81.60
##                          7 comps  8 comps  9 comps  10 comps  11 comps
## X                          85.11    88.04    90.03     91.92     93.35
## state_mentalhealth_util    83.65    84.26    85.34     86.57     87.28
##                          12 comps  13 comps  14 comps  15 comps  16 comps
## X                           94.68     95.91     96.91     97.71     98.35
## state_mentalhealth_util     89.50     89.73     92.44     92.54     92.64
##                          17 comps  18 comps  19 comps  20 comps  21 comps
## X                           98.88     99.28     99.51     99.70     99.86
## state_mentalhealth_util     92.66     93.64     93.71     94.32     94.33
##                          22 comps  23 comps  24 comps
## X                           99.95    100.00    100.00
## state_mentalhealth_util     94.93     95.31     95.58
```

```r
# Show the validation plot.
validationplot(pcr_fit, val.type="MSEP")
```




```r
# Plot the residuals vs the fitted values.
pcr_fitted_vals <- as.vector(fitted(pcr_fit, ncomp=5))
pcr_residuals <- as.vector(residuals(pcr_fit, ncomp=5))
plot(pcr_fitted_vals, pcr_residuals,
     xlab = "Fitted Values",
     ylab = "Residuals",
     main = "PCR: Residuals vs Fitted")
abline(h = 0, col = "red", lty = 2)
```




```r
# Get the predictions
pcr_preds_train <- predict(pcr_fit, data=GTrend_training_set_f, ncomp=pcr_m_selected)
pcr_preds_test <- predict(pcr_fit, data=test_set, ncomp=pcr_m_selected)

# Store and print the pcr mean square error for M_selected.
pcr_train_mse <- mean((pcr_preds_train-GTrend_training_set_f$state_mentalhealth_util)^2)
pcr_test_mse <- mean((pcr_preds_test-test_set$state_mentalhealth_util)^2)

#add the test and train RMSEs to the rmse_df
rmse_df <-  add_rmse_row(rmse_df, "Principal Component Regression", pcr_train_mse, pcr_test_mse)

paste("PCR Train MSE for M Selected:",pcr_m_selected,"is", pcr_train_mse)
```

```
## [1] "PCR Train MSE for M Selected: 1 is 0.71466220402035"
```

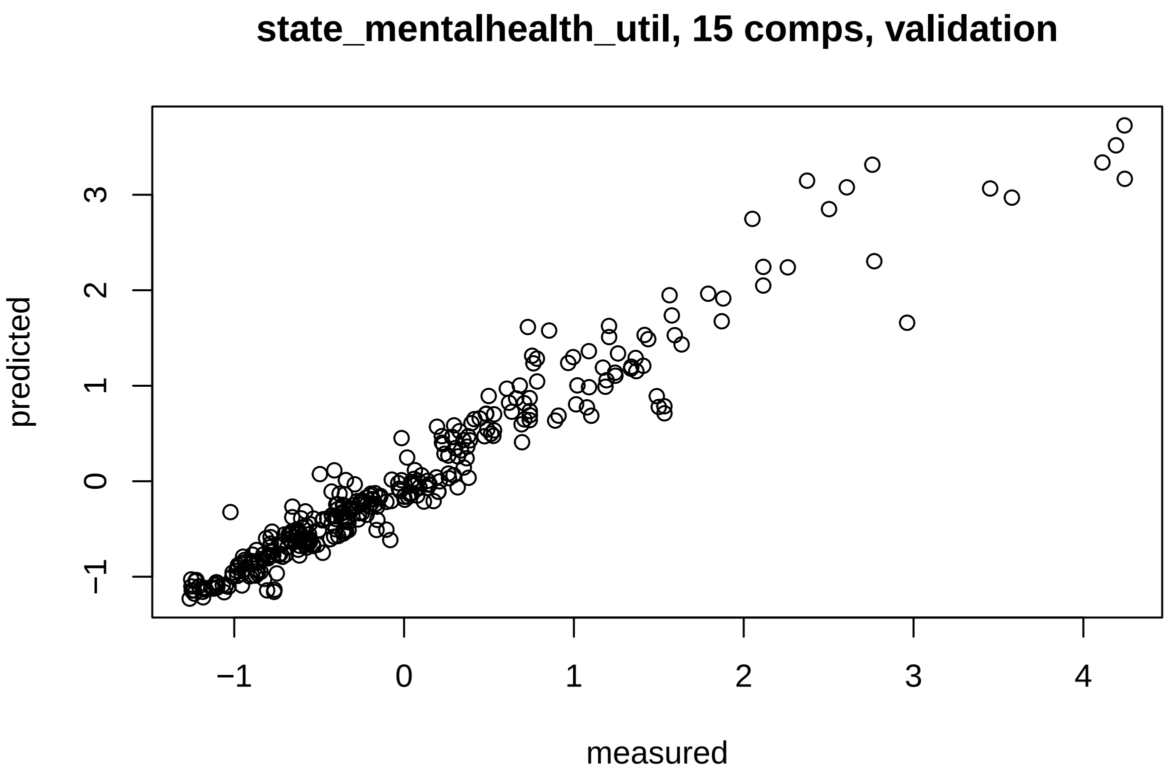
```r
paste("PCR Test MSE for M Selected:",pcr_m_selected,"is", pcr_test_mse)
```

```
## [1] "PCR Test MSE for M Selected: 1 is 0.283223434468817"
```

Partial Least Squares Regression (PLSR)

```r
# Set the PLS M selected value.
plsr_M_selected <- 15

# Get the PCR fit for the training data set
plsr_fit <- plsr(state_mentalhealth_util ~ ., data=GTrend_training_set_f ,
                 scale=TRUE, validation="CV", ncomp=plsr_M_selected)
```

```r
# Plot the PLSR fit
plot(plsr_fit)
```

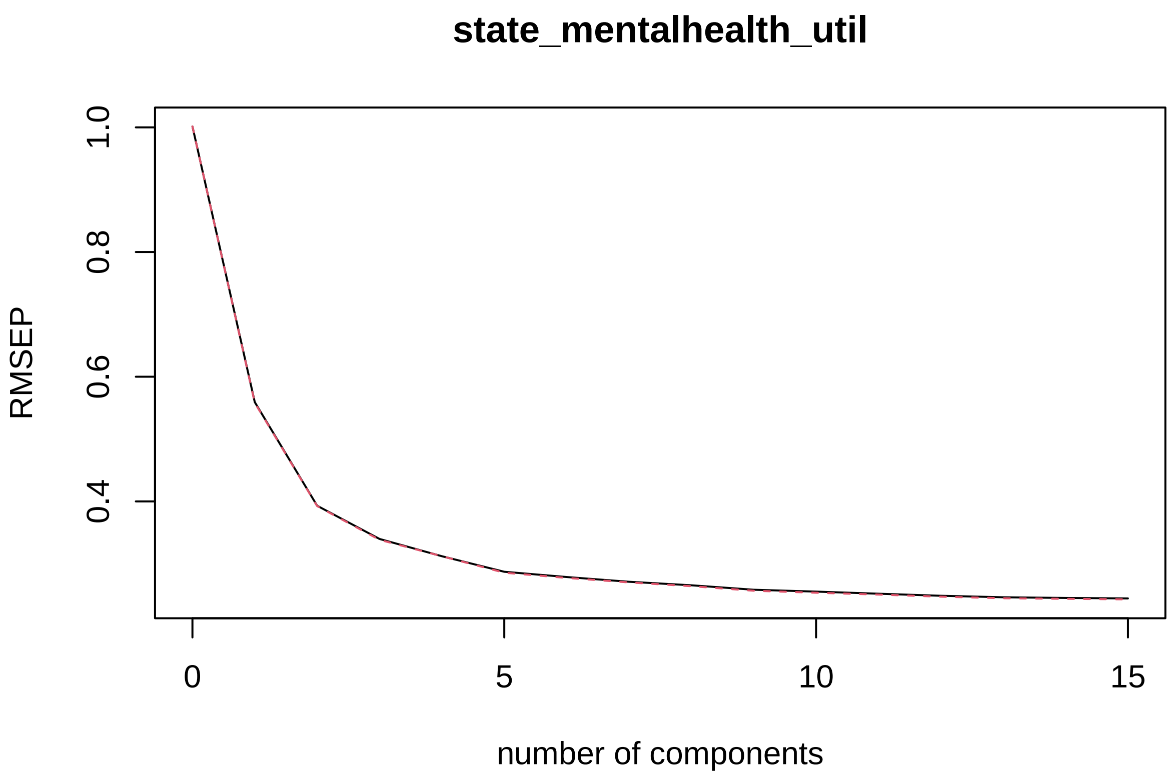



```r
# print the summary of the partial least square regression fit.
summary(plsr_fit)
```

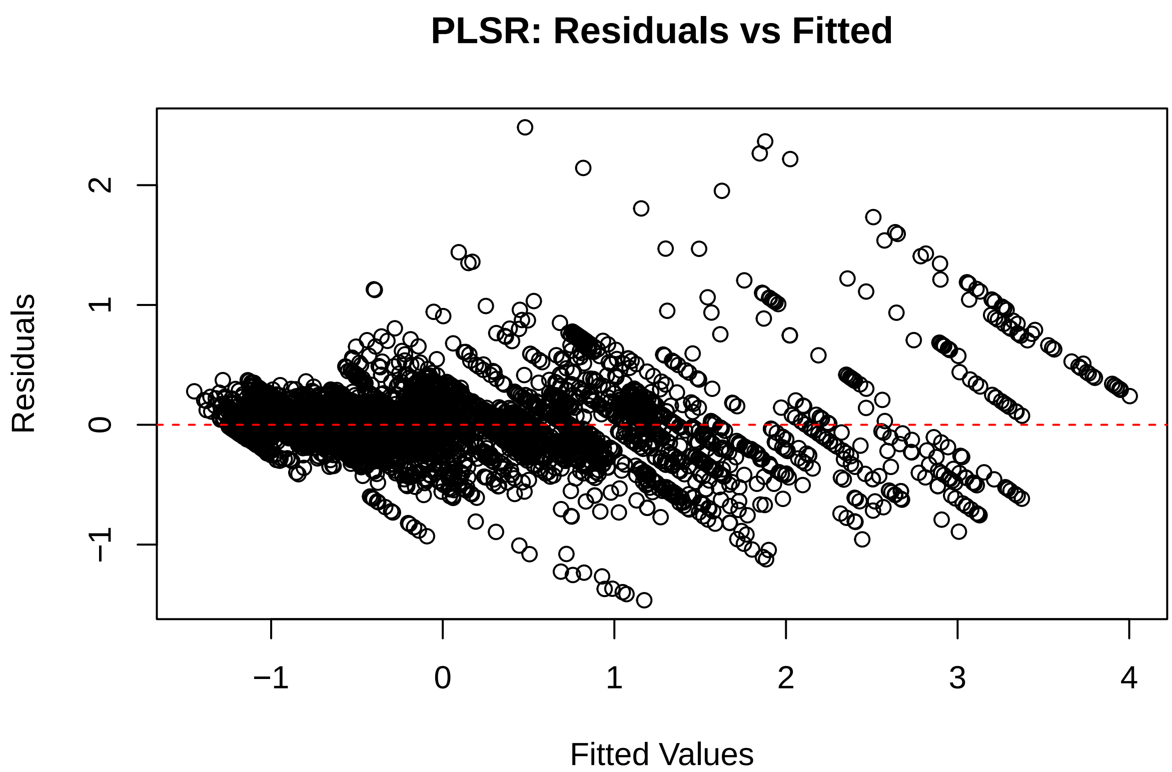
```
## Data:    X dimension: 336 24
##  Y dimension: 336 1
## Fit method: kernelpls
## Number of components considered: 15
##
## VALIDATION: RMSEP
## Cross-validated using 10 random segments.
##        (Intercept)  1 comps  2 comps  3 comps  4 comps  5 comps  6 comps
## CV           1.001   0.5592   0.3930   0.3398   0.3121   0.2871   0.2787
## adjCV        1.001   0.5581   0.3925   0.3384   0.3120   0.2856   0.2773
##        7 comps  8 comps  9 comps  10 comps  11 comps  12 comps  13 comps
## CV      0.2711   0.2654   0.2583    0.2553    0.2519    0.2486    0.2462
## adjCV   0.2700   0.2640   0.2567    0.2535    0.2505    0.2472    0.2447
##        14 comps  15 comps
## CV       0.2451    0.2444
## adjCV    0.2437    0.2429
##
## TRAINING: % variance explained
##                            1 comps  2 comps  3 comps  4 comps  5 comps  6 comps
## X                            25.36    42.66    49.62    61.74    67.95    73.56
## state_mentalhealth_util      70.66    85.34    89.82    91.59    93.17    93.70
##                            7 comps  8 comps  9 comps  10 comps  11 comps
```

```
## X                          79.65     82.67     84.56     87.13     90.81
## state_mentalhealth_util    93.99     94.36     94.70     94.87     94.95
##                         12 comps  13 comps  14 comps  15 comps
## X                          92.21     92.95     94.38     95.19
## state_mentalhealth_util    95.09     95.21     95.24     95.28
```

```
# Show the validation plot
validationplot(plsr_fit)
```




```
# Plot the residuals vs the fitted values.
plsr_fitted_vals <- as.vector(fitted(plsr_fit, ncomp=5))
plsr_residuals <- as.vector(residuals(plsr_fit, ncomp=5))
plot(plsr_fitted_vals, plsr_residuals,
     xlab = "Fitted Values",
     ylab = "Residuals",
     main = "PLSR: Residuals vs Fitted")
abline(h = 0, col = "red", lty = 2)
```




```r
# Get the predictions
plsr_train_preds <- predict(plsr_fit, data=GTrend_training_set_f, ncomp=plsr_M_selected)
plsr_test_preds <- predict(plsr_fit, data=test_set_f, ncomp=plsr_M_selected)

# Store and print the MSE value for the PLSR
plsr_train_mse <- mean((plsr_train_preds-GTrend_training_set_f$state_mentalhealth_util)^2)
plsr_test_mse <- mean((plsr_test_preds-test_set_f$state_mentalhealth_util)^2)

#add the test and train RMSEs to the rmse_df
rmse_df <-  add_rmse_row(rmse_df, "Partial Least Squares Regression", plsr_train_mse, plsr_test_mse)

paste("PLSR Train MSE for M Selected:",plsr_M_selected,"is", plsr_train_mse)
```

```
## [1] "PLSR Train MSE for M Selected: 15 is 0.0470118563506365"
```

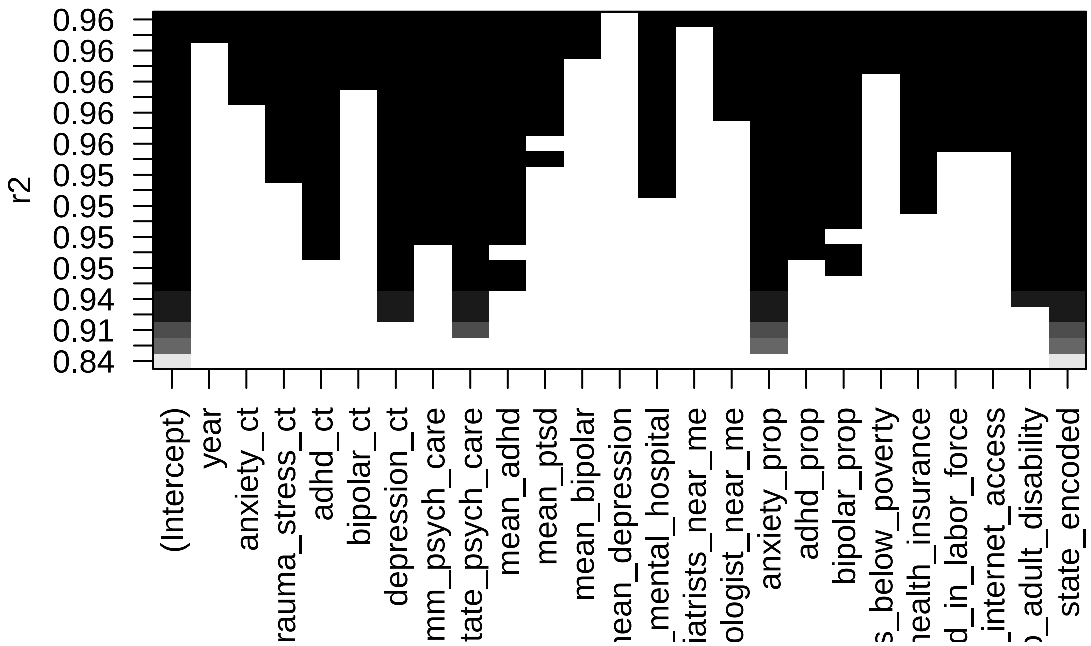
```r
paste("PLSR Test MSE for M Selected:",plsr_M_selected,"is", plsr_test_mse)
```

```
## [1] "PLSR Test MSE for M Selected: 15 is 1.72467053132728"
```

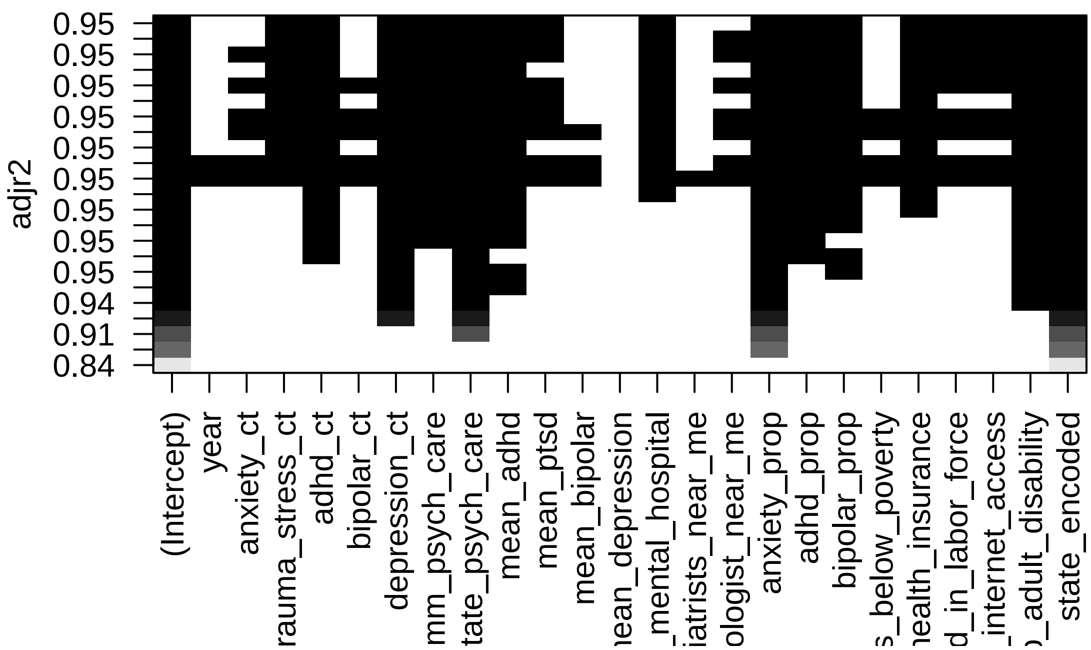
Best Subset Selection

```r
# Load library needed for regsubsets() function
library(leaps)

# The regsubsets() function (part of the leaps library) performs best sub- set selection
# by identifying the best model that contains a given number of predictors, where best
# is quantified using RSS.
```

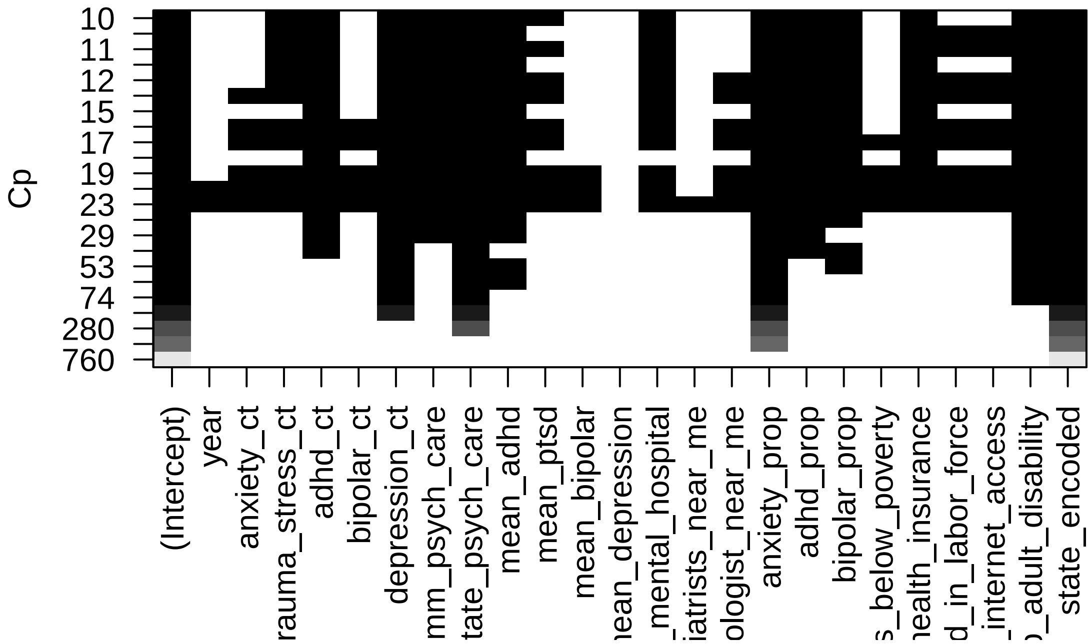
```r
reg_fit_train <- regsubsets(state_mentalhealth_util ~ ., data=GTrend_training_set_f, nvmax=23)

plot(reg_fit_train, scale="r2")
```



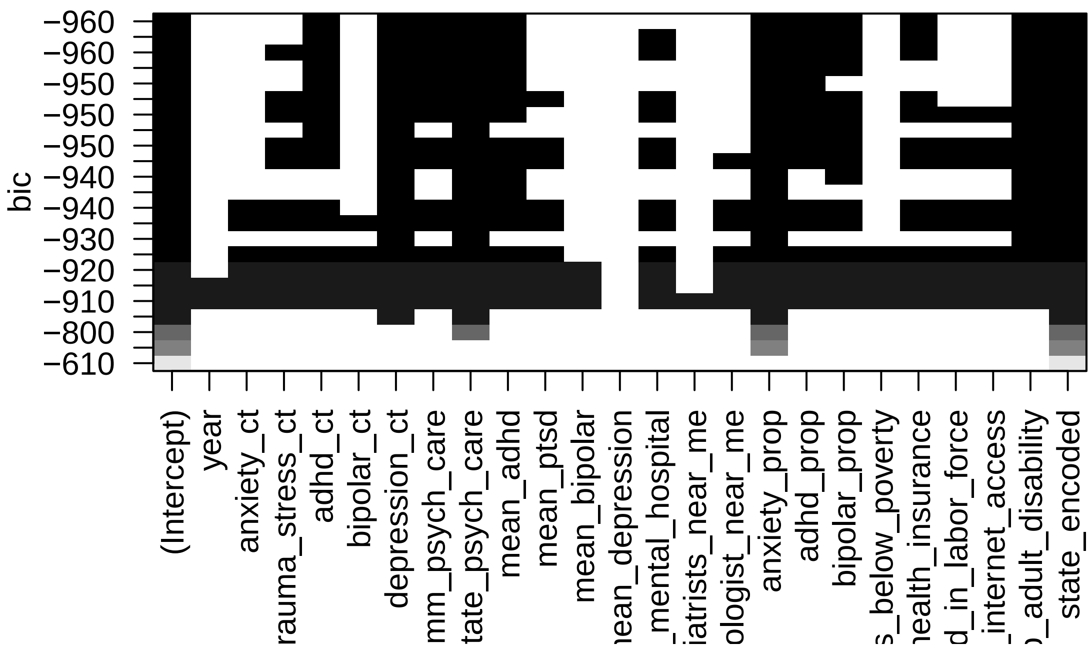

```r
plot(reg_fit_train, scale="adjr2")
```




```r
plot(reg_fit_train, scale="Cp")
```




```r
plot(reg_fit_train, scale="bic")
```




```r
# The summary() command outputs the best set of variables for each model size.
reg.summary <- summary(reg_fit_train)
print(reg.summary)
```

```
## Subset selection object
## Call: regsubsets.formula(state_mentalhealth_util ~ ., data = GTrend_training_set_f,
##     nvmax = 23)
## 24 Variables  (and intercept)
##                                       Forced in Forced out
```

```
## year                                    FALSE      FALSE
## anxiety_ct                              FALSE      FALSE
## trauma_stress_ct                        FALSE      FALSE
## adhd_ct                                 FALSE      FALSE
## bipolar_ct                              FALSE      FALSE
## depression_ct                           FALSE      FALSE
## comm_psych_care                         FALSE      FALSE
## state_psych_care                        FALSE      FALSE
## mean_adhd                               FALSE      FALSE
## mean_ptsd                               FALSE      FALSE
## mean_bipolar                            FALSE      FALSE
## mean_depression                         FALSE      FALSE
## mean_mental_hospital                    FALSE      FALSE
## mean_psychiatrists_near_me              FALSE      FALSE
## mean_psychologist_near_me               FALSE      FALSE
## anxiety_prop                            FALSE      FALSE
## adhd_prop                               FALSE      FALSE
## bipolar_prop                            FALSE      FALSE
## prop_families_below_poverty             FALSE      FALSE
## prop_adults_without_health_insurance    FALSE      FALSE
## prop_unemployed_in_labor_force          FALSE      FALSE
## prop_without_internet_access            FALSE      FALSE
## prop_adult_disability                   FALSE      FALSE
## state_encoded                           FALSE      FALSE
## 1 subsets of each size up to 23
## Selection Algorithm: exhaustive
##           year anxiety_ct trauma_stress_ct adhd_ct bipolar_ct depression_ct
## 1  ( 1 )  " "  " "        " "              " "     " "        " "
## 2  ( 1 )  " "  " "        " "              " "     " "        " "
## 3  ( 1 )  " "  " "        " "              " "     " "        " "
## 4  ( 1 )  " "  " "        " "              " "     " "        "*"
## 5  ( 1 )  " "  " "        " "              " "     " "        "*"
## 6  ( 1 )  " "  " "        " "              " "     " "        "*"
## 7  ( 1 )  " "  " "        " "              " "     " "        "*"
## 8  ( 1 )  " "  " "        " "              "*"     " "        "*"
## 9  ( 1 )  " "  " "        " "              "*"     " "        "*"
## 10  ( 1 ) " "  " "        " "              "*"     " "        "*"
## 11  ( 1 ) " "  " "        " "              "*"     " "        "*"
## 12  ( 1 ) " "  " "        " "              "*"     " "        "*"
## 13  ( 1 ) " "  " "        "*"              "*"     " "        "*"
## 14  ( 1 ) " "  " "        "*"              "*"     " "        "*"
## 15  ( 1 ) " "  " "        "*"              "*"     " "        "*"
## 16  ( 1 ) " "  " "        "*"              "*"     " "        "*"
## 17  ( 1 ) " "  " "        "*"              "*"     " "        "*"
## 18  ( 1 ) " "  "*"        "*"              "*"     " "        "*"
## 19  ( 1 ) " "  "*"        "*"              "*"     "*"        "*"
## 20  ( 1 ) " "  "*"        "*"              "*"     "*"        "*"
## 21  ( 1 ) " "  "*"        "*"              "*"     "*"        "*"
## 22  ( 1 ) "*"  "*"        "*"              "*"     "*"        "*"
## 23  ( 1 ) "*"  "*"        "*"              "*"     "*"        "*"
##           comm_psych_care state_psych_care mean_adhd mean_ptsd mean_bipolar
## 1  ( 1 )  " "             " "              " "       " "       " "
## 2  ( 1 )  " "             " "              " "       " "       " "
## 3  ( 1 )  " "             "*"              " "       " "       " "
```

```
## 4  ( 1 )  " "              "*"               " "        " "        " "
## 5  ( 1 )  " "              "*"               " "        " "        " "
## 6  ( 1 )  " "              "*"               "*"        " "        " "
## 7  ( 1 )  " "              "*"               "*"        " "        " "
## 8  ( 1 )  " "              "*"               " "        " "        " "
## 9  ( 1 )  "*"              "*"               "*"        " "        " "
## 10  ( 1 ) "*"              "*"               "*"        " "        " "
## 11  ( 1 ) "*"              "*"               "*"        " "        " "
## 12  ( 1 ) "*"              "*"               "*"        " "        " "
## 13  ( 1 ) "*"              "*"               "*"        " "        " "
## 14  ( 1 ) "*"              "*"               "*"        "*"        " "
## 15  ( 1 ) "*"              "*"               "*"        " "        " "
## 16  ( 1 ) "*"              "*"               "*"        "*"        " "
## 17  ( 1 ) "*"              "*"               "*"        "*"        " "
## 18  ( 1 ) "*"              "*"               "*"        "*"        " "
## 19  ( 1 ) "*"              "*"               "*"        "*"        " "
## 20  ( 1 ) "*"              "*"               "*"        "*"        " "
## 21  ( 1 ) "*"              "*"               "*"        "*"        "*"
## 22  ( 1 ) "*"              "*"               "*"        "*"        "*"
## 23  ( 1 ) "*"              "*"               "*"        "*"        "*"
##           mean_depression mean_mental_hospital mean_psychiatrists_near_me
## 1  ( 1 )  " "             " "                  " "
## 2  ( 1 )  " "             " "                  " "
## 3  ( 1 )  " "             " "                  " "
## 4  ( 1 )  " "             " "                  " "
## 5  ( 1 )  " "             " "                  " "
## 6  ( 1 )  " "             " "                  " "
## 7  ( 1 )  " "             " "                  " "
## 8  ( 1 )  " "             " "                  " "
## 9  ( 1 )  " "             " "                  " "
## 10  ( 1 ) " "             " "                  " "
## 11  ( 1 ) " "             " "                  " "
## 12  ( 1 ) " "             "*"                  " "
## 13  ( 1 ) " "             "*"                  " "
## 14  ( 1 ) " "             "*"                  " "
## 15  ( 1 ) " "             "*"                  " "
## 16  ( 1 ) " "             "*"                  " "
## 17  ( 1 ) " "             "*"                  " "
## 18  ( 1 ) " "             "*"                  " "
## 19  ( 1 ) " "             "*"                  " "
## 20  ( 1 ) " "             "*"                  " "
## 21  ( 1 ) " "             "*"                  " "
## 22  ( 1 ) " "             "*"                  " "
## 23  ( 1 ) " "             "*"                  "*"
##           mean_psychologist_near_me anxiety_prop adhd_prop bipolar_prop
## 1  ( 1 )  " "                       " "          " "       " "
## 2  ( 1 )  " "                       "*"          " "       " "
## 3  ( 1 )  " "                       "*"          " "       " "
## 4  ( 1 )  " "                       "*"          " "       " "
## 5  ( 1 )  " "                       "*"          " "       " "
## 6  ( 1 )  " "                       "*"          " "       " "
## 7  ( 1 )  " "                       "*"          " "       "*"
## 8  ( 1 )  " "                       "*"          "*"       "*"
## 9  ( 1 )  " "                       "*"          "*"       " "
```

```
## 10  ( 1 ) " "                        "*"          "*"        "*"
## 11  ( 1 ) " "                        "*"          "*"        "*"
## 12  ( 1 ) " "                        "*"          "*"        "*"
## 13  ( 1 ) " "                        "*"          "*"        "*"
## 14  ( 1 ) " "                        "*"          "*"        "*"
## 15  ( 1 ) " "                        "*"          "*"        "*"
## 16  ( 1 ) " "                        "*"          "*"        "*"
## 17  ( 1 ) "*"                        "*"          "*"        "*"
## 18  ( 1 ) "*"                        "*"          "*"        "*"
## 19  ( 1 ) "*"                        "*"          "*"        "*"
## 20  ( 1 ) "*"                        "*"          "*"        "*"
## 21  ( 1 ) "*"                        "*"          "*"        "*"
## 22  ( 1 ) "*"                        "*"          "*"        "*"
## 23  ( 1 ) "*"                        "*"          "*"        "*"
##           prop_families_below_poverty prop_adults_without_health_insurance
## 1  ( 1 )  " "                         " "
## 2  ( 1 )  " "                         " "
## 3  ( 1 )  " "                         " "
## 4  ( 1 )  " "                         " "
## 5  ( 1 )  " "                         " "
## 6  ( 1 )  " "                         " "
## 7  ( 1 )  " "                         " "
## 8  ( 1 )  " "                         " "
## 9  ( 1 )  " "                         " "
## 10  ( 1 ) " "                         " "
## 11  ( 1 ) " "                         "*"
## 12  ( 1 ) " "                         "*"
## 13  ( 1 ) " "                         "*"
## 14  ( 1 ) " "                         "*"
## 15  ( 1 ) " "                         "*"
## 16  ( 1 ) " "                         "*"
## 17  ( 1 ) " "                         "*"
## 18  ( 1 ) " "                         "*"
## 19  ( 1 ) " "                         "*"
## 20  ( 1 ) "*"                         "*"
## 21  ( 1 ) "*"                         "*"
## 22  ( 1 ) "*"                         "*"
## 23  ( 1 ) "*"                         "*"
##           prop_unemployed_in_labor_force prop_without_internet_access
## 1  ( 1 )  " "                            " "
## 2  ( 1 )  " "                            " "
## 3  ( 1 )  " "                            " "
## 4  ( 1 )  " "                            " "
## 5  ( 1 )  " "                            " "
## 6  ( 1 )  " "                            " "
## 7  ( 1 )  " "                            " "
## 8  ( 1 )  " "                            " "
## 9  ( 1 )  " "                            " "
## 10  ( 1 ) " "                            " "
## 11  ( 1 ) " "                            " "
## 12  ( 1 ) " "                            " "
## 13  ( 1 ) " "                            " "
## 14  ( 1 ) " "                            " "
## 15  ( 1 ) "*"                            "*"
```

```
## 16  ( 1 ) "*"                          "*"
## 17  ( 1 ) "*"                          "*"
## 18  ( 1 ) "*"                          "*"
## 19  ( 1 ) "*"                          "*"
## 20  ( 1 ) "*"                          "*"
## 21  ( 1 ) "*"                          "*"
## 22  ( 1 ) "*"                          "*"
## 23  ( 1 ) "*"                          "*"
##           prop_adult_disability state_encoded
## 1  ( 1 )  " "                   "*"
## 2  ( 1 )  " "                   "*"
## 3  ( 1 )  " "                   "*"
## 4  ( 1 )  " "                   "*"
## 5  ( 1 )  "*"                   "*"
## 6  ( 1 )  "*"                   "*"
## 7  ( 1 )  "*"                   "*"
## 8  ( 1 )  "*"                   "*"
## 9  ( 1 )  "*"                   "*"
## 10  ( 1 ) "*"                   "*"
## 11  ( 1 ) "*"                   "*"
## 12  ( 1 ) "*"                   "*"
## 13  ( 1 ) "*"                   "*"
## 14  ( 1 ) "*"                   "*"
## 15  ( 1 ) "*"                   "*"
## 16  ( 1 ) "*"                   "*"
## 17  ( 1 ) "*"                   "*"
## 18  ( 1 ) "*"                   "*"
## 19  ( 1 ) "*"                   "*"
## 20  ( 1 ) "*"                   "*"
## 21  ( 1 ) "*"                   "*"
## 22  ( 1 ) "*"                   "*"
## 23  ( 1 ) "*"                   "*"
```

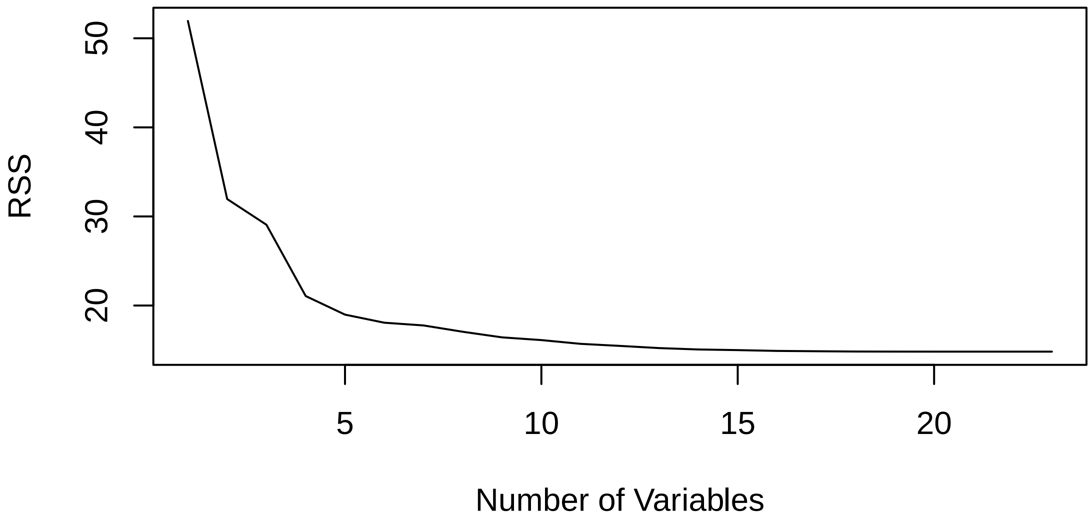
```
names(reg.summary)
```

```
## [1] "which"  "rsq"    "rss"    "adjr2"  "cp"     "bic"    "outmat" "obj"
```

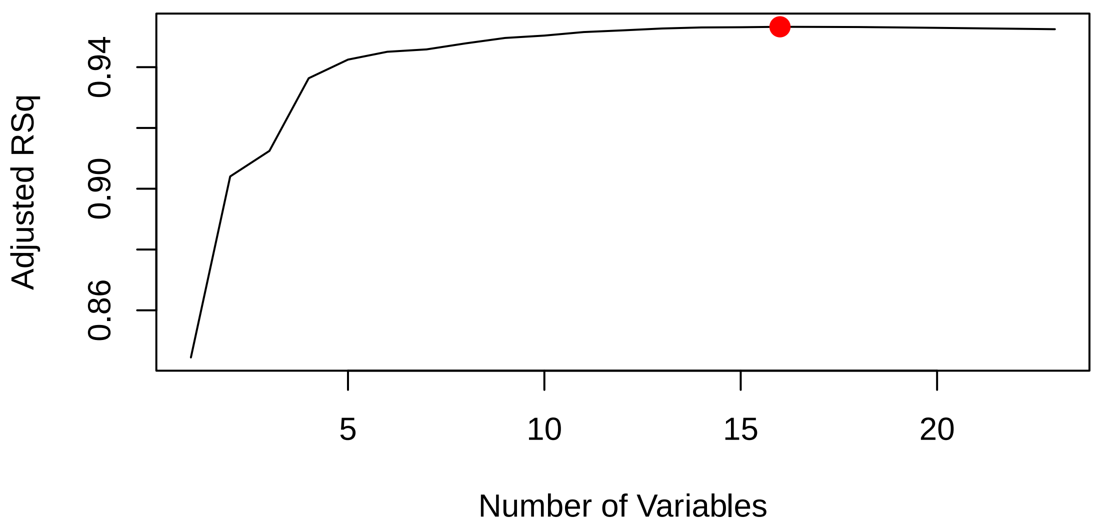
```
#Print the R^2 statistic
reg.summary$rsq
```

```
##  [1] 0.8449441 0.9046204 0.9132355 0.9371265 0.9433480 0.9460517 0.9469778
##  [8] 0.9490888 0.9509683 0.9518774 0.9531454 0.9538280 0.9545635 0.9550275
## [15] 0.9552410 0.9555108 0.9556173 0.9557120 0.9557389 0.9557495 0.9557497
## [22] 0.9557502 0.9557502
```

```
#par(mfrow=c(1,2))
plot(reg.summary$rss, xlab="Number of Variables", ylab="RSS", type="l")
```




```r
plot(reg.summary$adjr2 , xlab = "Number of Variables",ylab = "Adjusted RSq", type = "l")

# which.max(reg.summary$adjr2)
plot(reg.summary$adjr2 , xlab = "Number of Variables", ylab = "Adjusted RSq", type = "l")
points(which.max(reg.summary$adjr2), reg.summary$adjr2[which.max(reg.summary$adjr2)],
       col = "red", cex = 2, pch = 20)
```



Random Forest

```r
library(randomForest)
```

```
## randomForest 4.7-1.2
```

```
## Type rfNews() to see new features/changes/bug fixes.
```

```
##
## Attaching package: 'randomForest'
```

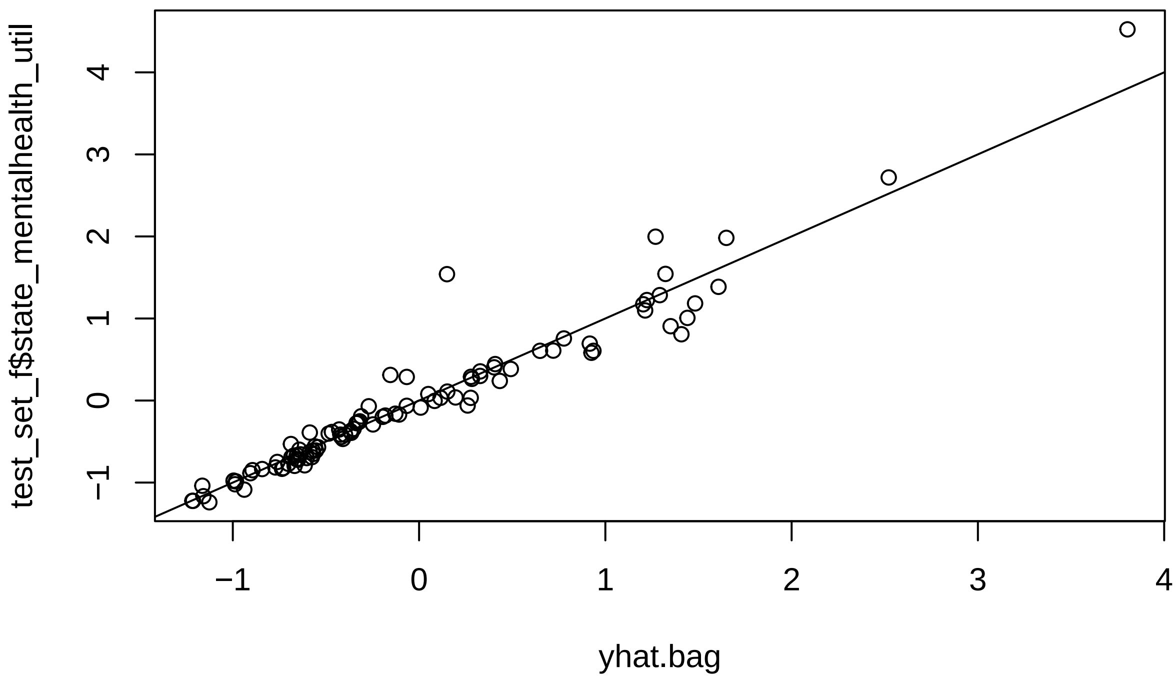
```
## The following object is masked from 'package:dplyr':
```

```
##
##     combine

## The following object is masked from 'package:ggplot2':
##
##     margin
```

```r
set.seed(42)
# Bagging
bag.data <- randomForest(state_mentalhealth_util ~ ., data=GTrend_training_set_f, mtry=24, importance=TI
bag.data
```

```
##
## Call:
##  randomForest(formula = state_mentalhealth_util ~ ., data = GTrend_training_set_f,      mtry = 24, in
##                Type of random forest: regression
##                      Number of trees: 500
## No. of variables tried at each split: 24
##
##           Mean of squared residuals: 0.07012883
##                     % Var explained: 92.97
```

```r
yhat.bag <- predict(bag.data, newdata=test_set_f)

plot(yhat.bag, test_set_f$state_mentalhealth_util)
abline(0,1)
```




```r
bagged_mse <- mean((yhat.bag - test_set_f$state_mentalhealth_util)^2)
paste ("Test MSE associated with the bagged regression is:", bagged_mse)
```

```
## [1] "Test MSE associated with the bagged regression is: 0.0547892901795257"
```

```r
# Random Forest
rf_model <- randomForest(state_mentalhealth_util ~ ., data=GTrend_training_set_f ,
                         mtry = 12, importance = TRUE)
print(rf_model)
```

```
##
## Call:
##  randomForest(formula = state_mentalhealth_util ~ ., data = GTrend_training_set_f,      mtry = 12, i
##                Type of random forest: regression
##                      Number of trees: 500
## No. of variables tried at each split: 12
##
##           Mean of squared residuals: 0.06616116
##                     % Var explained: 93.36
```

```r
yhat_train_rf <- predict(rf_model, newdata = GTrend_training_set_f)
yhat_test_rf <- predict(rf_model, newdata = test_set_f)
rf_train_mse <- mean((yhat_train_rf-test_set_f$state_mentalhealth_util)^2)
rf_test_mse <- mean((yhat_test_rf-test_set_f$state_mentalhealth_util)^2)

#add the test and train RMSEs to the rmse_df
rmse_df <- add_rmse_row(rmse_df, "Random Forest", rf_train_mse, rf_test_mse)

paste("Train MSE associated with the Random Forest is: =", rf_train_mse)
```

```
## [1] "Train MSE associated with the Random Forest is: = 1.68420378705617"
```

```r
paste("Test MSE associated with the Random Forest is: =", rf_test_mse)
```

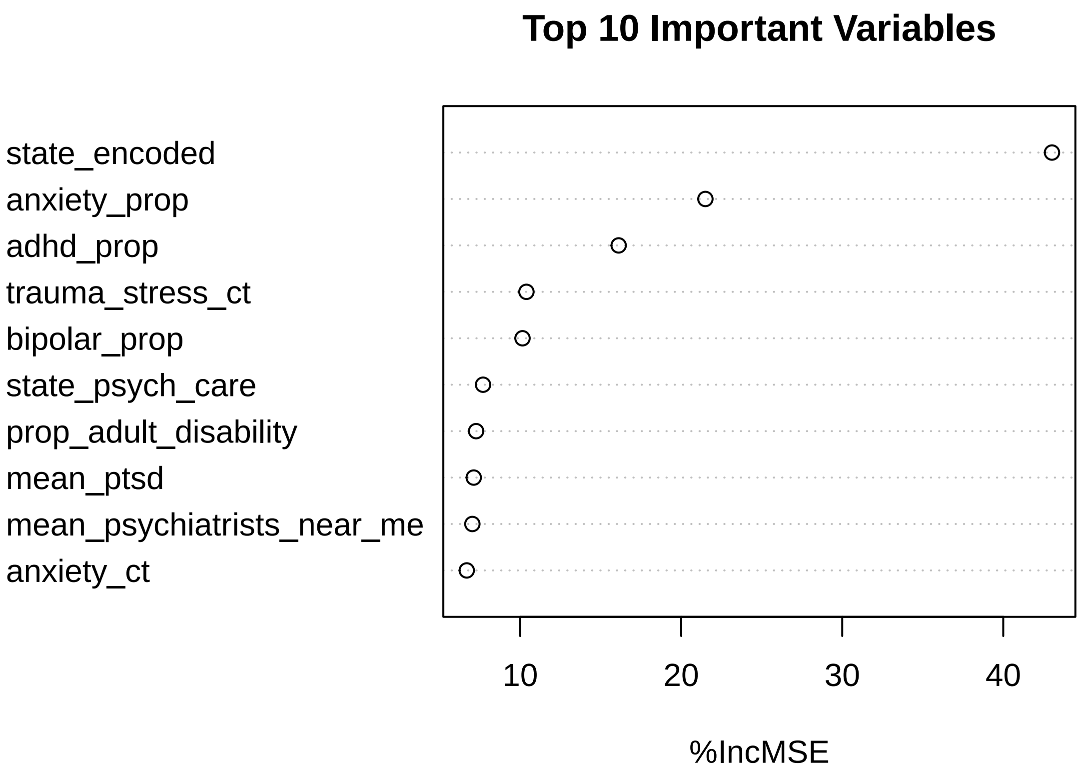
```
## [1] "Test MSE associated with the Random Forest is: = 0.0418992572644195"
```

```r
imp <- importance(rf_model)
# Let's sort the output of the importance() function
imp_df <- data.frame(Variable = rownames(imp), imp)
imp_sorted <- imp_df[order(-imp_df$X.IncMSE), ]
head(imp_sorted)
```

```
##                            Variable  X.IncMSE IncNodePurity
## state_encoded       state_encoded 43.025103    158.998105
## anxiety_prop         anxiety_prop 21.501464     69.000480
## adhd_prop               adhd_prop 16.115508     37.998461
## trauma_stress_ct trauma_stress_ct 10.387930      6.324673
## bipolar_prop         bipolar_prop 10.144681     18.797369
## state_psych_care state_psych_care  7.694198      4.145587
```

```r
# Show the importance plot
#varImpPlot(rf_model)
varImpPlot(
  x = rf_model,     # trained random forest
  sort = TRUE,      # sort by importance
```

```
  n.var = 10,       # show top 10 variables
  type = 1,         # mean decrease in accuracy
  main = "Top 10 Important Variables"
)
```

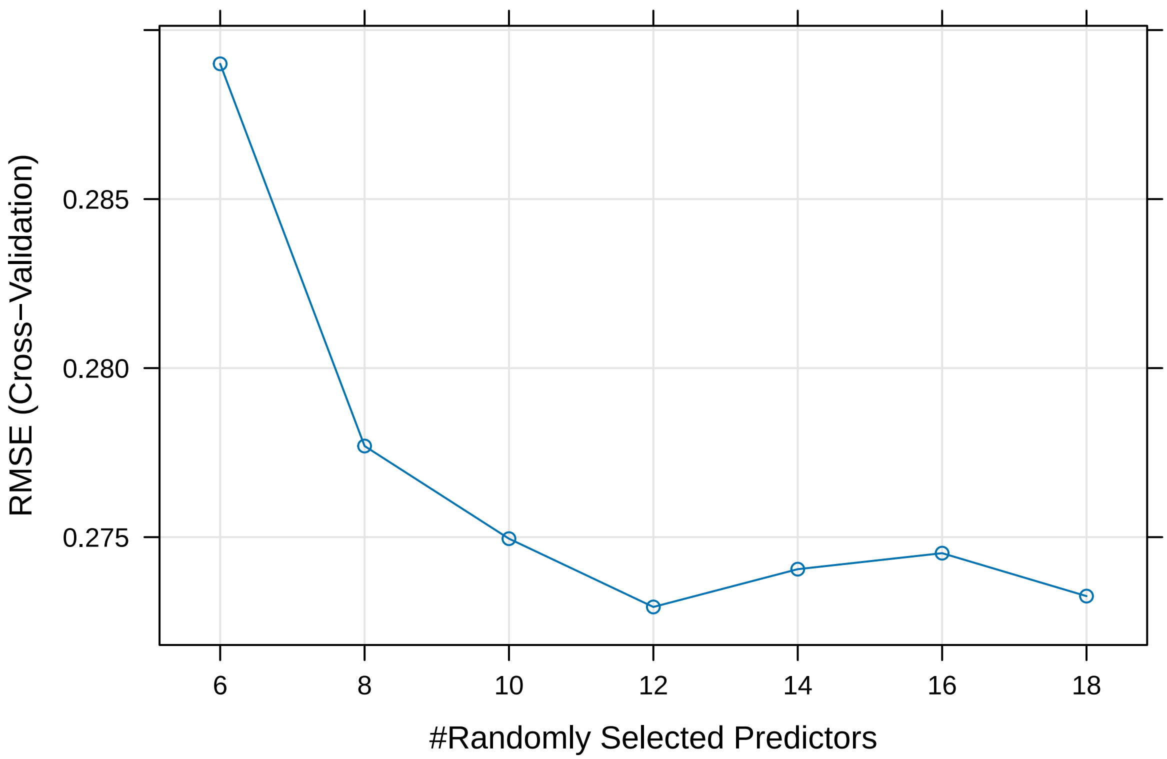



```
set.seed(42)

# Set up a 5 fold cross-vlidation for the random forest model.
rf_control <- trainControl(method="cv", number=5)

# Define the tuning grid with values for mtry at 8, 10, 12, or 14.
tune_grid <- expand.grid(.mtry = c(6, 8, 10, 12, 14, 16, 18))

# Train the random forest model using k-fold cross validation
rf_cv_model <- train(state_mentalhealth_util ~ .,
                     data = GTrend_training_set_f,
                     method = "rf",
                     trControl = rf_control,
                     tuneGrid = tune_grid,
                     importance = TRUE)
# Print the results
print(rf_cv_model)
```

```
## Random Forest
##
## 336 samples
##  24 predictor
##
```

```
## No pre-processing
## Resampling: Cross-Validated (5 fold)
## Summary of sample sizes: 268, 269, 269, 269, 269
## Resampling results across tuning parameters:
##
##   mtry  RMSE       Rsquared   MAE
##    6    0.2890014  0.9253191  0.1515799
##    8    0.2776950  0.9304545  0.1436800
##   10    0.2749552  0.9299127  0.1434332
##   12    0.2729347  0.9316564  0.1419093
##   14    0.2740527  0.9306149  0.1442547
##   16    0.2745261  0.9292596  0.1459483
##   18    0.2732558  0.9299838  0.1464340
##
## RMSE was used to select the optimal model using the smallest value.
## The final value used for the model was mtry = 12.
```

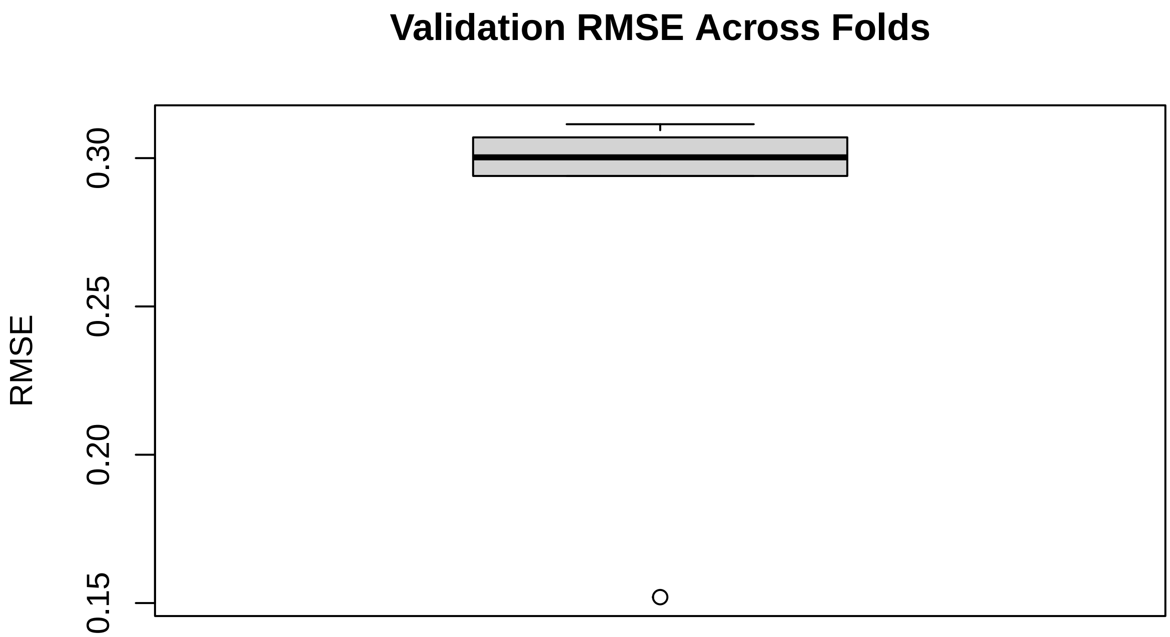
```r
# Show validation plot
plot(rf_cv_model)
```



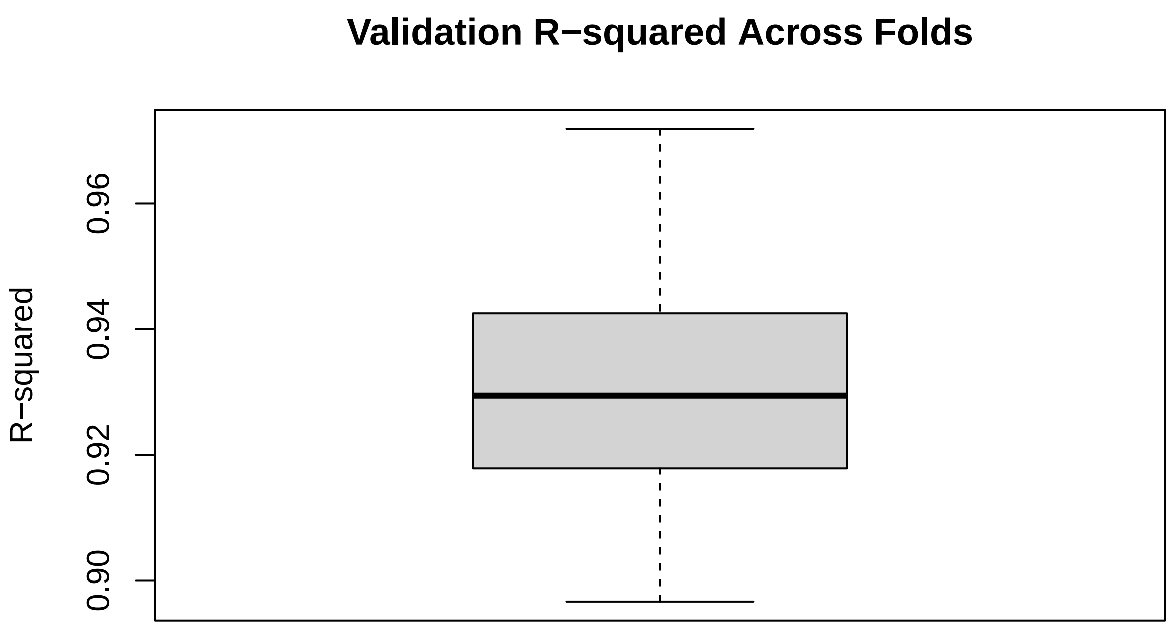

```r
names(rf_cv_model)
```

```
##  [1] "method"       "modelInfo"    "modelType"    "results"      "pred"
##  [6] "bestTune"     "call"         "dots"         "metric"       "control"
## [11] "finalModel"   "preProcess"   "trainingData" "ptype"        "resample"
## [16] "resampledCM"  "perfNames"    "maximize"     "yLimits"      "times"
## [21] "levels"       "terms"        "coefnames"    "xlevels"
```

```r
# Show RMSE across folds while using na.omit to remove null values before plotting
boxplot(na.omit(rf_cv_model$resample$RMSE),
        main = "Validation RMSE Across Folds",
        ylab = "RMSE")
```

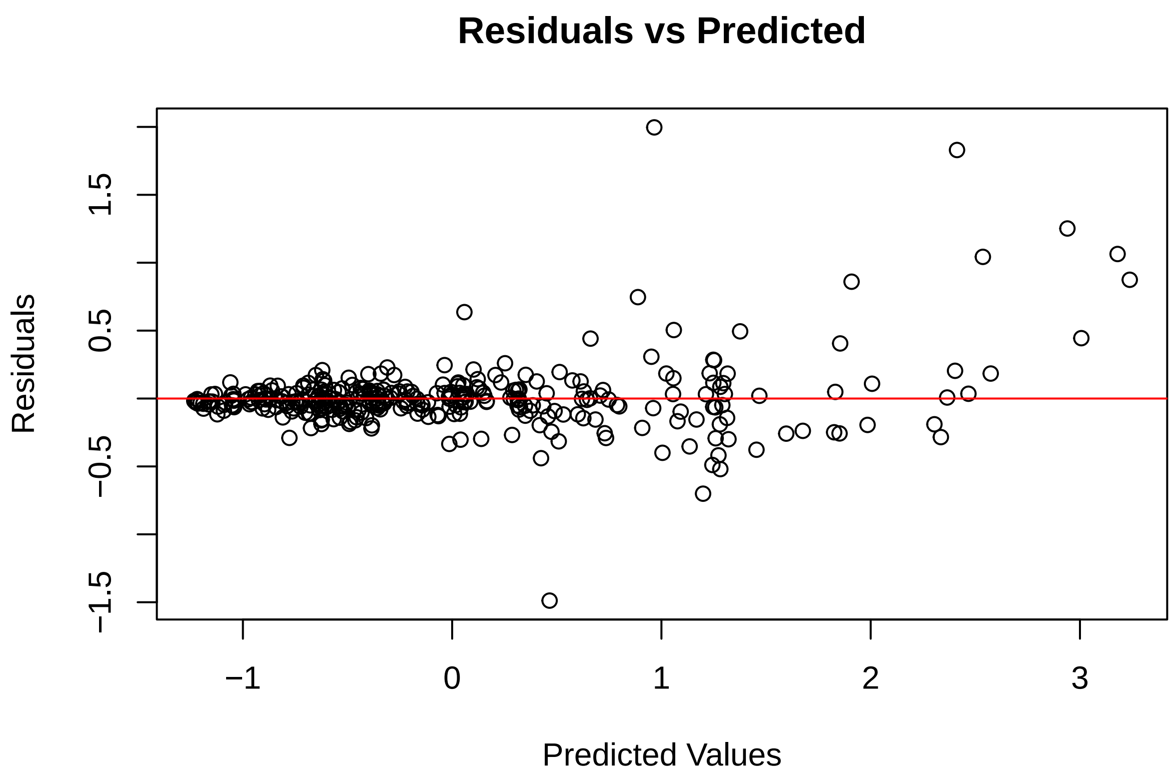



```r
# Show R squared across folds with na.omit() as above.
boxplot(na.omit(rf_cv_model$resample$Rsquared),
        main = "Validation R-squared Across Folds",
        ylab = "R-squared")
```




```r
# Show the residuals plot
# Residuals
```

```r
residuals <- rf_cv_model$finalModel$y - rf_cv_model$finalModel$predicted

# Plot residuals vs fitted
plot(rf_cv_model$finalModel$predicted, residuals,
      xlab = "Predicted Values",
      ylab = "Residuals",
      main = "Residuals vs Predicted")
abline(h = 0, col = "red")
```




```r
rmse_df
```

```
## # A tibble: 3 x 3
##   Model                            Train_RMSE Test_RMSE
##   <chr>                                 <dbl>     <dbl>
## 1 Principal Component Regression       0.715     0.283
## 2 Partial Least Squares Regression     0.0470    1.72
## 3 Random Forest                        1.68      0.0419
```