

# Further Analysis and Tuning

Team Rho

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## *#libraries*

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

## *#reading data*

```
data_GTrends <- read_excel("~/GitHub/DSE63110M_SP2025R2_Data-Science-Capstone/Data/googleTrendsMH.xlsx"
  sheet = "googleTrendsMH")
acs_data <- load("~/GitHub/DSE63110M_SP2025R2_Data-Science-Capstone/Data/ACS_for_MHGoogleTrends.Rdata")

acs_data <- ACS_data
ACS_data <- NULL
```

## *##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               1.000000000 -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

```

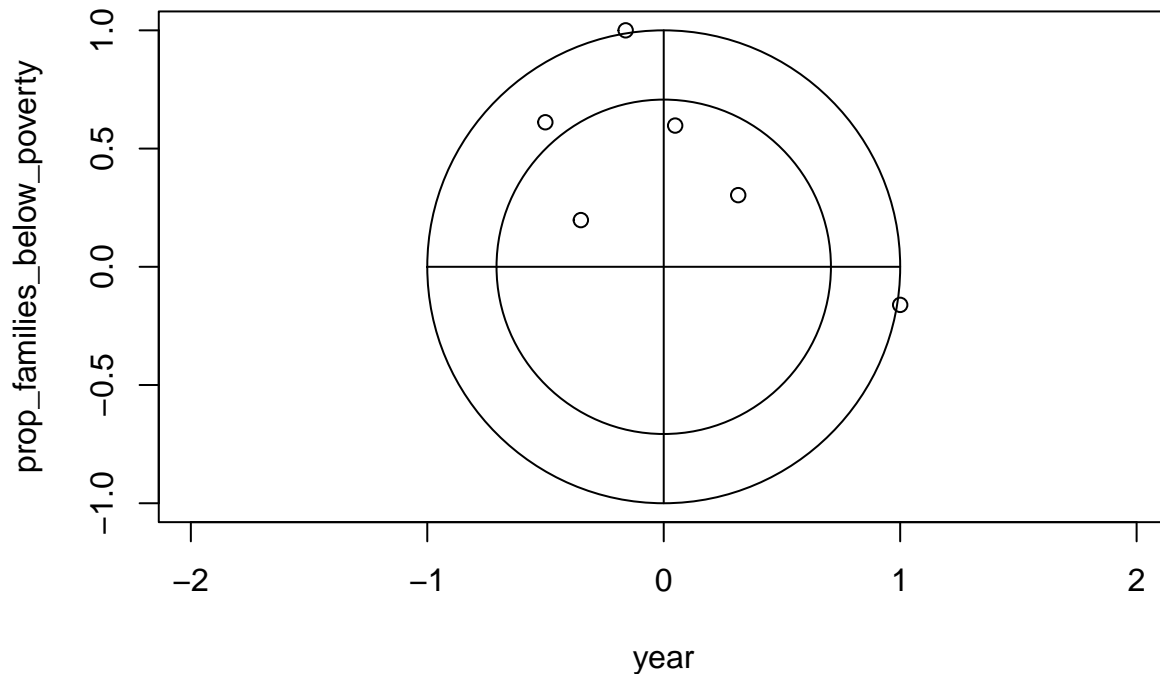
*#presenting correlation matrix in graphic format*

```

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))

```

## acs\_data correlation matrix



```
#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))])

#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_utili = 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

#joining both datasets acs_data and data_GTrends

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

#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	1.000000000	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

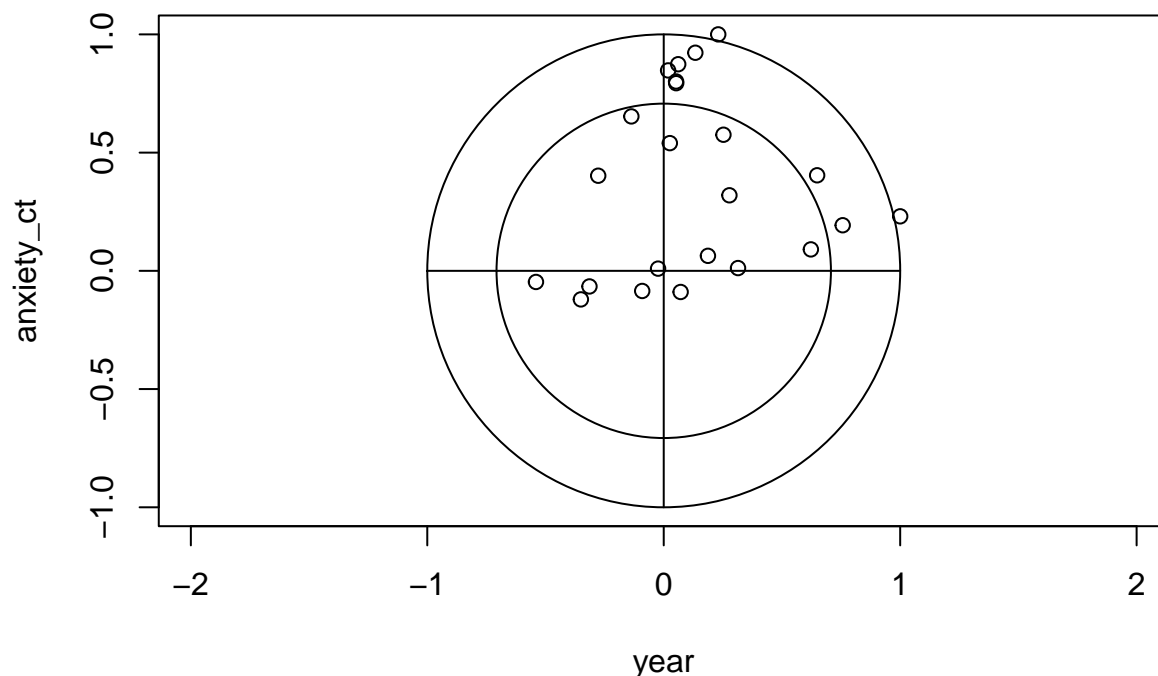
1. private, reside and comm\_psych\_care,
2. inpatient\_util vs outpatient\_util ( i already have state\_mentalhealth\_util)
3. mean\_therapist\_near\_me vs mean\_psychiatrist and mean\_psychologist
4. mean\_alltrend vs mean\_adhd, mean\_ptsd, mean\_anxiety, mean\_mentalhospital.
5. mean\_anxiety vs 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))
```

### Correlation Matrix of GTrends\_acs\_joined



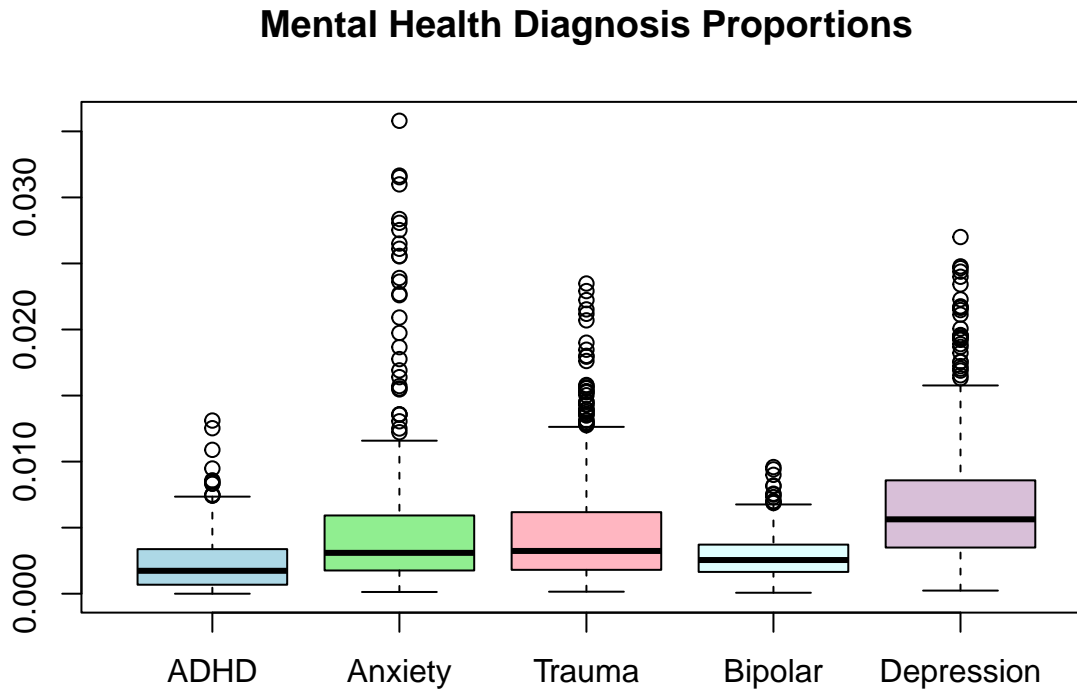
```
data <- data_GTrends
data$adhd_prop = data$adhd_ct/data$population_est
data$anxiety_prop = data$anxiety_ct/data$population_est
data$bipolar_prop = data$bipolar_ct/data$population_est
```

```

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" ))

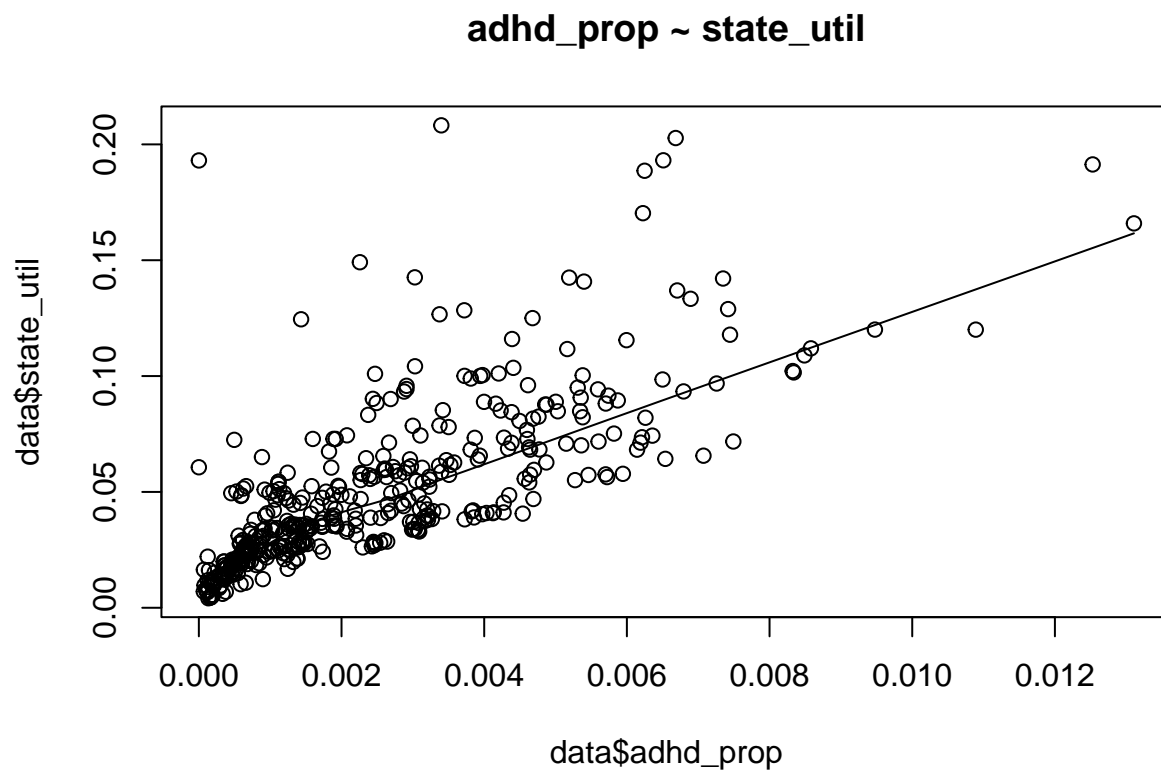
```



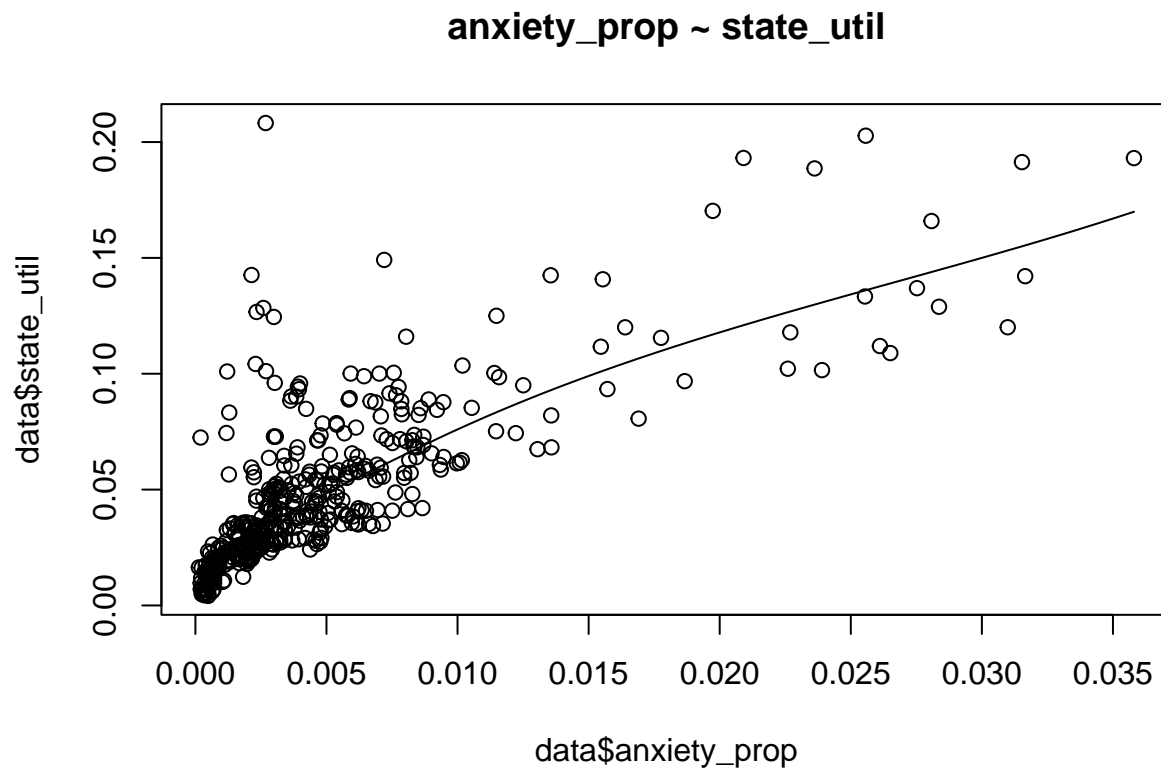
```

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")

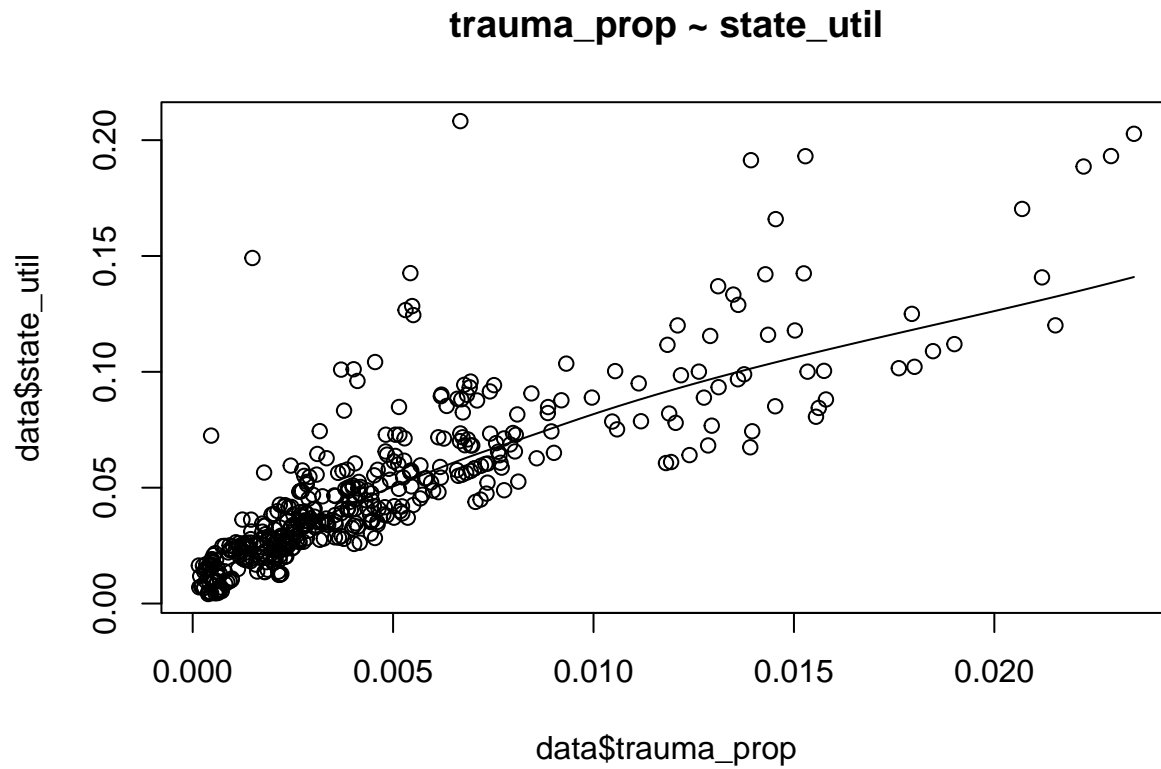
```



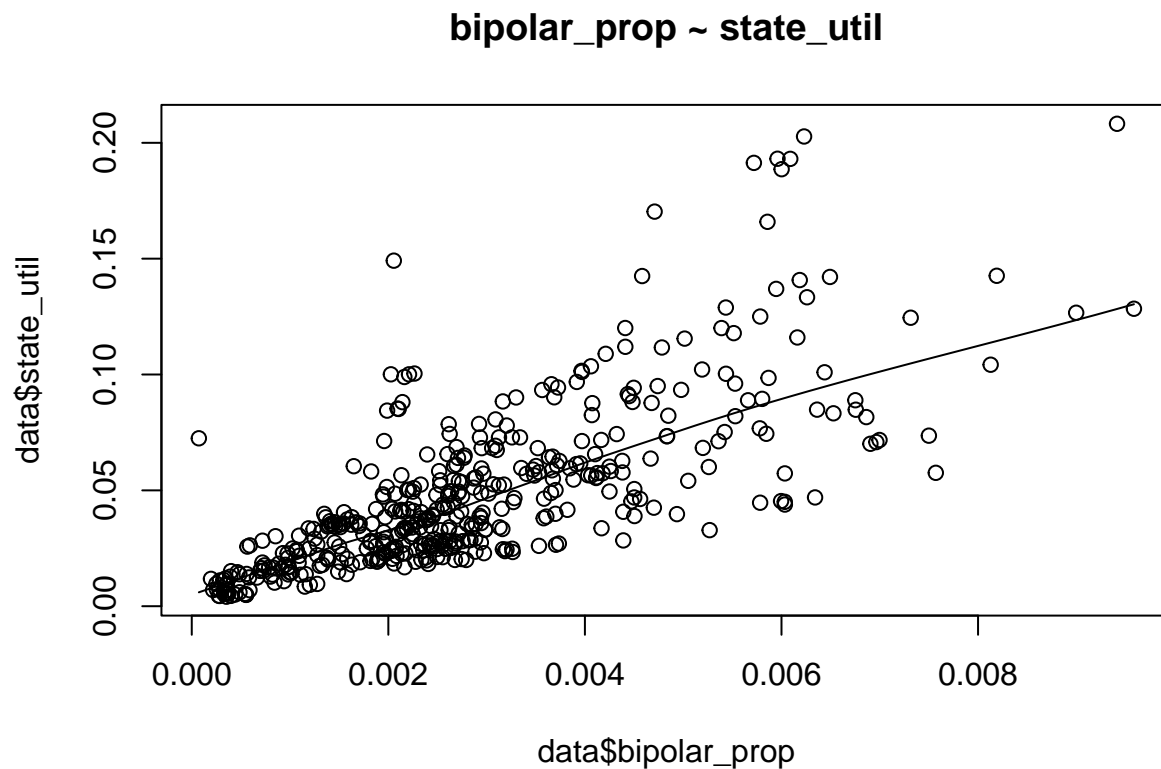
```
scatter.smooth(x=data$anxiety_prop, y=data$state_util, main="anxiety_prop ~ state_util")
```



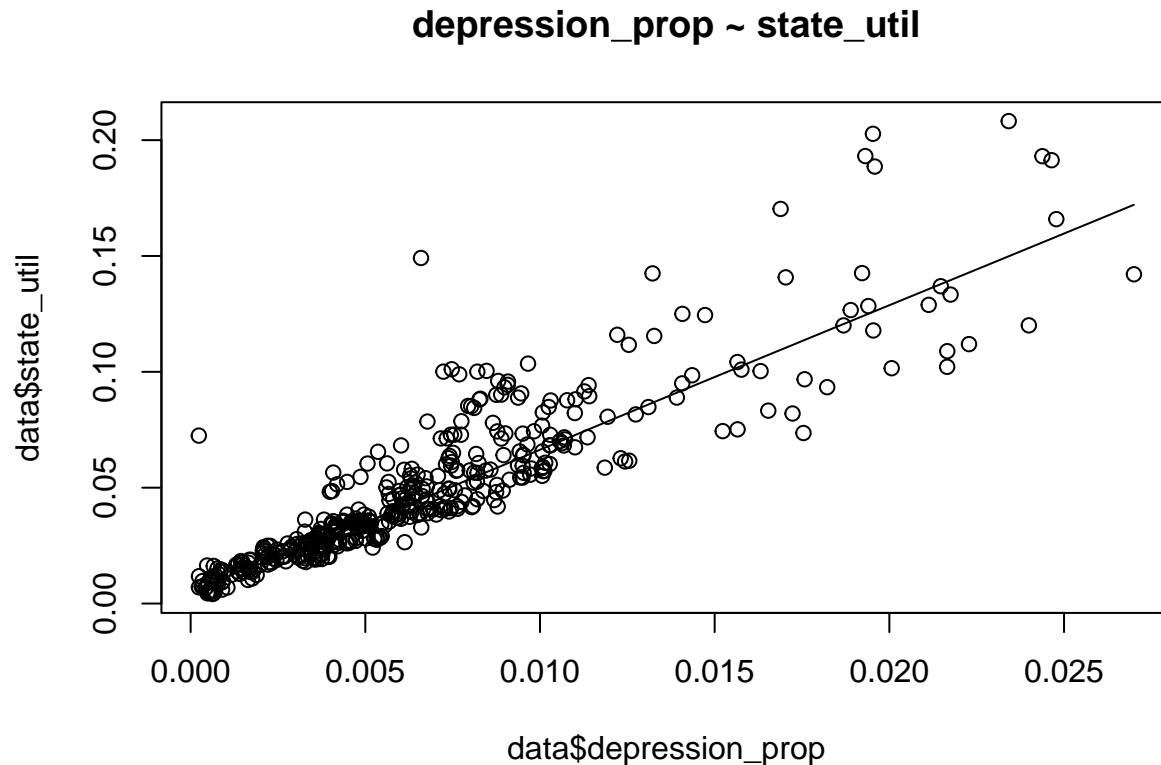
```
scatter.smooth(x=data$trauma_prop, y=data$state_util, main="trauma_prop ~ state_util")
```



```
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)
```

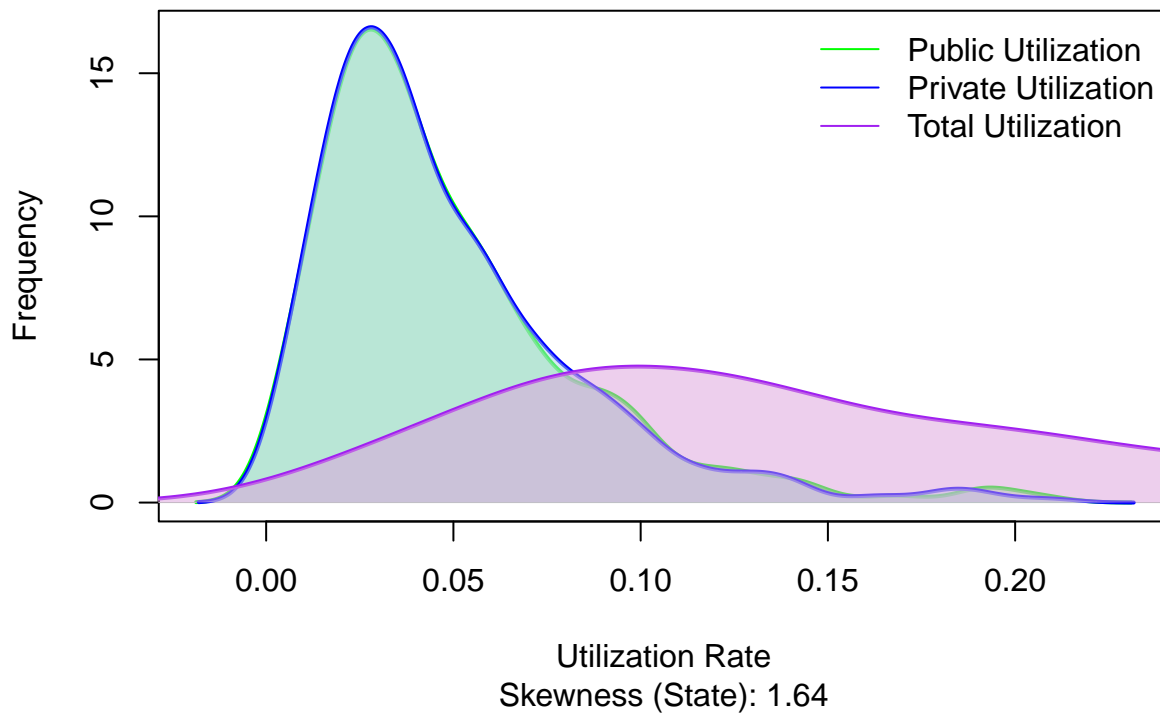
```

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")

```

## Public, Private Facility, & Total Utilization Density



```

#data split: train and test dataset

clean_GTrends_acs_joined <- GTrends_acs_joined %>%
  select(-fips, -population_est, -private_psych_care, -total_util,
        # Comment the next line out and replace it to include region
        #-outpatient_util, -region, -mean_anxiety, -resid_psych_care,
        -outpatient_util, -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"
```

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

```
## [1] 433 26
```

```
names(clean_GTrends_acs_joined)
```

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

```
# Remove some fields used in the calculation of the proportions
```

```
cols_to_exclude = c("anxiety_ct",
                    "trauma_stress_ct",
                    "adhd_ct", "bipolar_ct",
                    "depression_ct",
                    "comm_psych_care",
                    "state_psych_care")
clean_GTrends_acs_joined <- clean_GTrends_acs_joined[,!(names(clean_GTrends_acs_joined)
                                                         %in% cols_to_exclude)]
names(clean_GTrends_acs_joined)
```

```
## [1] "year"
## [2] "state"
## [3] "region"
## [4] "mean_adhd"
## [5] "mean_ptsd"
## [6] "mean_bipolar"
## [7] "mean_depression"
```



```
## [8] "mean_mental_hospital"
## [9] "mean_psychiatrists_near_me"
## [10] "mean_psychologist_near_me"
## [11] "state_mentalhealth_util"
## [12] "anxiety_prop"
## [13] "adhd_prop"
## [14] "bipolar_prop"
## [15] "prop_families_below_poverty"
## [16] "prop_adults_without_health_insurance"
## [17] "prop_unemployed_in_labor_force"
## [18] "prop_without_internet_access"
## [19] "prop_adult_disability"
```

```
#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/DSE63110M_SP2025R2_Data-Science-Capstone/Data/clean_GTrends_acs_joined_"
# write.csv(clean_GTrends_acs_joined, file_name, row.names = FALSE)
```

```
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 19
```

```
dim(test_set)
```

```
## [1] 97 19
```

```
head(test_set)
```

```
## # A tibble: 6 x 19
##   year state region      mean_adhd mean_ptsd mean_bipolar mean_depression
##   <dbl> <chr> <chr>          <dbl>      <dbl>         <dbl>          <dbl>
## 1  2013 AL    South           23.5        8.75          22.3           59
## 2  2013 AR    South           21.7       10.7          22.2          67.2
## 3  2013 CA    West Pacific    17.9        8.92          19.7          56.2
## 4  2013 DE    Atlantic       24.2        8.83          25.1           65
## 5  2013 FL    South           20.2         8            22            49
## 6  2013 IL    Central         19.8        7.42          20.9          54.5
## # i 12 more variables: 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>,
## # prop_unemployed_in_labor_force <dbl>, prop_without_internet_access <dbl>,
## # prop_adult_disability <dbl>

## One-hot encoding using fastDummies
train_encoded <- dummy_cols(GTrend_training_set,
                             select_columns = "region",
                             remove_first_dummy = FALSE, ## TRUE for true dummy encoding
                             remove_selected_columns = TRUE) ## Drops original columns

# Sanitize column names by replacing spaces in column names with underscores
train_encoded <- clean_names(train_encoded)

## Repeat to make test_encoded!
test_encoded <- dummy_cols(test_set,
                            select_columns = "region",
                            remove_first_dummy = FALSE, ## TRUE for true dummy encoding
                            remove_selected_columns = TRUE) ## Drops original columns

# Sanitize column names by replacing spaces in column names with underscores
test_encoded <- clean_names(test_encoded)

## Align test set with training set columns (IF NEEDED)
missingFeatures <- setdiff(names(train_encoded), names(test_encoded))

test_encoded[missingFeatures] <- 0
test_encoded <- test_encoded[, names(train_encoded)]
names(test_encoded)
```

```
## [1] "year"
## [2] "state"
## [3] "mean_adhd"
## [4] "mean_ptsd"
## [5] "mean_bipolar"
## [6] "mean_depression"
## [7] "mean_mental_hospital"
## [8] "mean_psychiatrists_near_me"
## [9] "mean_psychologist_near_me"
## [10] "state_mentalhealth_util"
## [11] "anxiety_prop"
## [12] "adhd_prop"
## [13] "bipolar_prop"
## [14] "prop_families_below_poverty"
## [15] "prop_adults_without_health_insurance"
## [16] "prop_unemployed_in_labor_force"
## [17] "prop_without_internet_access"
## [18] "prop_adult_disability"
## [19] "region_atlantic"
## [20] "region_central"
## [21] "region_south"
## [22] "region_west_pacific"
```

```
# Assign the encoded training set and test set
GTrend_training_set <- train_encoded
test_set <- test_encoded
```

TARGET ENCODING OF STATE BY Njagi

```
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"
```

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

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

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

```
class(GTrend_training_set$state)
```

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

```
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"
```

```
# 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) / (n() +
```

```
#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
```

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

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

```
names(GTrend_training_set_f)
```

```
## [1] "year"
## [2] "mean_adhd"
## [3] "mean_ptsd"
## [4] "mean_bipolar"
## [5] "mean_depression"
## [6] "mean_mental_hospital"
## [7] "mean_psychiatrists_near_me"
## [8] "mean_psychologist_near_me"
## [9] "state_mentalhealth_util"
## [10] "anxiety_prop"
## [11] "adhd_prop"
## [12] "bipolar_prop"
## [13] "prop_families_below_poverty"
## [14] "prop_adults_without_health_insurance"
## [15] "prop_unemployed_in_labor_force"
## [16] "prop_without_internet_access"
## [17] "prop_adult_disability"
## [18] "region_atlantic"
## [19] "region_central"
## [20] "region_south"
## [21] "region_west_pacific"
## [22] "state_encoded"
```

```
state_util_index <- 10
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 22
##   year mean_adhd mean_ptsd mean_bipolar mean_depression mean_mental_hospital
##   <dbl>   <dbl>   <dbl>       <dbl>         <dbl>         <dbl>
## 1 -1.66   -0.742   -1.07         0.757         -0.657         -0.259
## 2 -1.66   -0.944   -0.932         0.514         -1.35          0.222
## 3 -1.66   -0.613   -1.46         0.806         -0.969          0.185
## 4 -1.66   -0.586   -0.0113      -0.411         -0.293         -2.04
## 5 -1.66   -0.613   -0.826         0.806          0.396         -0.656
## 6 -1.66   -0.577   -1.92          0.271         -0.540         -0.275
## # i 16 more variables: 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>,
## # prop_unemployed_in_labor_force <dbl>, prop_without_internet_access <dbl>,
## # prop_adult_disability <dbl>, region_atlantic <dbl>, ...

#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: 19 x 4
##   variable      class Number of Missing Va-1 Number of Unique Val-2
##   <chr>         <chr>          <int>          <int>
## 1 year         nume~              0             10
## 2 state        char~              0             46
## 3 region       char~              0              4
## 4 mean_adhd    nume~              0            205
## 5 mean_ptsd    nume~              0            114
## 6 mean_bipolar nume~              0             97
## 7 mean_depression nume~              0            230
## 8 mean_mental_hospital nume~              0            272
## 9 mean_psychiatrists_near_~ nume~              0             59
## 10 mean_psychologist_near_me nume~              0            153
## 11 state_mentalhealth_util nume~              0            433
## 12 anxiety_prop nume~              0            433
## 13 adhd_prop    nume~              0            433
## 14 bipolar_prop nume~              0            433
## 15 prop_families_below_pove~ nume~              0            433
## 16 prop_adults_without_heal~ nume~              0            433
## 17 prop_unemployed_in_labor~ nume~              0            433
## 18 prop_without_internet_ac~ nume~              0            433
## 19 prop_adult_disability     nume~              0            433
## # i abbreviated names: 1: 'Number of Missing Values',
## # 2: 'Number of Unique Values'
```

```
codebook$variable
```

```
## [1] "year"
## [2] "state"
## [3] "region"
## [4] "mean_adhd"
## [5] "mean_ptsd"
## [6] "mean_bipolar"
```

```
## [7] "mean_depression"
## [8] "mean_mental_hospital"
## [9] "mean_psychiatrists_near_me"
## [10] "mean_psychologist_near_me"
## [11] "state_mentalhealth_util"
## [12] "anxiety_prop"
## [13] "adhd_prop"
## [14] "bipolar_prop"
## [15] "prop_families_below_poverty"
## [16] "prop_adults_without_health_insurance"
## [17] "prop_unemployed_in_labor_force"
## [18] "prop_without_internet_access"
## [19] "prop_adult_disability"

# Create an empty dataframe with three fields store storing model train and test RMSE values.
mse_df <- tibble(
  Model = character(),
  Train_MSE = numeric(),
  Test_MSE = numeric()
)

# Function to add rows to the mse_df
add_rmse_row <- function(df, model_name, train_mse, test_mse) {
  new_row <- tibble(
    Model = model_name,
    Train_MSE = train_mse,
    Test_MSE = test_mse
  )
  updated_df <- bind_rows(df, new_row)
  return(updated_df)
}

GTrend_training_set_f <- subset(GTrend_training_set_f, select = -state_encoded)
test_set_f <- subset(test_set_f, select = -state_encoded)
```

## INITIAL MODELS BY Njagi

### 1. LINEAR REGRESSION (ELASTIC NET REGULARIZATION)

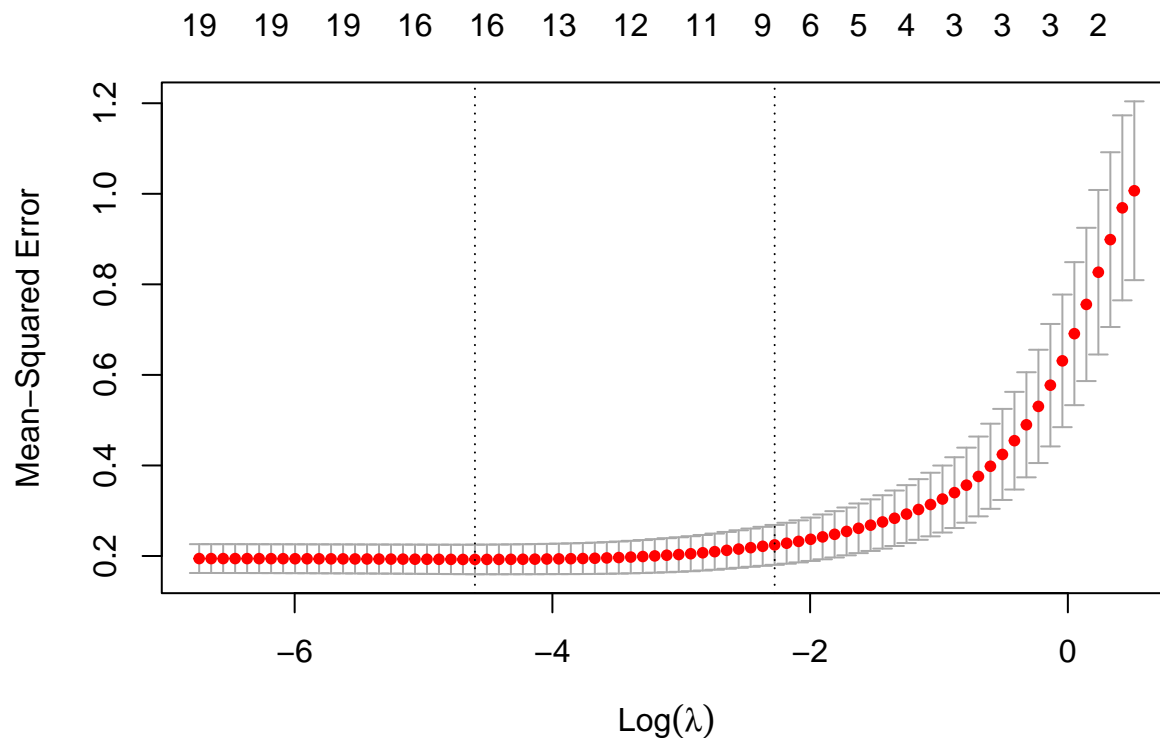
```
# DEVELOPING THE MODEL (LR. ENR)

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 matrix
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
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): 0.174418509310218"
```

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

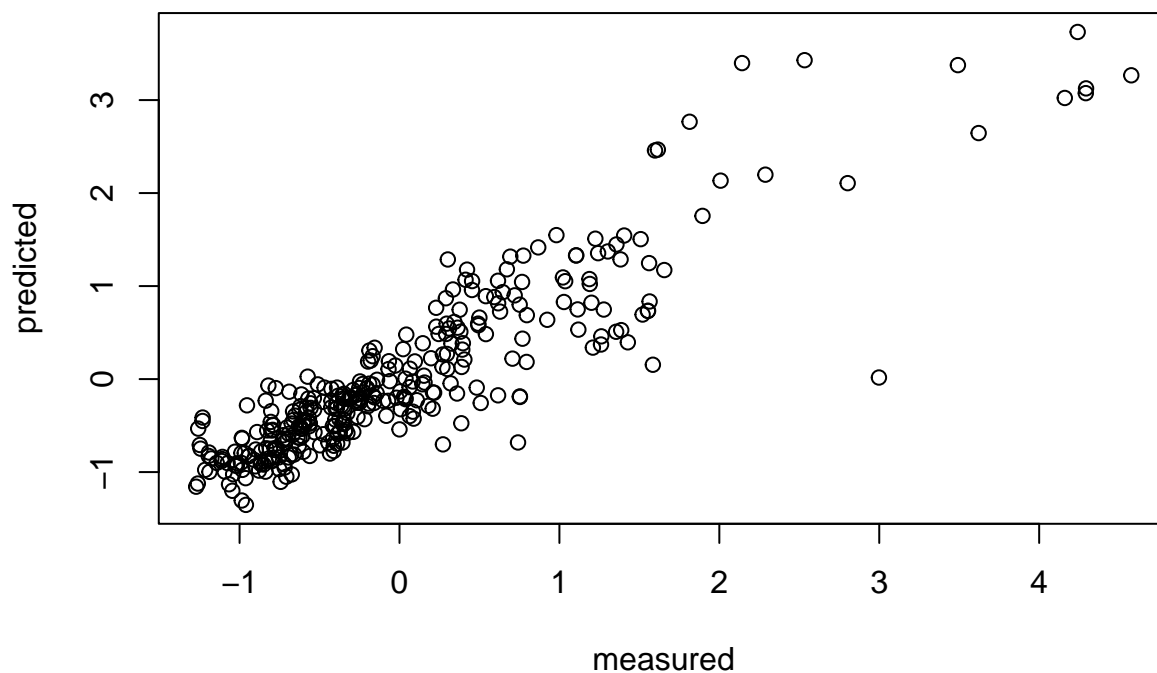
```
## [1] "MSE (1SE): 0.144032133888517"
```

## Principal Component Regression (PCR)

```
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)
```

### state\_mentalhealth\_util, 20 comps, validation



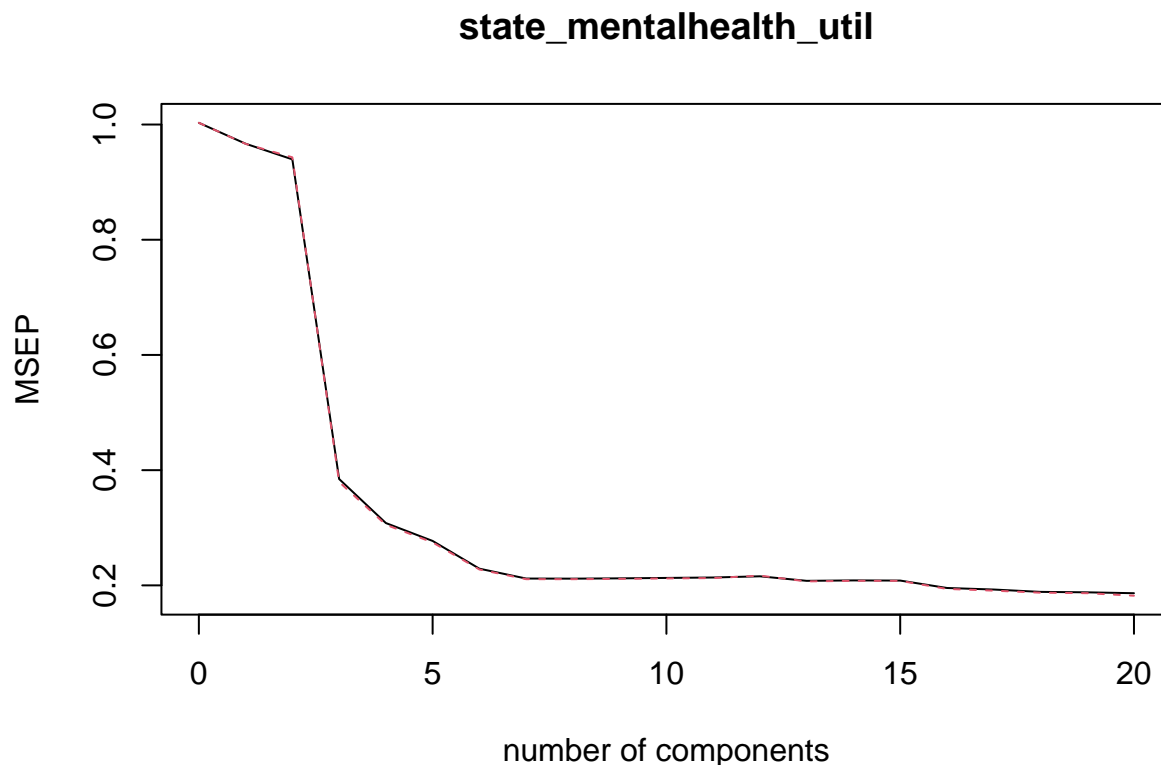
```
# Show the summary of the PCR fit.
summary(pcr_fit)
```

```
## Data:      X dimension: 336 20
## Y dimension: 336 1
## Fit method: svdpc
## Number of components considered: 20
##
## VALIDATION: RMSEP
## Cross-validated using 10 random segments.
##      (Intercept)  1 comps  2 comps  3 comps  4 comps  5 comps  6 comps
## CV           1.001   0.9832   0.9693   0.6202   0.5551   0.5264   0.4785
## adjCV         1.001   0.9831   0.9711   0.6161   0.5524   0.5240   0.4770
```



```
##          7 comps  8 comps  9 comps 10 comps 11 comps 12 comps 13 comps
## CV       0.4602   0.4601   0.4606   0.4614   0.4622   0.4645   0.4559
## adjCV    0.4591   0.4591   0.4596   0.4605   0.4612   0.4657   0.4549
##          14 comps 15 comps 16 comps 17 comps 18 comps 19 comps 20 comps
## CV       0.4567   0.4564   0.4421   0.4391   0.4344   0.4335   0.4317
## adjCV    0.4559   0.4559   0.4403   0.4368   0.4327   0.4318   0.4267
##
## TRAINING: % variance explained
##
##          1 comps  2 comps  3 comps  4 comps  5 comps  6 comps
## X          18.927   33.91   46.70   56.97   65.80   73.58
## state_mentalhealth_util 4.613   12.00   64.83   71.91   74.73   78.53
##
##          7 comps  8 comps  9 comps 10 comps 11 comps
## X          79.65   84.25   87.91   90.61   92.61
## state_mentalhealth_util 80.06   80.13   80.13   80.15   80.26
##
##          12 comps 13 comps 14 comps 15 comps 16 comps
## X          94.02   95.42   96.63   97.66   98.50
## state_mentalhealth_util 80.53   81.17   81.18   81.61   83.33
##
##          17 comps 18 comps 19 comps 20 comps
## X          99.17   99.72  100.00  100.00
## state_mentalhealth_util 83.56   83.64   83.73   83.89
```

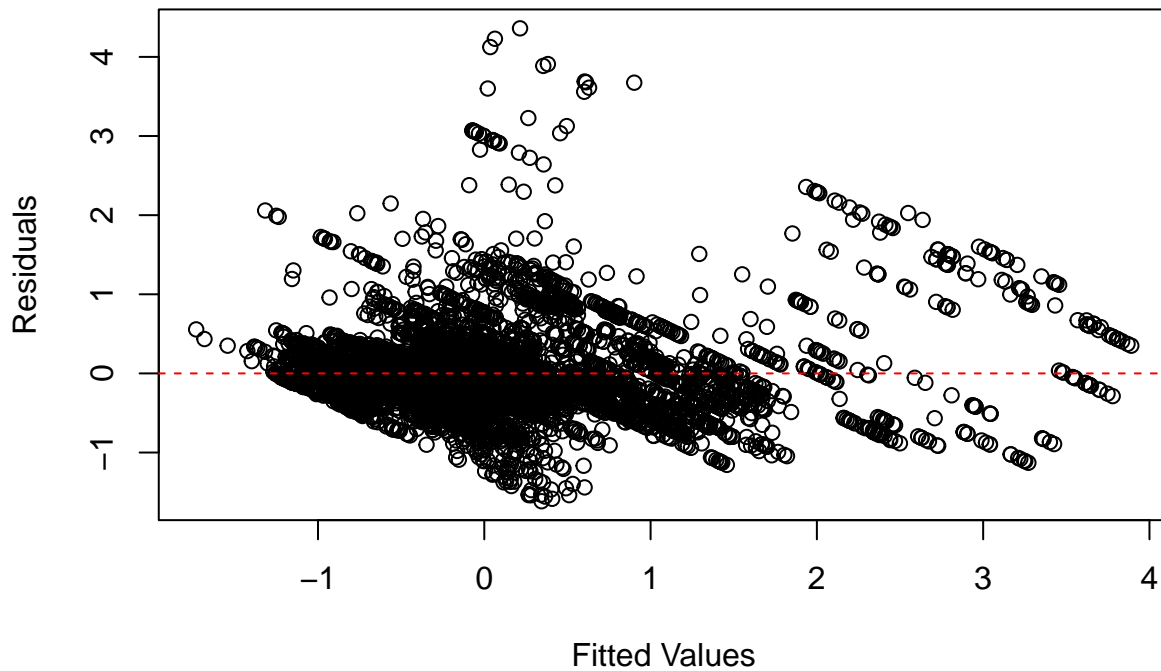
```
# Show the validation plot.
validationplot(pcr_fit, val.type="MSEP")
```



```
# 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)
```

## PCR: Residuals vs Fitted



```
# 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 mse_df
mse_df <- add_rmse_row(mse_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 0.951035111329286"
```

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

```
## [1] "PCR Test MSE for M Selected: 1 is 0.0500971387884519"
```

## Partial Least Squares Regression (PLSR)

```

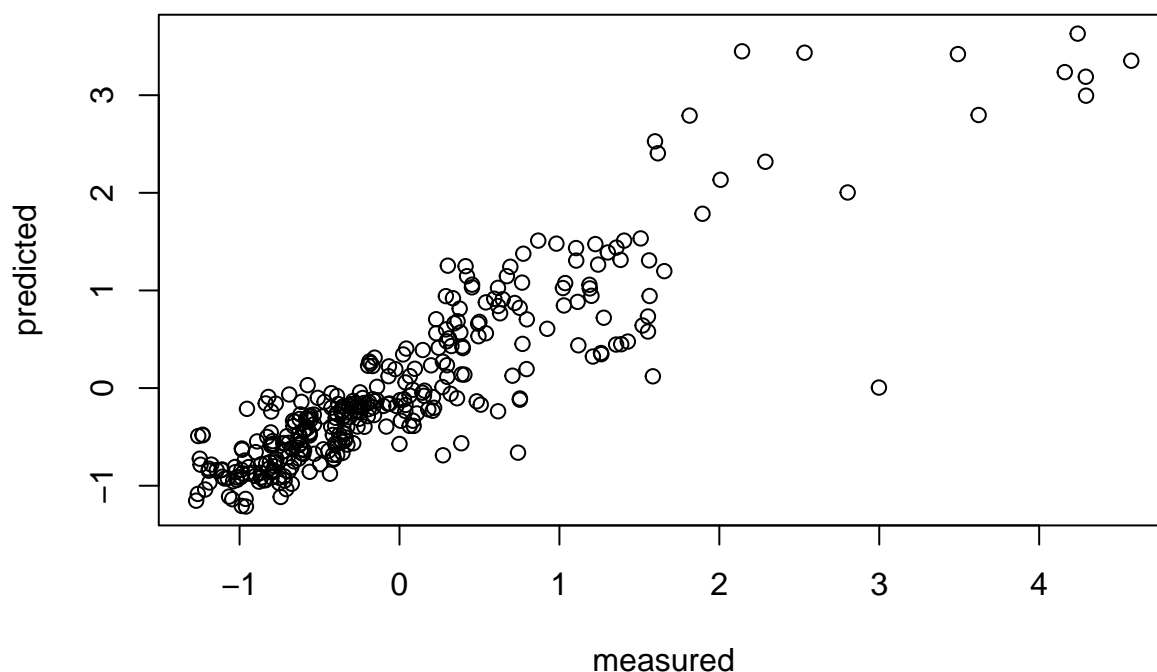
# Set the PLS M selected value.
plsr_M_selected <- 15

# 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)

# Plot the PLSR fit
plot(plsr_fit)

```

### state\_mentalhealth\_util, 15 comps, validation



```

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

```

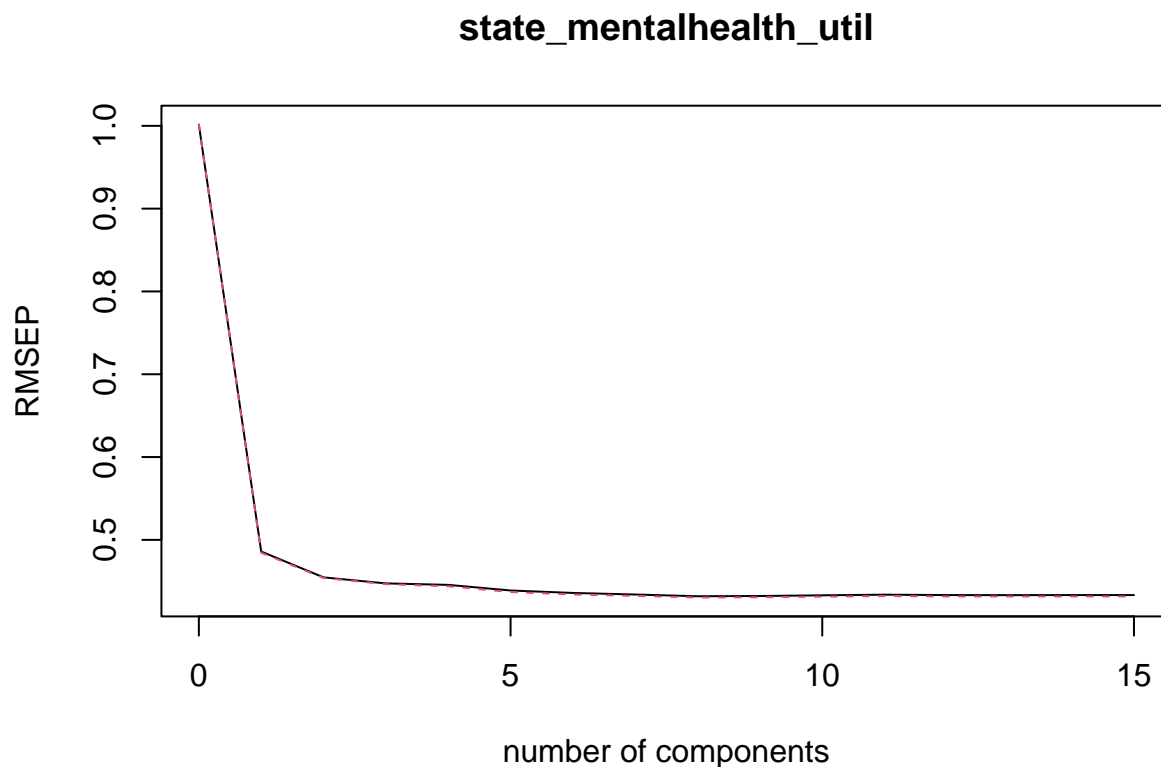
```

## Data:      X dimension: 336 20
## 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   0.4859   0.4547   0.4474   0.4457   0.4389   0.4359
## adjCV        1.001   0.4844   0.4539   0.4465   0.4440   0.4369   0.4341
##      7 comps  8 comps  9 comps 10 comps 11 comps 12 comps 13 comps
## CV       0.4340  0.4319  0.4322   0.4330   0.4338   0.4333   0.4332
## adjCV    0.4323  0.4304  0.4307   0.4314   0.4321   0.4317   0.4316
##      14 comps 15 comps
## CV       0.4333   0.4333

```

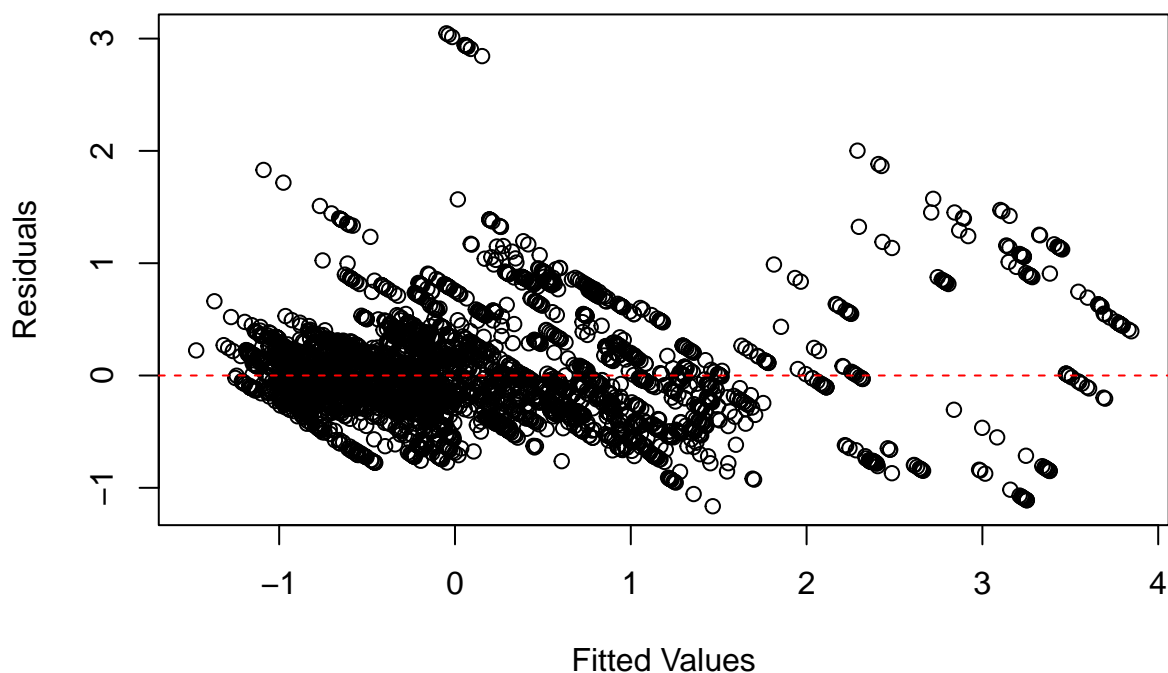
```
## adjCV    0.4317    0.4317
##
## TRAINING: % variance explained
##
##          1 comps  2 comps  3 comps  4 comps  5 comps  6 comps
## X          13.50   28.78   39.36   46.94   55.35   63.66
## state_mentalhealth_util  77.84   80.74   81.76   82.80   83.44   83.59
##
##          7 comps  8 comps  9 comps 10 comps 11 comps
## X          69.94   73.91   80.18   84.69   87.71
## state_mentalhealth_util  83.65   83.70   83.71   83.72   83.72
##
##          12 comps 13 comps 14 comps 15 comps
## X          89.32   91.33   93.11   95.81
## state_mentalhealth_util  83.73   83.73   83.73   83.73
```

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

## PLSR: Residuals vs Fitted



```
# 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 mse_df
mse_df <- add_rmse_row(mse_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 0.162217750970185"
```

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

```
## [1] "PLSR Test MSE for M Selected: 15 is 1.82066666254515"
```

## Best Subset Selection

```
# 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.
```

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

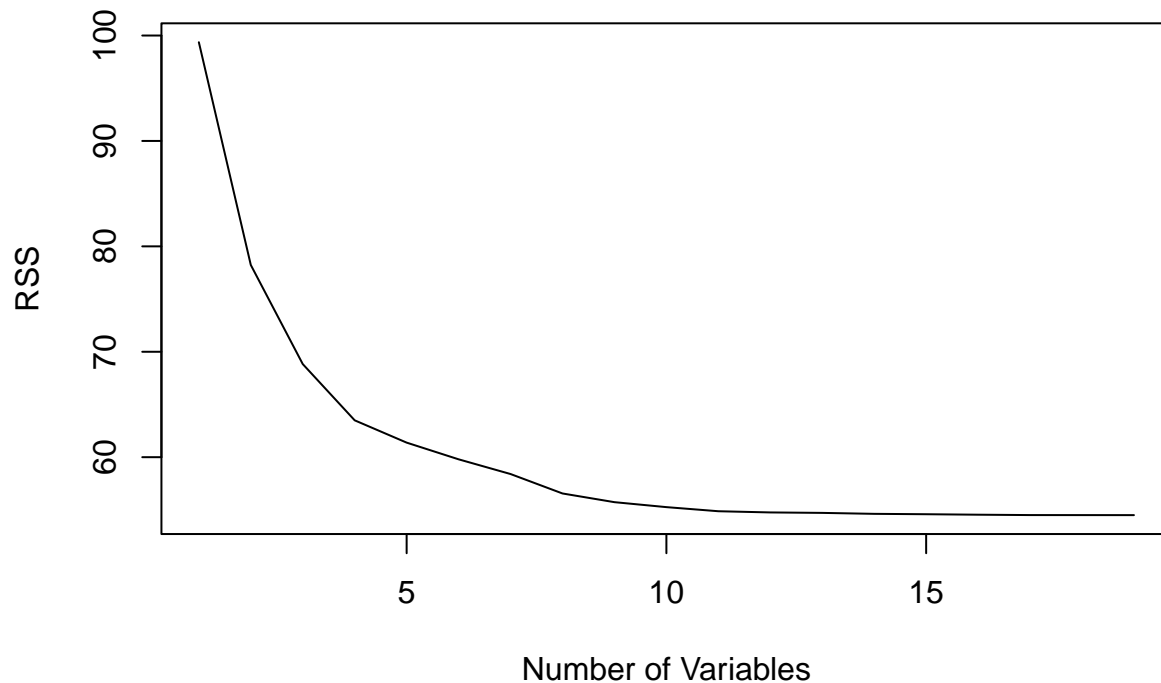
# plot(reg_fit_train, scale="r2")
# plot(reg_fit_train, scale="adjr2")
# plot(reg_fit_train, scale="Cp")
# plot(reg_fit_train, scale="bic")
# The summary() command outputs the best set of variables for each model size.
reg.summary <- summary(reg_fit_train)
#print(reg.summary)
names(reg.summary)
```

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

```
#Print the R2 statistic
reg.summary$rsq
```

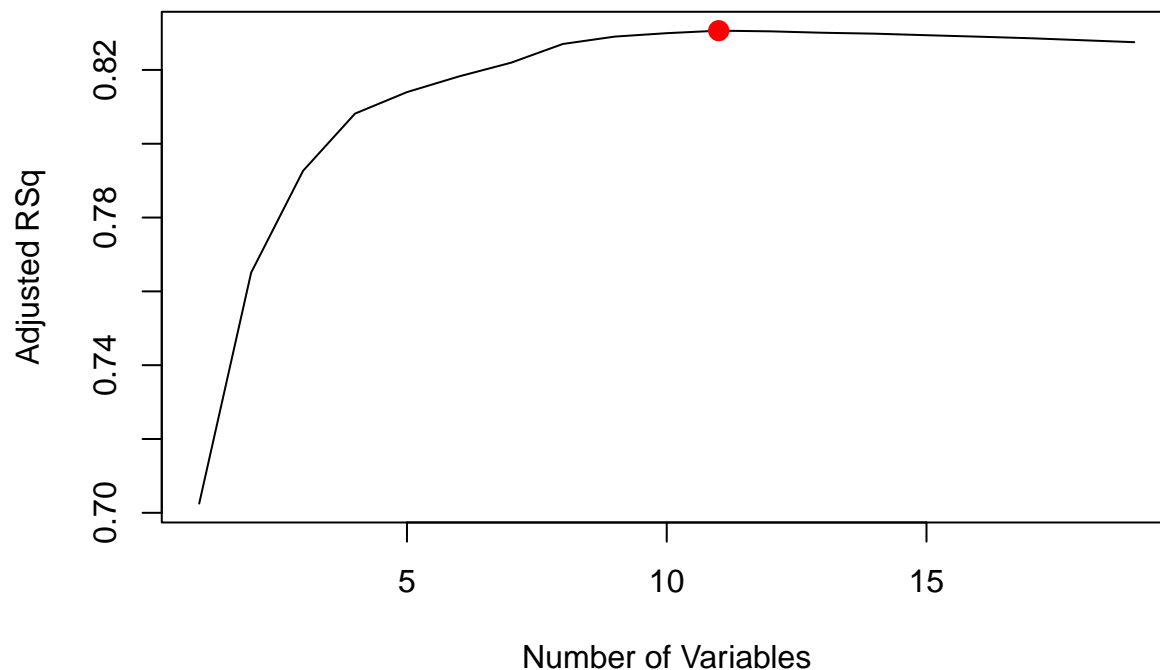
```
## [1] 0.7033899 0.7664626 0.7945254 0.8104569 0.8167684 0.8214928 0.8256666
## [8] 0.8311657 0.8336291 0.8350343 0.8361984 0.8365343 0.8366701 0.8369419
## [15] 0.8370466 0.8371783 0.8372828 0.8372922 0.8372982
```

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



```
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)
```



```
names(GTrend_training_set_f)
```

```
## [1] "year"
## [2] "mean_adhd"
## [3] "mean_ptsd"
## [4] "mean_bipolar"
## [5] "mean_depression"
## [6] "mean_mental_hospital"
## [7] "mean_psychiatrists_near_me"
## [8] "mean_psychologist_near_me"
## [9] "state_mentalhealth_util"
## [10] "anxiety_prop"
## [11] "adhd_prop"
## [12] "bipolar_prop"
## [13] "prop_families_below_poverty"
## [14] "prop_adults_without_health_insurance"
## [15] "prop_unemployed_in_labor_force"
## [16] "prop_without_internet_access"
## [17] "prop_adult_disability"
## [18] "region_atlantic"
## [19] "region_central"
## [20] "region_south"
## [21] "region_west_pacific"
```

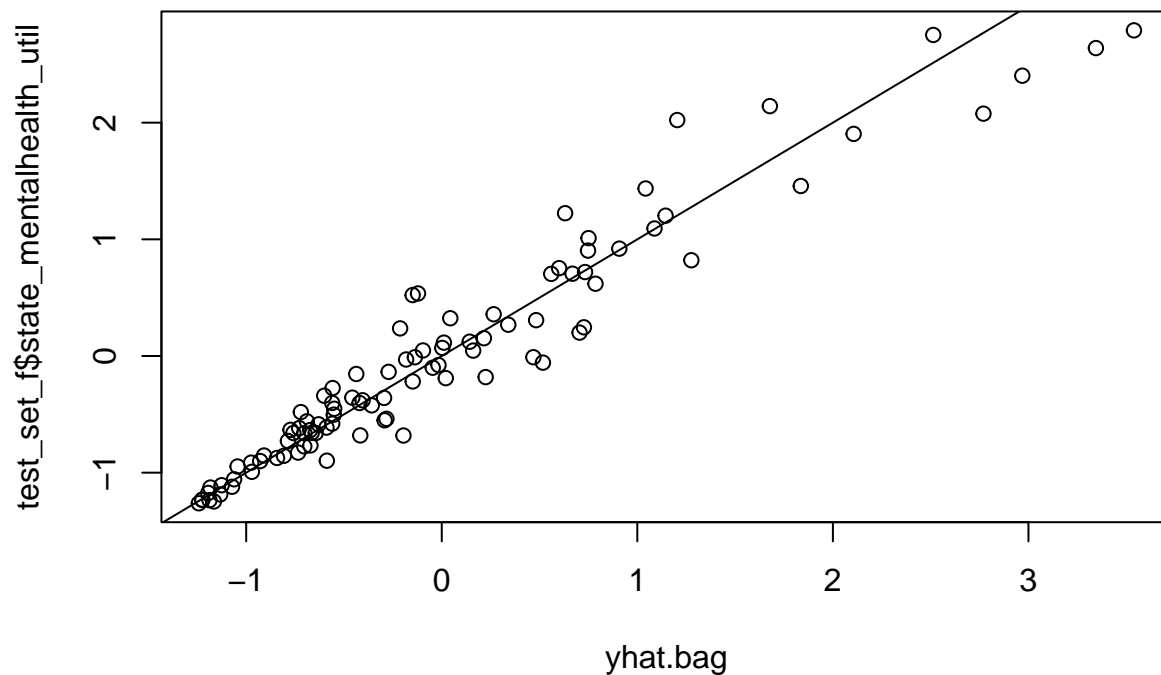
## Random Forest

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

```
##
## Call:
## randomForest(formula = state_mentalhealth_util ~ ., data = GTrend_training_set_f, mtry = 24, i
##           Type of random forest: regression
##           Number of trees: 500
## No. of variables tried at each split: 20
##
##           Mean of squared residuals: 0.153798
##           % Var explained: 84.57
```

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

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



```
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: 0.0768783554129373"
```

```
# 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: 0.1407095
##           % Var explained: 85.89

yhat_train_rf <- predict(rf_model, newdata = GTrend_training_set_f)
yhat_test_rf  <- predict(rf_model, newdata = test_set_f)

# Calculate the train and test mean square errors
rf_train_mse <- mean((yhat_train_rf - GTrend_training_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 mse_df
mse_df <- add_rmse_row(mse_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: = 0.0229959391087562"

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

## [1] "Test MSE associated with the Random Forest is: = 0.0598082618119365"

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
## anxiety_prop      anxiety_prop
## adhd_prop          adhd_prop
## region_atlantic    region_atlantic
## bipolar_prop        bipolar_prop
## prop_adult_disability prop_adult_disability
## prop_adults_without_health_insurance prop_adults_without_health_insurance
##           X.IncMSE IncNodePurity
## anxiety_prop      37.09654      144.022967
## adhd_prop          29.29780       80.444476
## region_atlantic    17.47484        5.667759
## bipolar_prop        15.32167       40.312699
## prop_adult_disability 13.82353        9.046076
## prop_adults_without_health_insurance 12.96077        7.261165

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

```

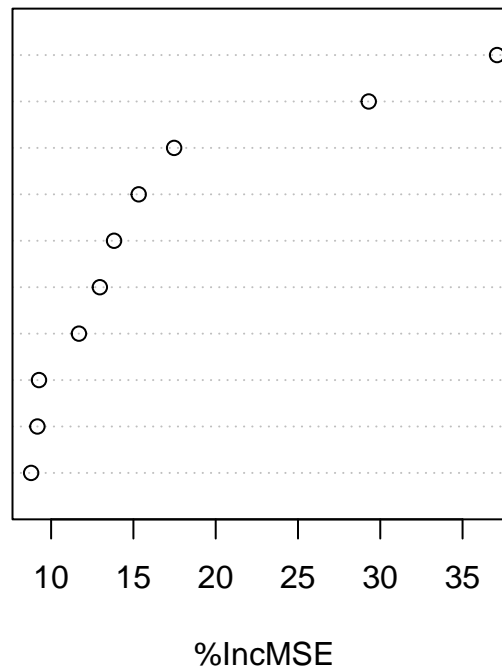
```

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

```

## Top 10 Important Variables

anxiety\_prop  
 adhd\_prop  
 region\_atlantic  
 bipolar\_prop  
 prop\_adult\_disability  
 prop\_adults\_without\_health\_insurance  
 mean\_ptsd  
 prop\_families\_below\_poverty  
 region\_south  
 mean\_mental\_hospital



```

set.seed(42)

# Set up a 5 fold cross-validation 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)

```

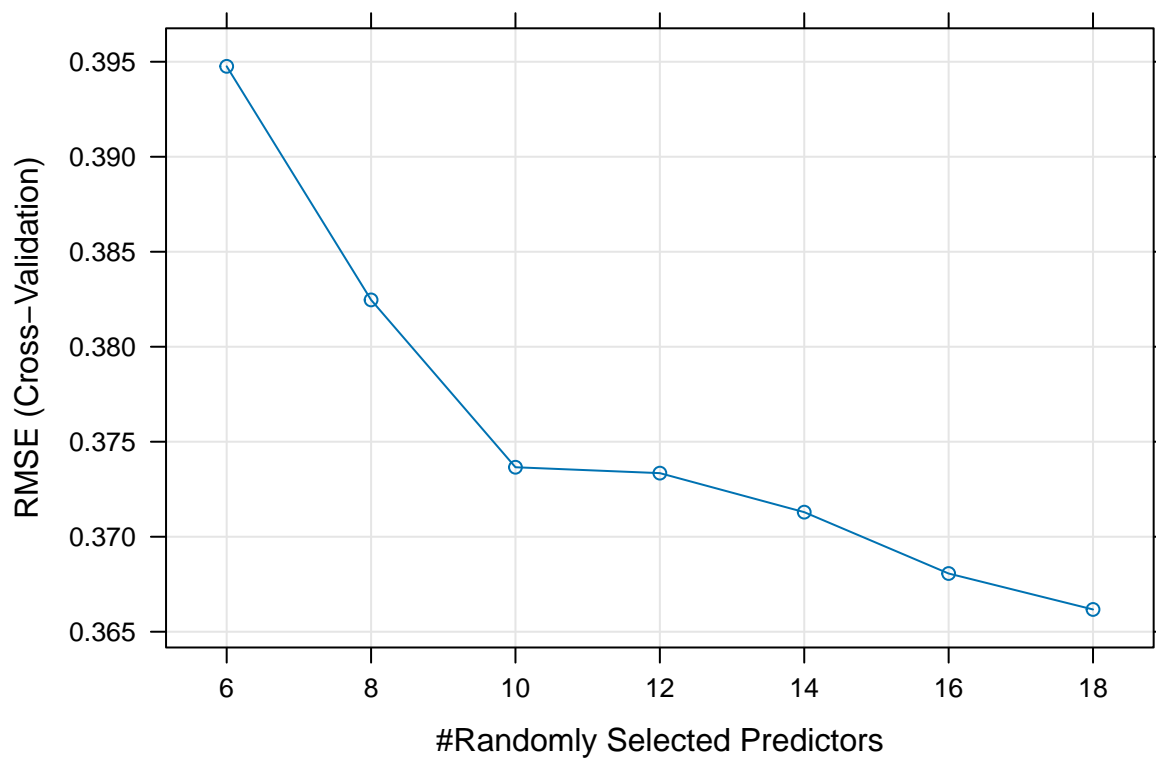
```

## Random Forest
##
## 336 samples
## 20 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     0.3947596  0.8635422  0.2320103
##   8     0.3824648  0.8664910  0.2221859
##  10     0.3736568  0.8709446  0.2171305
##  12     0.3733471  0.8695153  0.2150267
##  14     0.3712944  0.8707548  0.2167764
##  16     0.3680641  0.8726990  0.2163042
##  18     0.3661722  0.8737767  0.2174629
##
## RMSE was used to select the optimal model using the smallest value.
## The final value used for the model was mtry = 18.
```

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

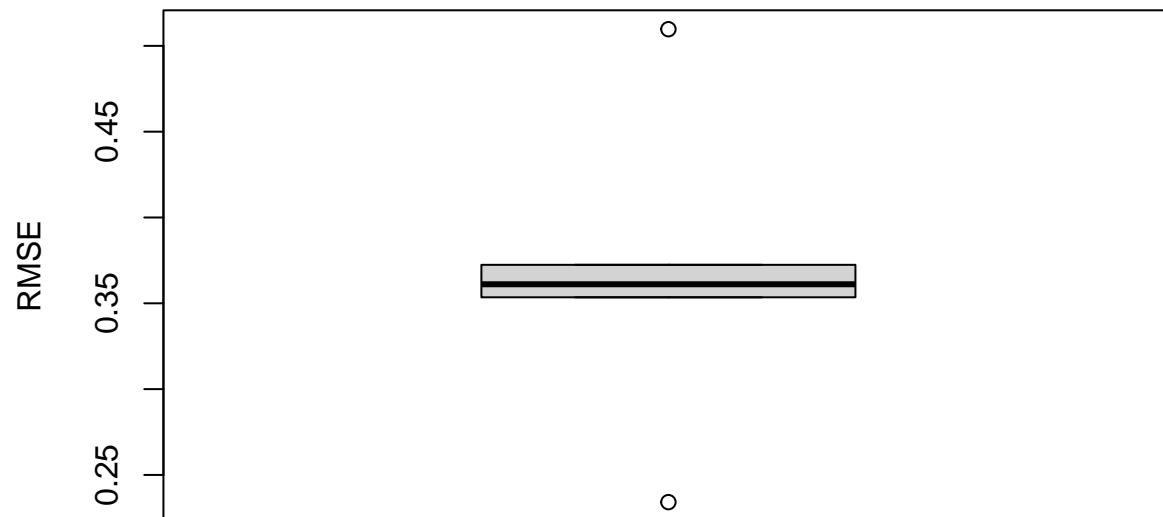


```
names(rf_cv_model)
```

```
## [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"
```

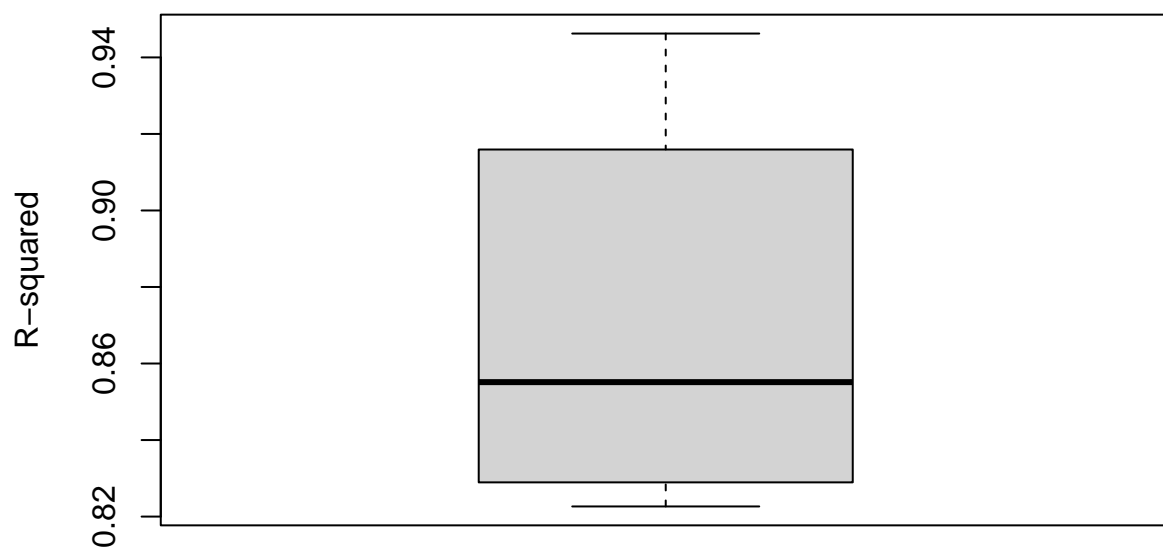
```
# Show RMSE across folds while using na.omit to remove null values before plotting
boxplot(na.omit(rf_cv_model$resample$RMSE),
        main = "Validation RMSE Across Folds",
        ylab = "RMSE")
```

### Validation RMSE Across Folds



```
# 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")
```

### Validation R-squared Across Folds

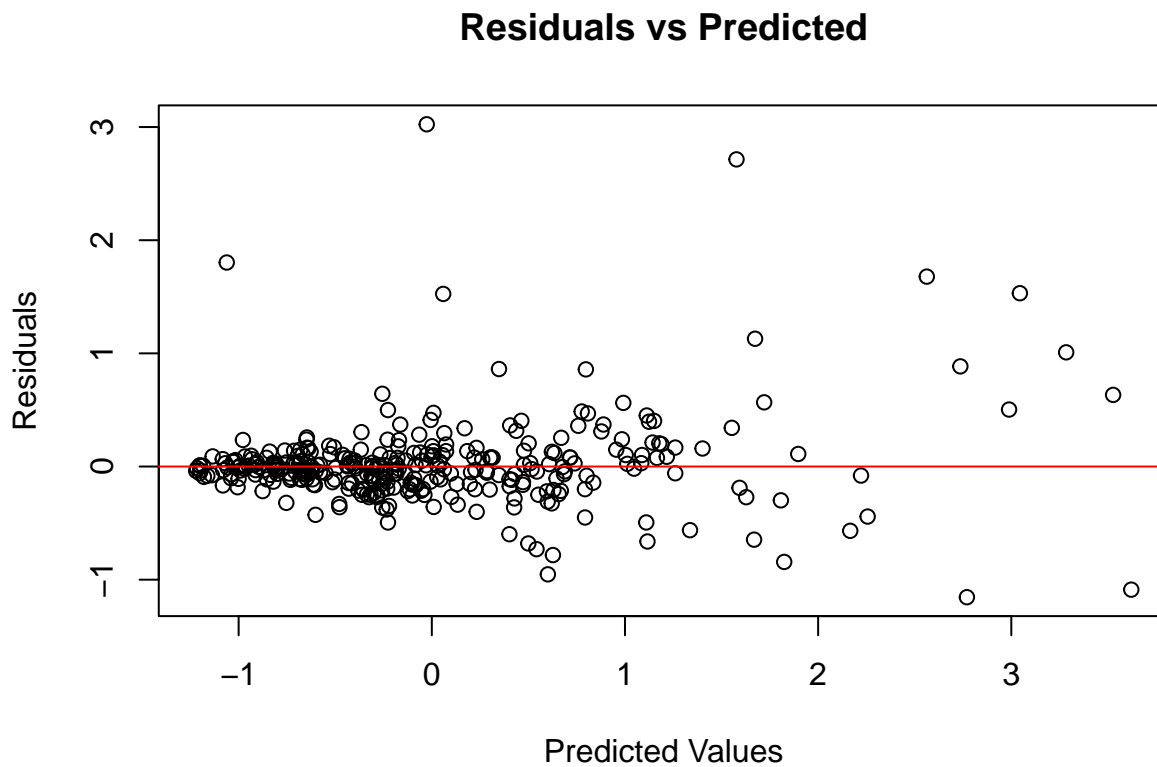


```

# Show the residuals plot
# Residuals
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")

```



```
mse_df
```

```

## # A tibble: 3 x 3
##   Model                                Train_MSE Test_MSE
##   <chr>                                <dbl>    <dbl>
## 1 Principal Component Regression      0.951    0.0501
## 2 Partial Least Squares Regression   0.162    1.82
## 3 Random Forest                      0.0230   0.0598

```

```
names(GTrend_training_set_f)
```

```

## [1] "year"
## [2] "mean_adhd"
## [3] "mean_ptsd"
## [4] "mean_bipolar"
## [5] "mean_depression"

```

```
## [6] "mean_mental_hospital"
## [7] "mean_psychiatrists_near_me"
## [8] "mean_psychologist_near_me"
## [9] "state_mentalhealth_util"
## [10] "anxiety_prop"
## [11] "adhd_prop"
## [12] "bipolar_prop"
## [13] "prop_families_below_poverty"
## [14] "prop_adults_without_health_insurance"
## [15] "prop_unemployed_in_labor_force"
## [16] "prop_without_internet_access"
## [17] "prop_adult_disability"
## [18] "region_atlantic"
## [19] "region_central"
## [20] "region_south"
## [21] "region_west_pacific"
```

**Tune MTRY Hyperparameter to 10 from 12\*** Let's do some hyperparameter tuning. We have the opportunity to reset the mtry value from 12 to 10 here, calculate and collect the MSE for comparison with other MSE values from the other models. We can also tune the number tree using some specific values.

```
# Random Forest with MTRY=10
```

```
rf_model_mtry_10 <- randomForest(state_mentalhealth_util ~ .,
                                data=GTrend_training_set_f,
                                mtry = 10, importance = TRUE)
print(rf_model_mtry_10)
```

```
##
## Call:
## randomForest(formula = state_mentalhealth_util ~ ., data = GTrend_training_set_f,      mtry = 10, i
##               Type of random forest: regression
##               Number of trees: 500
## No. of variables tried at each split: 10
##
##               Mean of squared residuals: 0.1447743
##               % Var explained: 85.48
```

```
yhat_train_rf_mtry_10 <- predict(rf_model_mtry_10, newdata = GTrend_training_set_f)
yhat_test_rf_mtry_10 <- predict(rf_model_mtry_10, newdata = test_set_f)
```

```
# Calculate the test and train mean square errors
```

```
rf_train_mse_mtry_10 <- mean((yhat_train_rf_mtry_10 - GTrend_training_set_f$state_mentalhealth_util)^2)
rf_test_mse_mtry_10 <- mean((yhat_test_rf_mtry_10 - test_set_f$state_mentalhealth_util)^2)
```

```
#add the test and train RMSEs to the mse_df
```

```
mse_df <- add_rmse_row(mse_df, "Random Forest -MTRY=10", rf_train_mse_mtry_10, rf_test_mse_mtry_10)
```

```
paste("Train MSE associated with the Random Forest is: =", rf_train_mse_mtry_10)
```

```
## [1] "Train MSE associated with the Random Forest is: = 0.0240820269403093"
```

```
paste("Test MSE associated with the Random Forest is: =", rf_test_mse_mtry_10)
```

```
## [1] "Test MSE associated with the Random Forest is: = 0.0567264392835883"
```

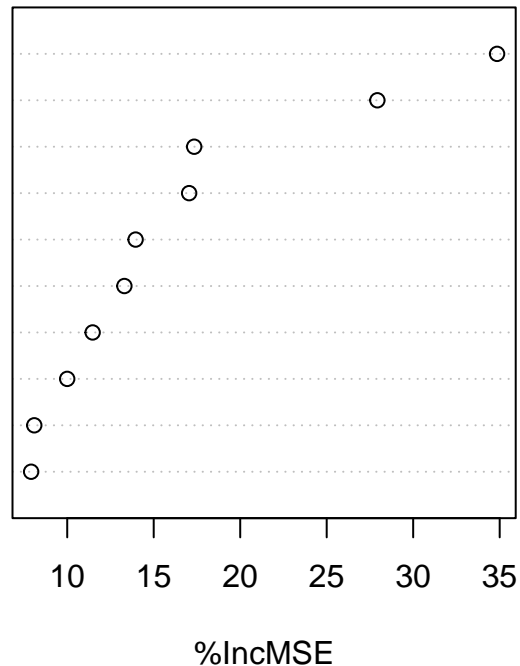
```
imp <- importance(rf_model_mtry_10)
# Let's sort the output of the importance() function
imp_df <- data.frame(Variable = rownames(imp), imp)
imp_sorted <- imp_df[order(-imp_df$X.IncMSE), ]
head(imp_sorted)
```

```
##                                     Variable
## anxiety_prop                      anxiety_prop
## adhd_prop                          adhd_prop
## bipolar_prop                      bipolar_prop
## region_atlantic                   region_atlantic
## prop_adult_disability              prop_adult_disability
## prop_adults_without_health_insurance prop_adults_without_health_insurance
##                                X.IncMSE IncNodePurity
## anxiety_prop                   34.84977    128.984475
## adhd_prop                      27.92970     82.570129
## bipolar_prop                   17.34013     44.139455
## region_atlantic                17.04821      5.335939
## prop_adult_disability           13.95330      8.503060
## prop_adults_without_health_insurance 13.30347      8.108508
```

```
# Show the importance plot
#varImpPlot(rf_model)
varImpPlot(
  x = rf_model_mtry_10,    # 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"
)
```

## Top 10 Important Variables

anxiety\_prop  
adhd\_prop  
bipolar\_prop  
region\_atlantic  
prop\_adult\_disability  
prop\_adults\_without\_health\_insurance  
mean\_ptsd  
region\_south  
mean\_mental\_hospital  
prop\_families\_below\_poverty



```
print(mse_df)
```

```
## # A tibble: 4 x 3
##   Model                                Train_MSE Test_MSE
##   <chr>                                <dbl>     <dbl>
## 1 Principal Component Regression      0.951     0.0501
## 2 Partial Least Squares Regression    0.162     1.82
## 3 Random Forest                      0.0230    0.0598
## 4 Random Forest -MTRY=10             0.0241    0.0567
```

```
set.seed(42)

rf_data <- GTrend_training_set_f[, c(-10)]
rf_label <- GTrend_training_set_f$state_mentalhealth_util

ntree_grid <- c(50, 100, 200, 500, 1000)
control <- trainControl(method = "cv", number = 5)

results <- data.frame(ntree = integer(), Accuracy = numeric())

for (nt in ntree_grid) {
  set.seed(12)
  rf_model <- train(x = rf_data,
    y = rf_label,
    method = "rf",
    metric = "RMSE",
    tuneGrid = expand.grid(mtry = sqrt(ncol(rf_data))),
    trControl = control,
```



```

    ntree = nt
  )

  results <- rbind(results, data.frame(ntree = nt, RMSE = min(rf_model$results$RMSE)))
}

print(results)

```

```

##   ntree    RMSE
## 1    50 0.3220948
## 2   100 0.3148988
## 3   200 0.3096738
## 4   500 0.3020946
## 5  1000 0.3004423

```

```

best_ntree <- results$ntree[which.min(results$RMSE)]
paste("Best number of trees:", best_ntree)

```

```

## [1] "Best number of trees: 1000"

```

```

plot(
  results$ntree, results$RMSE,
  type = "b",
  xlab = "Number of Trees",
  ylab = "RMSE",
  main = "Random Forest Tuning: Number of Trees vs RMSE",
  pch = 19
)

```

## Random Forest Tuning: Number of Trees vs RMSE

