Model 3

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Helper Packages And Modeling Packages

```
# Load Helper Packages
library(dplyr)
```

```
##
## Attaching package: 'dplyr'
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
library(ggplot2)
```

```
## Warning: package 'ggplot2' was built under R version 4.2.2
```

```
library(stringr)
library(gridExtra)
```

```
##
## Attaching package: 'gridExtra'
```

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

```
library(readr)
library(bestNormalize)
```

```
## Warning: package 'bestNormalize' was built under R version 4.2.2
```

```
# Load Modeling Packages
library(cluster)
library(factoextra)
```

```
## Warning: package 'factoextra' was built under R version 4.2.2
```

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

```
library(tidyverse)
```

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.2 --
```

```
## v tibble  3.1.8     v purrr   0.3.5
```

```
## v tidyr   1.2.1     v forcats 0.5.2
## -- Conflicts ---------------------------------------- tidyverse_conflicts() --
## x gridExtra::combine() masks dplyr::combine()
## x dplyr::filter()      masks stats::filter()
## x dplyr::lag()         masks stats::lag()
```

```
library(mclust)
```

```
## Warning: package 'mclust' was built under R version 4.2.2
```

```
## Package 'mclust' version 6.0.0
## Type 'citation("mclust")' for citing this R package in publications.
##
## Attaching package: 'mclust'
##
## The following object is masked from 'package:purrr':
##
##     map
```

CLUSTERING TECHNIQUES

In this model, we will execute and differentiate the clustering techniques results from K-Means, Hierarchical and Model based clustering disregarding the binary output and categorical variables in the data set. We will start by normalizing the data *"radiomics_completedata"*.

Loading the Data

The data contains 197 rows and 431 columns with *Failure.binary* binary output.

```
Model3Arawdata <- read_csv("radiomics_completedata.csv")
```

```
## Rows: 197 Columns: 431
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## chr   (1): Institution
## dbl (430): Failure.binary, Failure, Entropy_cooc.W.ADC, GLNU_align.H.PET, Mi...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
Model3Arawdata
```

```
## # A tibble: 197 x 431
##    Institution Failure~1 Failure Entro~2 GLNU_~3 Min_h~4 Max_h~5 Mean_~6 Varia~7
##    <chr>           <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>
##  1 A                   0   49.3     12.9    46.3    6.25   17.8     9.78   6.81
##  2 A                   1   12.6     12.2    27.5   11.0    26.5    15.4   12.9
##  3 A                   0   79.8     12.8    90.2    2.78    6.88    4.30   0.923
##  4 A                   1   17.9     13.5   326.     6.30   22.0    10.3    6.65
##  5 A                   0   39.6     12.6    89.6    3.58    7.92    4.45   0.572
##  6 A                   1    4.77    13.2   102.     2.60    6.21    3.77   0.615
##  7 A                   0   25       12.2    36.8    8.65   28.2    14.9   17.7
##  8 A                   0   35.8     12.3    51.0    5.71   13.0     7.73   2.60
##  9 A                   1   35.3     13.4    27.2    5.88   14.8     9.12   4.40
```

```
## 10 A                   1   17.8     12.6    20.2    5.70   17.1     8.55   6.12
## # ... with 187 more rows, 422 more variables:
## #   Standard_Deviation_hist.PET <dbl>, Skewness_hist.PET <dbl>,
## #   Kurtosis_hist.PET <dbl>, Energy_hist.PET <dbl>, Entropy_hist.PET <dbl>,
## #   AUC_hist.PET <dbl>, H_suv.PET <dbl>, Volume.PET <dbl>,
## #   X3D_surface.PET <dbl>, ratio_3ds_vol.PET <dbl>,
## #   ratio_3ds_vol_norm.PET <dbl>, irregularity.PET <dbl>,
## #   tumor_length.PET <dbl>, Compactness_v1.PET <dbl>, ...
```

Data Reprocessing

Checking for null and missing values

We are using *anyNA()* function to determine if there is any missing value in the data.

```
anyNA(Model3Arawdata)
```

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

```
#The output will show either *True* or *False*. There are missing values If True, thus you have to omit

#[1] FALSE

# The result is False, hence, the data has no missing values.
```

Checking the Normality of the Data We are using *Shapiro-Wilk's Test* to check the normality of the data.

```
Model3Anumrawdata <- Model3Arawdata%>%select_if(is.numeric)

Model3Anumrawdata <- Model3Anumrawdata[ , -1]

Model3ASWtest <- apply(Model3Anumrawdata, 2, function(x){shapiro.test(x)})
```

Next we need to list only the p-value of the respective variables to proceed with the test. We are using the *unlist()* and *lapply()* functions to achieve this goal.

```
Model3ADRpvalue <- unlist(lapply(Model3ASWtest, function(x) x$p.value))
```

```
sum(Model3ADRpvalue<0.05)  # not normally distributed
```

```
## [1] 428
```

```
sum(Model3ADRpvalue>0.05)  # normally distributed
```

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

```
Model3ASWtest$Entropy_cooc.W.ADC
```

```
##
##  Shapiro-Wilk normality test
##
## data:  x
## W = 0.98903, p-value = 0.135
```

```
# [1] 428
# [1] 1

#  Currently, there are 428 variables that are not normally distributed and only the Entropy_cooc.W.ADC
```

The goal is that all variables should be normally distributed. Next, we are using *orderNorm()* function. And we need to exclude the *Entropy_cooc.W.ADC* since it is already normally distributed.

```
Model3ADRtransrawdata <- Model3Arawdata[,c(3,5:length(names(Model3Arawdata)))]

Model3ADRtransrawdata <- apply(Model3ADRtransrawdata,2,orderNorm)

Model3ADRtransrawdata <- lapply(Model3ADRtransrawdata, function(x) x$x.t)

Model3ADRtransrawdata <- Model3ADRtransrawdata%>%as.data.frame()

Model3ASWtest <- apply(Model3ADRtransrawdata,2,shapiro.test)

Model3ASWtest <- unlist(lapply(Model3ASWtest, function(x) x$p.value))
```

Next, we will be testing the data to check the normality or the transformed data.

```
sum(Model3ASWtest <0.05)  # for not normally distributed
```

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

```
sum(Model3ASWtest >0.05)  # for normally distributed
```

```
## [1] 428
```

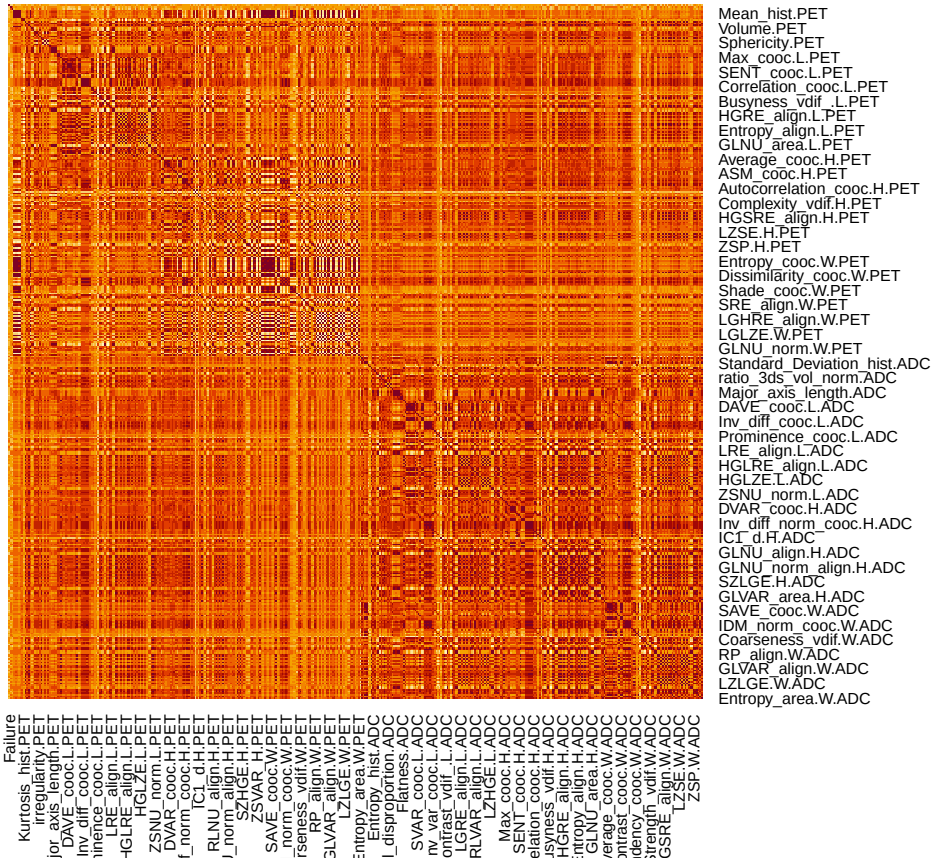
```
#[1] 0
#[1] 428

# Now, the 428 variables that were initially not normally distributed are now normally distributed.
```

```
Model3Arawdata[,c(3,5:length(names(Model3Arawdata)))]=Model3ADRtransrawdata
```

We are getting the correlation of the whole data except the categorical variables

```
Model3ACorrMat = cor(Model3Arawdata[,-c(1,2)])
heatmap(Model3ACorrMat,Rowv=NA,Colv=NA,scale="none",revC = T)
```



Finally, we will convert the data frame output of data reprocessing into "csv" file, which will we use for the entire Final Project.

```
library(data.table)
```

```
##
## Attaching package: 'data.table'
```

```
## The following object is masked from 'package:purrr':
##
##     transpose
```

```
## The following objects are masked from 'package:dplyr':
##
##     between, first, last
```

```
fwrite(Model3Arawdata, "Model3_Final_Project_Data.csv")
```

Lastly, let's check if the dataframe we have exported to CSV is really the normal data.

```
Model3Arawdata1 <- read_csv("Model3_Final_Project_Data.csv")
```

```
## Rows: 197 Columns: 431
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## chr   (1): Institution
## dbl (430): Failure.binary, Failure, Entropy_cooc.W.ADC, GLNU_align.H.PET, Mi...
##
## i Use `spec()` to retrieve the full column specification for this data.
```

```
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
Model3Arawdata1
```

```
## # A tibble: 197 x 431
##    Institution Failure~1 Failure Entro~2 GLNU_~3 Min_h~4 Max_h~5 Mean_~6 Varia~7
##    <chr>           <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>
##  1 A                   0   1.15     12.9  -0.433  -0.270 -0.257   -0.192  0.0509
##  2 A                   1  -0.533    12.2  -1.02    0.671  0.405    0.490  0.687
##  3 A                   0   2.24     12.8   0.179  -1.41  -1.57    -1.53  -1.57
##  4 A                   1  -0.140    13.5   2.00   -0.218  0.0764  -0.153  0.0127
##  5 A                   0   0.787    12.6   0.153  -1.06  -1.15    -1.45  -1.91
##  6 A                   1  -2.80     13.2   0.391  -1.57  -1.91    -1.72  -1.84
##  7 A                   0   0.218    12.2  -0.687   0.284  0.519    0.405  0.915
##  8 A                   0   0.623    12.3  -0.405  -0.461 -0.719   -0.639 -0.623
##  9 A                   1   0.578    13.4  -1.04   -0.391 -0.593   -0.378 -0.244
## 10 A                   1  -0.160    12.6  -1.38   -0.475 -0.310   -0.475 -0.0127
## # ... with 187 more rows, 422 more variables:
## #   Standard_Deviation_hist.PET <dbl>, Skewness_hist.PET <dbl>,
## #   Kurtosis_hist.PET <dbl>, Energy_hist.PET <dbl>, Entropy_hist.PET <dbl>,
## #   AUC_hist.PET <dbl>, H_suv.PET <dbl>, Volume.PET <dbl>,
## #   X3D_surface.PET <dbl>, ratio_3ds_vol.PET <dbl>,
## #   ratio_3ds_vol_norm.PET <dbl>, irregularity.PET <dbl>,
## #   tumor_length.PET <dbl>, Compactness_v1.PET <dbl>, ...
```

```
Model3Anumrawdata1 <- Model3Arawdata1%>%select_if(is.numeric)

Model3Anumrawdata1 <- Model3Anumrawdata1[ , -1]

Model3ASWtest1 <- apply(Model3Anumrawdata1, 2, function(y){shapiro.test(y)})

Model3ADRpvalue1 <- unlist(lapply(Model3ASWtest1, function(y) y$p.value))

sum(Model3ADRpvalue1<0.05)  # not normally distributed
```

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

```
sum(Model3ADRpvalue1>0.05)  # normally distributed
```

```
## [1] 429
```

```
#Yes! We were able to produce the correct CSV file and we are now ready to use it for the entire projec
```

MODEL 3

```
# Load the dataset
model3data <- read_csv("Model3_Final_Project_Data.csv")
```

```
## Rows: 197 Columns: 431
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## chr   (1): Institution
## dbl (430): Failure.binary, Failure, Entropy_cooc.W.ADC, GLNU_align.H.PET, Mi...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
model3data
```

```
## # A tibble: 197 x 431
##    Institution Failure~1 Failure Entro~2 GLNU_~3 Min_h~4 Max_h~5 Mean_~6 Varia~7
##    <chr>           <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>
##  1 A                   0   1.15     12.9  -0.433  -0.270 -0.257   -0.192  0.0509
##  2 A                   1  -0.533    12.2  -1.02    0.671  0.405    0.490  0.687
##  3 A                   0   2.24     12.8   0.179  -1.41  -1.57    -1.53  -1.57
##  4 A                   1  -0.140    13.5   2.00   -0.218  0.0764  -0.153  0.0127
##  5 A                   0   0.787    12.6   0.153  -1.06  -1.15    -1.45  -1.91
##  6 A                   1  -2.80     13.2   0.391  -1.57  -1.91    -1.72  -1.84
##  7 A                   0   0.218    12.2  -0.687   0.284  0.519    0.405  0.915
##  8 A                   0   0.623    12.3  -0.405  -0.461 -0.719   -0.639 -0.623
##  9 A                   1   0.578    13.4  -1.04   -0.391 -0.593   -0.378 -0.244
## 10 A                   1  -0.160    12.6  -1.38   -0.475 -0.310   -0.475 -0.0127
## # ... with 187 more rows, 422 more variables:
## #   Standard_Deviation_hist.PET <dbl>, Skewness_hist.PET <dbl>,
## #   Kurtosis_hist.PET <dbl>, Energy_hist.PET <dbl>, Entropy_hist.PET <dbl>,
## #   AUC_hist.PET <dbl>, H_suv.PET <dbl>, Volume.PET <dbl>,
## #   X3D_surface.PET <dbl>, ratio_3ds_vol.PET <dbl>,
## #   ratio_3ds_vol_norm.PET <dbl>, irregularity.PET <dbl>,
## #   tumor_length.PET <dbl>, Compactness_v1.PET <dbl>, ...
```

Scaling/Standardizing the Data

```
model3fdata <- scale(model3data[c(3:431)])
head(model3fdata)
```

```
##         Failure Entropy_cooc.W.ADC GLNU_align.H.PET Min_hist.PET Max_hist.PET
## [1,]  1.1542812         0.55290547       -0.4333655   -0.2706594  -0.25747509
## [2,] -0.5335831        -0.06486729       -1.0166957    0.6709820   0.40556015
## [3,]  2.2372022         0.45990825        0.1792170   -1.4150181  -1.56968040
## [4,] -0.1405364         1.14318298        1.9997211   -0.2181792   0.07647307
## [5,]  0.7872480         0.34499368        0.1533960   -1.0603294  -1.15426355
## [6,] -2.8042412         0.84917904        0.3917753   -1.5696804  -1.91367122
##      Mean_hist.PET Variance_hist.PET Standard_Deviation_hist.PET
## [1,]    -0.1921714        0.05095448                 -0.06370859
## [2,]     0.4900236        0.68701098                  0.50442967
## [3,]    -1.5275205       -1.56968040                 -1.48790984
## [4,]    -0.1533960        0.01273346                 -0.08924999
## [5,]    -1.4505021       -1.91367122                 -1.91367122
## [6,]    -1.7165060       -1.83980971                 -1.83980971
##      Skewness_hist.PET Kurtosis_hist.PET Energy_hist.PET Entropy_hist.PET
## [1,]        -0.1533960        -0.3105060     -0.19217136       -0.1533960
## [2,]         0.1405248        -0.2443353     -0.08924999       -0.7700043
## [3,]        -1.3180073        -1.4505021     -0.20515797       -0.1405248
## [4,]         0.1792170         0.8586682     -0.46150957        0.2181792
## [5,]         1.1298434         1.4879098      0.01273346       -0.9546481
## [6,]        -0.2838909         0.1020415     -0.17921704        0.2312375
##      AUC_hist.PET   H_suv.PET Volume.PET X3D_surface.PET ratio_3ds_vol.PET
## [1,]   -0.5189411  0.05095448 -0.8586682      -0.8404111        -0.2443353
## [2,]   -0.3508513  1.03826584 -1.4150181      -0.5631547         0.6394275
## [3,]   -0.7032182 -1.28828023 -0.2181792       0.2838909        -0.2706594
```

```
## [4,]    0.5932479 -0.25747509  0.4194224       0.9749140        -0.8224296
## [5,]    0.5781359 -1.61482620 -0.1405248      -0.6394275         0.6238874
## [6,]   -0.3780645 -1.41501808 -0.7872387      -0.4055602         0.1533960
##      ratio_3ds_vol_norm.PET irregularity.PET tumor_length.PET
## [1,]            -0.57813595       0.32389526      -0.33734333
## [2,]             0.39177534       0.49002356      -0.51894198
## [3,]             0.14052475      -0.02546898      -0.01273363
## [4,]             0.27065942      -1.34894519       0.68701181
## [5,]             0.37806448       0.33734270      -0.75299666
## [6,]             0.01273346       0.05095448      -0.21817968
##      Compactness_v1.PET Compactness_v2.PET Spherical_disproportion.PET
## [1,]         -0.3038327         -0.4972144                 -0.57813595
## [2,]         -0.6709825         -0.9152478                  0.39177534
## [3,]         -0.5482991         -0.7700052                  0.14052475
## [4,]         -0.5932484         -0.8224305                  0.27065942
## [5,]         -0.6551238         -0.8960704                  0.37806448
## [6,]         -0.5044301         -0.7196129                  0.01273346
##      Sphericity.PET Asphericity.PET Center_of_mass.PET Max_3D_diam.PET
## [1,]     -0.1921714     -0.57813595         0.36442422      -0.6238874
## [2,]     -0.8404111      0.39177534        -0.03820863      -0.7700043
## [3,]     -0.6551233      0.14052475        -0.75299544      -0.2838909
## [4,]     -0.7196121      0.27065942         0.47571828       0.3105060
## [5,]     -0.8224296      0.37806448        -0.19217136      -0.8224296
## [6,]     -0.5781359      0.01273346        -1.06032943      -0.5044297
##      Major_axis_length.PET Minor_axis_length.PET Least_axis_length.PET
## [1,]            -0.8404111            -0.8047097            -0.3780645
## [2,]            -0.7872387            -0.6394275            -0.7529954
## [3,]            -0.2574751            -0.4900236            -0.2971722
## [4,]             0.2971722             0.7872387             0.9546481
## [5,]            -0.7700043            -1.1298434            -0.7362013
## [6,]            -0.4757183            -0.4473933            -1.3489452
##      Elongation.PET Flatness.PET Max_cooc.L.PET Average_cooc.L.PET
## [1,]    -0.23123752    0.3238953    -0.35085134        -0.10204149
## [2,]    -0.07647307   -0.1662927     0.03820863        -0.29717220
## [3,]    -0.82242955   -0.3917753    -0.32389526         0.47571828
## [4,]     0.27065942    0.7196121    -0.15339601        -1.17939112
## [5,]    -0.67098197   -0.2574751    -0.02546898        -1.31800728
## [6,]    -0.29717220   -1.3180073    -0.27065942        -0.05095448
##      Variance_cooc.L.PET Entropy_cooc.L.PET DAVE_cooc.L.PET DVAR_cooc.L.PET
## [1,]          0.06370859          0.1020415     -0.11484968      -0.2971722
## [2,]          0.33734270         -0.7529954      0.46150957       0.6394275
## [3,]          0.11484968          0.3780645     -0.05095448      -0.2838909
## [4,]         -1.83980971         -0.7700043     -1.34894519      -1.5275205
## [5,]         -0.62388738         -1.2052851     -0.49002356      -0.3508513
## [6,]         -0.20515797          0.1148497     -0.14052475      -0.2706594
##      DENT_cooc.L.PET SAVE_cooc.L.PET SVAR_cooc.L.PET SENT_cooc.L.PET
## [1,]      -0.1662927     -0.10204149       0.2181792      0.23123752
## [2,]       0.4055602     -0.29717220       0.1662927      0.05095448
## [3,]      -0.1405248      0.47571828       0.2706594      0.46150957
## [4,]      -1.3489452     -1.17939112      -1.3489452     -0.82242955
## [5,]      -0.5044297     -1.31800728      -0.8224296     -0.89606941
## [6,]      -0.2051580     -0.06370859      -0.1792170     -0.06370859
##      ASM_cooc.L.PET Contrast_cooc.L.PET Dissimilarity_cooc.L.PET
## [1,]  -2.838909e-01         -0.03820863              -0.11484968
```

```
## [2,]  -1.020415e-01          0.63942746              0.46150957
## [3,]  -3.780645e-01         -0.02546898             -0.05095448
## [4,]  -7.647307e-02         -1.28828023             -1.34894519
## [5,]  -5.421149e-17         -0.35085134             -0.49002356
## [6,]  -3.508513e-01         -0.07647307             -0.14052475
##      Inv_diff_cooc.L.PET Inv_diff_norm_cooc.L.PET IDM_cooc.L.PET
## [1,]         -0.37806448              -0.33734270    -0.44739330
## [2,]         -0.62388738              -0.75299544    -0.59324787
## [3,]         -0.65512329              -0.44739330    -0.70321822
## [4,]          0.40556015               0.40556015     0.41942235
## [5,]          0.05095448               0.02546898     0.06370859
## [6,]         -0.36442422              -0.28389090    -0.39177534
##      IDM_norm_cooc.L.PET Inv_var_cooc.L.PET Correlation_cooc.L.PET
## [1,]         -0.32389526         -0.4194224             0.02546898
## [2,]         -0.78723867         -0.5482987            -1.08292088
## [3,]         -0.37806448         -0.6394275             0.06370859
## [4,]          0.36442422          0.4757183             0.39177534
## [5,]          0.05095448          0.1148497            -0.54829867
## [6,]         -0.24433531         -0.3780645            -0.24433531
##      Autocorrelation_cooc.L.PET Tendency_cooc.L.PET Shade_cooc.L.PET
## [1,]              -1.273346e-02           0.2181792       0.35085134
## [2,]              -1.405248e-01           0.1662927      -0.05095448
## [3,]               7.529954e-01           0.2706594      -1.45050212
## [4,]              -1.179391e+00          -1.3489452      -0.21817922
## [5,]              -1.415018e+00          -0.8224296       0.75299544
## [6,]              -5.421149e-17          -0.1792170      -0.08924999
##      Prominence_cooc.L.PET IC1_.L.PET  IC2_.L.PET Coarseness_vdif_.L.PET
## [1,]            0.29717220  0.1148497 -0.03820863          -1.276768e-01
## [2,]            0.11484968 -0.1276767  0.07647307          -1.405249e-01
## [3,]            0.10204149  0.3373427 -0.24433531          -6.370871e-02
## [4,]           -1.15426355  0.9546481 -0.77000435          -5.335627e-01
## [5,]           -0.08924999  0.3780645 -0.36442422          -9.599724e-08
## [6,]           -0.14052475  0.3105060 -0.23123752          -7.647318e-02
##      Contrast_vdif_.L.PET Busyness_vdif_.L.PET Complexity_vdif_.L.PET
## [1,]           0.10204149           -0.4900236            -0.03820863
## [2,]           0.70321822           -0.5631547             0.56315472
## [3,]           0.07647307           -0.8772156            -0.35085134
## [4,]          -1.52752054            0.8960694            -0.99558794
## [5,]          -0.11484968           -0.5482987            -0.08924999
## [6,]          -0.08924999           -0.6394275            -0.36442422
##      Strength_vdif_.L.PET SRE_align.L.PET LRE_align.L.PET GLNU_align.L.PET
## [1,]           0.23123752   -1.533960e-01      -0.3780645       -0.5044297
## [2,]           0.37806448    6.370859e-02      -0.6709820       -0.6084963
## [3,]           0.05095448   -5.421149e-17      -0.6870110       -0.5482987
## [4,]          -1.10607816   -6.238874e-01       0.3917753        1.1542636
## [5,]           0.80470972   -1.792170e-01      -0.4333655       -0.4615096
## [6,]           0.11484968   -2.312375e-01      -0.3644242       -0.5189411
##      RLNU_align.L.PET RP_align.L.PET LGRE_align.L.PET HGRE_align.L.PET
## [1,]       -0.4473933    -0.12767671       0.05095448      -0.03820863
## [2,]       -0.7529954     0.03820863       0.10204149      -0.10204149
## [3,]       -0.3917753     0.02546898      -0.54829867       0.56315472
## [4,]        1.2596485    -0.65512329      -0.35085134      -1.12984341
## [5,]       -0.7700043    -0.11484968       0.51894110      -1.38122903
## [6,]       -0.3780645    -0.17921704      -0.33734270       0.08924999
```

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##      LGSRE_align.L.PET HGSRE_align.L.PET LGHRE_align.L.PET HGLRE_align.L.PET
## [1,]        0.06370859       -0.01273346        0.03820863       -0.07647307
## [2,]        0.10204149       -0.10204149        0.19217136       -0.23123752
## [3,]       -0.54829867        0.56315472       -0.60849632        0.57813595
## [4,]       -0.35085134       -1.12984341       -0.28389090       -1.10607816
## [5,]        0.54829867       -1.31800728        0.50442967       -1.41501808
## [6,]       -0.32389526        0.08924999       -0.35085134        0.01273346
##      GLNU_norm_align.L.PET RLNU_norm_align.L.PET GLVAR_align.L.PET
## [1,]         -2.838909e-01            -0.1148497        0.06370859
## [2,]         -5.421149e-17             0.2051580        0.31050605
## [3,]         -4.900236e-01             0.1533960        0.40556015
## [4,]         -1.020415e-01            -0.7362013       -1.45050212
## [5,]          2.443353e-01            -0.1405248       -0.91524677
## [6,]         -3.508513e-01            -0.1921714       -0.11484968
##      RLVAR_align.L.PET Entropy_align.L.PET SZSE.L.PET LZSE.L.PET LGLZE.L.PET
## [1,]        -0.3238953          0.01273346 -0.5189411  0.1921714  0.02546898
## [2,]        -0.5482987         -0.87721561  0.2574751 -0.7032182  0.10204149
## [3,]        -0.5781359          0.27065942  0.5335625 -2.2371600 -0.49002356
## [4,]         0.4900236         -0.49002356 -0.9152468  0.4473933 -0.36442422
## [5,]        -0.4055602         -1.52752054  0.3508513 -1.5696804  0.54829867
## [6,]        -0.3373427          0.12767671 -0.2971722 -0.1405248 -0.37806448
##      HGLZE.L.PET SZLGE.L.PET SZHGE.L.PET LZLGE.L.PET LZHGE.L.PET
## [1,] -0.01273346 -0.02546898 -0.08924999  0.16629268   0.1148497
## [2,] -0.12767671  0.10204149 -0.10204149  0.12767671  -0.5044297
## [3,]  0.54829867 -0.40556015  0.59324787 -0.75299544   0.2574751
## [4,] -1.12984341 -0.36442422 -1.06032943 -0.03820863  -0.8224296
## [5,] -1.38122903  0.62388738 -1.23201233  0.27065942  -1.7747932
## [6,]  0.08924999 -0.39177534  0.02546898 -0.20515797   0.1405248
##      GLNU_area.L.PET ZSNU.L.PET  ZSP.L.PET GLNU_norm.L.PET ZSNU_norm.L.PET
## [1,]      -0.5189411 -0.5189411 -0.5044297     -0.29717220      -0.6084963
## [2,]      -0.6551233 -0.7872387  0.2051580     -0.01273346       0.3238953
## [3,]      -0.5335625 -0.3508513  0.5932479     -0.50442967       0.6084963
## [4,]       1.1542636  1.2052851 -1.0382658     -0.07647307      -1.1298434
## [5,]      -0.4333655 -0.7529954  0.4194224      0.25747509       0.4615096
## [6,]      -0.5044297 -0.4473933 -0.2706594     -0.35085134      -0.3238953
##      GLVAR_area.L.PET ZSVAR.L.PET Entropy_area.L.PET Max_cooc.H.PET
## [1,]       0.06370859   0.2312375         0.16629268     -0.6238874
## [2,]       0.27065942  -0.2312375        -0.93476628     -0.3373427
## [3,]       0.40556015  -1.6148262        -0.32389526      0.8404111
## [4,]      -1.45050212   0.9152468         0.23123752     -0.3780645
## [5,]      -0.91524677  -1.3180073        -1.71650601      1.9997211
## [6,]      -0.24433531  -0.1921714        -0.05095448      1.2596485
##      Average_cooc.H.PET Variance_cooc.H.PET Entropy_cooc.H.PET DAVE_cooc.H.PET
## [1,]         -0.2971722       -4.333655e-01        -0.47571828      -0.3105060
## [2,]         -0.4900236       -3.917753e-01         0.08924999       0.2838909
## [3,]          0.3373427       -6.709820e-01        -1.45050212      -0.7700043
## [4,]         -0.8772156       -5.421149e-17        -0.50442967      -0.4473933
## [5,]          0.6394275       -2.428639e+00        -1.99972110      -2.1037376
## [6,]          0.4194224       -1.205285e+00        -1.91367122      -1.2596485
##      DVAR_cooc.H.PET DENT_cooc.H.PET SAVE_cooc.H.PET SVAR_cooc.H.PET
## [1,]      -0.4900236      0.28389090     -0.05095448       0.1148497
## [2,]      -0.1020415     -0.95464809     -1.15426355      -0.5482987
## [3,]      -0.1792170      0.16629268      0.49002356       0.4757183
## [4,]      -0.5189411      0.03820863     -0.73620133       0.3238953
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## [5,]      -2.4286392     -0.08924999      0.65512329       0.1020415
## [6,]      -0.3780645     -1.77479325      0.56315472      -1.2596485
##      SENT_cooc.H.PET ASM_cooc.H.PET Contrast_cooc.H.PET
## [1,]       0.2574751     -0.4900236          -0.2838909
## [2,]       0.5044297     -0.6551233           0.2838909
## [3,]      -0.6394275      0.9152468          -0.5631547
## [4,]       0.1662927     -0.4333655          -0.5335625
## [5,]      -1.0603294      2.1037376          -2.4286392
## [6,]      -0.9347663      1.3489452          -0.9749140
##      Dissimilarity_cooc.H.PET Inv_diff_cooc.H.PET Inv_diff_norm_cooc.H.PET
## [1,]               -0.3105060          -0.4757183              -0.28389090
## [2,]                0.2838909          -1.0166957              -0.63942746
## [3,]               -0.7700043           0.5335625               0.10204149
## [4,]               -0.4473933          -0.2574751              -0.08924999
## [5,]               -2.1037376           1.0382658               0.62388738
## [6,]               -1.2596485           0.9347663               0.40556015
##      IDM_cooc.H.PET IDM_norm_cooc.H.PET Inv_var_cooc_.H.PET
## [1,]     -0.4900236         -0.23123752           0.1792170
## [2,]     -1.0603294         -0.60849632           0.2706594
## [3,]      0.7700043         -0.10204149          -0.5781359
## [4,]     -0.2574751         -0.06370859           0.2838909
## [5,]      1.1793911          0.60849632          -0.2838909
## [6,]      1.0166957          0.16629268          -0.6238874
##      Correlation_cooc.H.PET Autocorrelation_cooc.H.PET Tendency_cooc.H.PET
## [1,]             0.01273346                -0.3508513          -0.2574751
## [2,]            -0.84041109                -0.5932479          -0.4473933
## [3,]            -0.12767671                 0.3508513          -0.6870110
## [4,]             0.40556015                -0.7032182           0.2971722
## [5,]            -0.99558794                 0.6394275          -2.4286392
## [6,]            -0.54829867                 0.4333655          -1.1298434
##      Shade_cooc.H.PET Prominence_cooc.H.PET IC1_d.H.PET IC2_d.H.PET
## [1,]       0.56315472            -0.2706594  0.36442422 -0.08924999
## [2,]      -0.03820863            -0.3917753  0.89606941 -0.73620133
## [3,]      -0.24433531            -0.6709820 -0.19217136 -0.31050605
## [4,]      -0.59324787             0.5044297 -0.27065942  0.33734270
## [5,]       1.83980971            -2.4286392  0.32389526 -1.23201233
## [6,]       0.53356248            -1.2882802 -0.03820863 -0.75299544
##      Coarseness_vdif.H.PET Contrast_vdif.H.PET Busyness_vdif.H.PET
## [1,]           -0.11484971          -0.3780645          -0.6084963
## [2,]           -0.03820861          -0.9749140          -0.8960694
## [3,]           -0.29717235           1.2320123          -0.2706594
## [4,]           -0.49002384          -0.5781359           0.6709820
## [5,]           -0.19217145          -0.8772156          -0.6870110
## [6,]           -0.36442443           1.4879098          -0.1020415
##      Complexity_vdif.H.PET Strength_vdif.H.PET SRE_align.H.PET LRE_align.H.PET
## [1,]         -5.421149e-17           0.1533960      0.03820863      -0.5335625
## [2,]          2.971722e-01           0.4473933      0.49002356      -1.4505021
## [3,]         -1.276767e-01           0.3238953     -1.20528514       0.6238874
## [4,]         -2.443353e-01          -0.8224296     -0.35085134      -0.1020415
## [5,]         -8.224296e-01           1.0166957     -1.56968040       0.8047097
## [6,]         -2.706594e-01           0.3105060     -1.71650601       1.1542636
##      RLNU_align.H.PET RP_align.H.PET LGRE_align.H.PET HGRE_align.H.PET
## [1,]       -0.3238953     0.01273346      -0.24433531       -0.4757183
## [2,]       -0.5044297     0.49002356      -0.21817922       -0.7872387
```

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## [3,]       -0.7032182    -1.34894519      -0.32389526        0.1276767
## [4,]        0.9347663    -0.44739330      -0.02546898       -0.4194224
## [5,]       -1.0603294    -1.61482620      -0.49002356        0.6394275
## [6,]       -0.8960694    -1.83980971      -0.43336550        0.5482987
##      LGSRE_align.H.PET HGSRE_align.H.PET LGHRE_align.H.PET HGLRE_align.H.PET
## [1,]       -0.21817922       -0.32389526       -0.23123748        -0.5932479
## [2,]       -0.19217136       -0.05095448       -0.28389089        -1.7747932
## [3,]       -0.33734270       -1.41501808       -0.33734273         0.9955879
## [4,]       -0.06370859       -0.67098197        0.03820884        -0.1921714
## [5,]       -0.49002356        0.63942746       -0.44739340         1.2596485
## [6,]       -0.46150957        0.10204149       -0.32389528         1.3812290
##      GLNU_norm_align.H.PET RLNU_norm_align.H.PET GLVAR_align.H.PET
## [1,]            -0.3917753         -5.421149e-17        -0.4194224
## [2,]            -0.6394275          5.335625e-01        -0.5335625
## [3,]             0.7362013         -1.318007e+00        -0.7032182
## [4,]            -0.4900236         -4.473933e-01         0.1405248
## [5,]             1.4505021         -1.569680e+00        -2.4286392
## [6,]             1.1060782         -1.839810e+00        -1.2052851
##      RLVAR_align.H.PET Entropy_align.H.PET SZSE.H.PET LZSE.H.PET LGLZE.H.PET
## [1,]        -0.4900236          -0.2706594 -0.2706594 -0.1405248 -0.23123752
## [2,]        -1.2596485          -0.1020415  0.7196121 -2.8041692 -0.21817922
## [3,]         1.0603294          -1.1298434 -0.9955879  0.9152468 -0.32389526
## [4,]         0.1020415           0.1662927 -0.4900236  0.8224296 -0.07647307
## [5,]         1.1793911          -1.7165060 -1.2052851  1.1298434 -0.49002356
## [6,]         1.4505021          -1.1542636 -1.2320123  1.4879098 -0.40556015
##        HGLZE.H.PET SZLGE.H.PET SZHGE.H.PET LZLGE.H.PET LZHGE.H.PET
## [1,]  1.276767e-01  -0.2181792 -0.02546898 -0.37806448  -0.2838909
## [2,] -6.551233e-01  -0.1662927  0.36442422 -0.70321822  -1.9997211
## [3,] -5.421149e-17  -0.3373427 -1.31800728  0.01273346   0.9347663
## [4,]  5.932479e-01  -0.1276767 -0.62388738  0.70321822   0.5932479
## [5,]  6.870110e-01  -0.4900236  0.46150957  0.54829867   1.0166957
## [6,]  3.917753e-01  -0.4333655 -0.95464809  1.17939112   1.4150181
##      GLNU_area.H.PET  ZSNU.H.PET  ZSP.H.PET GLNU_norm.H.PET ZSNU_norm.H.PET
## [1,]      -0.4615096 -0.32389526 -0.1662927      -0.3917753      -0.2181792
## [2,]      -0.5932479 -0.01273346  0.8960694      -0.6551233       0.8586682
## [3,]      -0.2312375 -0.82242955 -0.9749140       0.8960694      -1.0603294
## [4,]       1.1298434  0.77000435 -0.6084963      -0.4615096      -0.4757183
## [5,]      -0.6084963 -1.17939112 -1.1298434       0.9955879      -1.2320123
## [6,]      -0.4757183 -1.12984341 -1.2882802       1.0382658      -1.3812290
##      GLVAR_area.H.PET ZSVAR_H.PET Entropy_area.H.PET Max_cooc.W.PET
## [1,]       -0.4333655  -0.2181792         -0.2838909     -0.4757183
## [2,]       -0.4900236  -1.8398097         -0.8224296     -0.3780645
## [3,]       -0.8224296   0.8224296         -0.9546481      0.4473933
## [4,]        0.1792170   0.7529954          0.6084963     -0.4333655
## [5,]       -2.4286392   0.9749140         -1.1060782      1.5275205
## [6,]       -0.9546481   1.3489452         -1.0382658      0.9152468
##      Average_cooc.W.PET Variance_cooc.W.PET Entropy_cooc.W.PET DAVE_cooc.W.PET
## [1,]        -0.11484968          0.02546898         -0.1020415      -0.1020415
## [2,]         0.27065942          0.70321822          0.1662927       0.5631547
## [3,]        -1.15426355         -1.56968040         -1.1793911      -1.4879098
## [4,]        -0.02546898         -0.01273346         -0.1148497      -0.2838909
## [5,]        -2.42863924         -1.83980971         -1.9136712      -1.7165060
## [6,]        -1.83980971         -1.91367122         -1.8398097      -1.7747932
##      DVAR_cooc.W.PET DENT_cooc.W.PET SAVE_cooc.W.PET SVAR_cooc.W.PET
```

```
## [1,]      0.01273346      -0.1921714     -0.11484968      0.05095448
## [2,]      0.78723867       0.2971722      0.27065942      0.67098197
## [3,]     -1.48790984      -1.4150181     -1.15426355     -1.45050212
## [4,]     -0.10204149      -0.3508513     -0.02546898      0.02546898
## [5,]     -1.31800728      -1.6148262     -2.42863924     -1.83980971
## [6,]     -1.77479325      -1.7747932     -1.83980971     -1.91367122
##      SENT_cooc.W.PET ASM_cooc.W.PET Contrast_cooc.W.PET
## [1,]      0.01273346     -0.3508516          0.01273346
## [2,]      0.37806448     -0.4403688          0.80470972
## [3,]     -1.28828023      0.4757183         -1.45050212
## [4,]      0.05095448     -0.3238955         -0.15339601
## [5,]     -1.83980971      1.4505024         -1.56968040
## [6,]     -1.71650601      1.0166959         -1.77479325
##      Dissimilarity_cooc.W.PET Inv_diff_cooc.W.PET Inv_diff_norm_cooc.W.PET
## [1,]               -0.1020415          -0.4757183              -0.28389090
## [2,]                0.5631547          -1.0382658              -0.85866816
## [3,]               -1.4879098           0.4900236              -0.23123752
## [4,]               -0.2838909          -0.2706594               0.37806448
## [5,]               -1.7165060           0.7529954               0.11484968
## [6,]               -1.7747932           0.7032182              -0.07647307
##      IDM_cooc.W.PET IDM_norm_cooc.W.PET Inv_var_cooc.W.PET
## [1,]     -0.4757183         -0.27726923         -0.4333655
## [2,]     -1.0382658         -0.78723892         -0.9749140
## [3,]      0.7196121         -0.20515808          0.7700043
## [4,]     -0.2706594          0.36442425         -0.2181792
## [5,]      0.9749140          0.05095443          0.8047097
## [6,]      0.9546481         -0.03820870          0.9955879
##      Correlation_cooc.W.PET Autocorrelation_cooc.W.PET Tendency_cooc.W.PET
## [1,]             0.02546898                0.05095448          0.05095448
## [2,]            -1.06032943                0.35085134          0.67098197
## [3,]             0.06370859               -1.12984341         -1.45050212
## [4,]             0.37806448                0.11484968          0.02546898
## [5,]            -0.73620133               -2.23715996         -1.83980971
## [6,]            -0.28389090               -1.83980971         -1.91367122
##      Shade_cooc.W.PET Prominence_cooc.W.PET   IC1_d.W.PET IC2_d.W.PET
## [1,]        0.2838909            0.03820863  3.780645e-01 -0.11484968
## [2,]        0.5335625            0.67098197  2.574751e-01  0.02546898
## [3,]       -1.5696804           -1.45050212 -5.421149e-17 -0.41942235
## [4,]        0.3917753            0.23123752 -1.020415e-01  0.17921704
## [5,]       -0.6551233           -1.41501808  6.709820e-01 -1.45050212
## [6,]       -1.2052851           -1.83980971  1.921714e-01 -0.95464809
##      Coarseness_vdif.W.PET Contrast_vdif.W.PET Busyness_vdif.W.PET
## [1,]         -1.533960e-01          0.08924999         -0.43336550
## [2,]         -1.405248e-01          1.06032943         -1.06032943
## [3,]         -5.421149e-17         -1.03826584          0.54829867
## [4,]         -5.482987e-01         -0.80470972          0.07647307
## [5,]          2.546898e-02         -1.41501808          0.80470972
## [6,]         -7.647307e-02         -1.38122903          1.01669574
##      Complexity_vdif.W.PET Strength_vdif.W.PET SRE_align.W.PET LRE_align.W.PET
## [1,]            -0.1020415           0.3917753       0.1148497      -0.5189411
## [2,]             0.5631547           1.0166957       0.4055602      -1.2882802
## [3,]            -1.2320123          -1.4505021      -0.9749140       0.3644242
## [4,]             0.1792170          -0.4194224      -0.2838909      -0.1533960
## [5,]            -1.2052851          -0.6551233      -1.2596485       0.4194224
```

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## [6,]           -1.8398097          -1.6148262      -1.5275205       0.5482987
##      GLNU_align.W.PET RLNU_align.W.PET RP_align.W.PET LGRE_align.W.PET
## [1,]      -0.77000435       -0.3238953     0.07647307       -0.1405248
## [2,]      -1.23201233       -0.6394275     0.41942235       -0.2971722
## [3,]      -0.11484968       -0.5932479    -1.12984341        0.5482987
## [4,]       1.08292088        1.2052851    -0.32389526       -0.7529954
## [5,]      -0.03820863       -0.9749140    -1.34894519        1.3812290
## [6,]       0.10204149       -0.6551233    -1.56968040        0.8960694
##      HGRE_align.W.PET LGSRE_align.W.PET HGSRE_align.W.PET LGHRE_align.W.PET
## [1,]    -5.421149e-17        -0.1276767     -5.421149e-17        -0.1405248
## [2,]     3.780645e-01        -0.2971722      3.780645e-01        -0.3644242
## [3,]    -1.232012e+00         0.4900236     -1.205285e+00         0.6238874
## [4,]     1.662927e-01        -0.7529954      1.148497e-01        -0.6709820
## [5,]    -2.428639e+00         1.2596485     -1.913671e+00         1.6148262
## [6,]    -1.839810e+00         0.8586682     -1.839810e+00         1.0829209
##      HGLRE_align.W.PET GLNU_norm_align.W.PET RLNU_norm_align.W.PET
## [1,]        -0.1276767            -0.3780645            0.05095448
## [2,]         0.3238953            -0.6084963            0.49002356
## [3,]        -1.0603294             0.5932479           -1.15426355
## [4,]         0.1792170            -0.5044297           -0.37806448
## [5,]        -2.4286392             1.4879098           -1.52752054
## [6,]        -1.8398097             1.1060782           -1.66352051
##      GLVAR_align.W.PET RLVAR_align.W.PET Entropy_align.W.PET SZSE.W.PET
## [1,]        0.03820863       -0.43336555         -0.24433531 -0.1020415
## [2,]        0.68701098       -0.99558812         -0.03820863  0.6084963
## [3,]       -1.56968040        0.93476655         -1.12984341 -0.9347663
## [4,]        0.02546898       -0.02546894          0.06370859 -0.4900236
## [5,]       -1.91367122        0.99558823         -2.23715996 -1.2052851
## [6,]       -1.83980971        1.25964883         -1.25964848 -1.3180073
##      LZSE.W.PET LGLZE.W.PET   HGLZE.W.PET SZLGE.W.PET SZHGE.W.PET LZLGE.W.PET
## [1,] -0.4473933  -0.2443353 -5.421149e-17  -0.2574751  0.01273346 -0.01273346
## [2,] -1.4879098  -0.3373427  3.917753e-01  -0.2051580  0.46150957 -0.53356248
## [3,]  0.6709820   0.7700043 -1.232012e+00   0.8047097 -1.31800728  0.54829867
## [4,]  0.2051580  -0.7032182  1.148497e-01  -0.7872387  0.11484968 -0.27065942
## [5,]  0.7700043   1.3489452 -1.913671e+00   1.2052851 -1.83980971  1.20528514
## [6,]  1.2882802   0.9152468 -1.839810e+00   0.9546481 -1.91367122  1.61482620
##      LZHGE.W.PET GLNU_area.W.PET ZSNU.W.PET  ZSP.W.PET GLNU_norm.W.PET
## [1,]  -0.4194224      -0.5781359 -0.2312375 -0.2181792      -0.4055602
## [2,]  -0.2181792      -1.0382658 -0.3238953  0.5932479      -0.5932479
## [3,]  -0.6394275      -0.1148497 -0.6870110 -1.0382658       0.7362013
## [4,]   0.4333655       1.1060782  0.8960694 -0.5932479      -0.5189411
## [5,]  -2.1037376      -0.2574751 -1.1793911 -1.1542636       1.3489452
## [6,]  -0.8960694      -0.1533960 -0.9749140 -1.4879098       1.1793911
##      ZSNU_norm.W.PET GLVAR_area.W.PET ZSVAR.W.PET Entropy_area.W.PET
## [1,]      -0.2051580       0.03820863  -0.3373427         -0.3508513
## [2,]       0.6870110       0.62388738  -1.0166957         -0.4473933
## [3,]      -0.9749140      -1.28828023   0.8224296         -1.1542636
## [4,]      -0.5335625       0.06370859   0.4055602          0.3780645
## [5,]      -1.3180073      -1.77479325   0.8047097         -1.5696804
## [6,]      -1.4505021      -1.83980971   1.2882802         -1.0166957
##      Min_hist.ADC Max_hist.ADC Mean_hist.ADC Variance_hist.ADC
## [1,]    0.4475228  -0.31070344   -0.05095448         0.4333655
## [2,]   -1.1111899  -0.42661942   -0.31050605        -0.2181792
## [3,]    0.6402049   0.50450261    0.06370859         1.1060782
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## [4,]   -1.1111899   0.51901885   -0.11484968         0.7032182
## [5,]   -1.1111899  -0.06382412   -1.01669574         0.3644242
## [6,]   -1.1111899   0.08918521    0.46150957         1.7747932
##      Standard_Deviation_hist.ADC Skewness_hist.ADC Kurtosis_hist.ADC
## [1,]                   0.2443353         0.9546481        -0.2181792
## [2,]                  -0.3917753        -1.5696804         0.7362013
## [3,]                   0.7362013         1.4150181         1.2320123
## [4,]                   0.4333655        -0.4333655        -0.4757183
## [5,]                   0.1533960        -0.3105060        -0.1792170
## [6,]                   1.1542636        -1.0829209        -2.8041692
##      Energy_hist.ADC Entropy_hist.ADC AUC_hist.ADC Volume.ADC X3D_surface.ADC
## [1,]      0.15339594      -1.61482620   -0.2181796 -0.8404111      -1.3180073
## [2,]     -0.07647335      -0.82242955   -0.9546489 -1.2320123      -0.9546481
## [3,]     -0.25090024      -0.01273346    0.3780644 -0.2706594      -0.4757183
## [4,]     -0.41942296       0.41942235   -0.2443357  0.3917753       0.2574751
## [5,]     -0.18569070      -0.20515797   -0.5482992 -0.2181792      -0.4615096
## [6,]     -0.28389138      -0.02546898   -1.0166966 -0.7362013      -0.3373427
##      ratio_3ds_vol.ADC ratio_3ds_vol_norm.ADC irregularity.ADC
## [1,]         0.7700047            -0.02546898       0.43336550
## [2,]         0.1533962            -1.10607816      -0.03820863
## [3,]        -0.4757183            -1.52752054      -1.34894519
## [4,]        -0.5044297             0.29717220      -0.84041109
## [5,]        -0.3780645            -1.15426355      -0.99558794
## [6,]         0.3105063             0.41942235      -0.27065942
##      Compactness_v1.ADC Compactness_v2.ADC Spherical_disproportion.ADC
## [1,]        -0.24433531         -0.5044297                 -0.02546898
## [2,]         0.03820863          0.4194224                 -1.10607816
## [3,]         0.12767671          0.6084963                 -1.52752054
## [4,]        -0.44739330         -1.0829209                  0.29717220
## [5,]         0.05095448          0.4757183                 -1.15426355
## [6,]        -0.53356248         -1.3812290                  0.41942235
##      Sphericity.ADC Asphericity.ADC Center_of_mass.ADC Max_3D_diam.ADC
## [1,]     -0.4900236     -0.02546898          0.2574751     -1.38122903
## [2,]      0.3780645     -1.10607816          0.2971722     -0.77000435
## [3,]      0.5044297     -1.52752054          0.7032182     -0.59324787
## [4,]     -1.1298434      0.31050605          0.5781359      0.07647307
## [5,]      0.4194224     -1.15426355         -0.4055602     -0.68701098
## [6,]     -1.4150181      0.50442967          0.7362013     -0.50442967
##      Major_axis_length.ADC Minor_axis_length.ADC Least_axis_length.ADC
## [1,]           -0.50442967           -1.52752054           -1.48790984
## [2,]           -1.38122903           -0.75299544           -0.39177534
## [3,]           -0.97491405           -0.31050605           -0.21817922
## [4,]           -0.02546898           -0.01273346            0.19217136
## [5,]           -1.06032943           -0.36442422            0.01273346
## [6,]           -0.24433531           -0.37806448           -0.53356248
##      Elongation.ADC Flatness.ADC Max_cooc.L.ADC Average_cooc.L.ADC
## [1,]    -2.42863924   -2.4286397     0.10204149         -0.7196121
## [2,]     0.01273346    0.4194225    -0.29717220          0.4055602
## [3,]     0.28389090    0.1792171    -0.01273346         -2.4286392
## [4,]    -0.39177534    0.1084434    -0.08924999         -0.4055602
## [5,]     0.46150957    0.7032184    -0.12767671         -0.3105060
## [6,]    -0.67098197   -0.9749142    -0.49002356          0.3373427
##      Variance_cooc.L.ADC Entropy_cooc.L.ADC DAVE_cooc.L.ADC DVAR_cooc.L.ADC
## [1,]           0.7872387        -0.87721561      0.36442422       1.3180073
```

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## [2,]          -0.5932479        -0.57813595     -0.51894110      -0.6238874
## [3,]           1.0166957        -0.08924999      0.07647307       1.1298434
## [4,]          -0.7700043        -0.60849632     -1.08292088      -1.1542636
## [5,]          -0.4194224        -0.25747509     -0.31050605      -0.4900236
## [6,]           1.2052851         0.60849632      0.29717220       0.8586682
##      DENT_cooc.L.ADC SAVE_cooc.L.ADC SVAR_cooc.L.ADC SENT_cooc.L.ADC
## [1,]      0.43336550      -0.7196121       0.6709820      -0.2181792
## [2,]     -0.51894110       0.4055602      -0.7529954      -1.3812290
## [3,]      0.07647307      -2.4286392       1.1793911       0.6394275
## [4,]     -0.97491405      -0.4055602      -0.6394275      -0.1405248
## [5,]     -0.33734270      -0.3105060      -0.6084963      -0.2312375
## [6,]      0.37806448       0.3373427       1.3812290      -0.9749140
##      ASM_cooc.L.ADC Contrast_cooc.L.ADC Dissimilarity_cooc.L.ADC
## [1,]   2.730047e-06           1.1060782               0.36442422
## [2,]  -1.662910e-01          -0.5044297              -0.51894110
## [3,]  -1.020394e-01           0.6870110               0.07647307
## [4,]  -1.276748e-01          -1.1060782              -1.08292088
## [5,]  -2.443342e-01          -0.3105060              -0.31050605
## [6,]  -4.686025e-01           0.7872387               0.29717220
##      Inv_diff_cooc.L.ADC Inv_diff_norm_cooc.L.ADC IDM_cooc.L.ADC
## [1,]          -0.2838909              -0.67098275  -1.921714e-01
## [2,]          -0.2312375              -0.05095454  -2.574751e-01
## [3,]          -0.1276767              -0.35085175  -5.421149e-17
## [4,]           0.2706594               0.31050641   2.838909e-01
## [5,]          -0.3373427              -0.17921725  -3.373427e-01
## [6,]          -0.7032182              -0.68701178  -6.709820e-01
##      IDM_norm_cooc.L.ADC Inv_var_cooc.L.ADC Correlation_cooc.L.ADC
## [1,]         -0.87721561      -2.443353e-01             -0.8586682
## [2,]         -0.07647307      -2.051580e-01             -0.5781359
## [3,]         -0.49002356      -5.421149e-17              0.4900236
## [4,]          0.19217136       2.443353e-01              0.4473933
## [5,]         -0.16629268      -3.373427e-01             -0.6084963
## [6,]         -0.62388738      -7.032182e-01              0.5932479
##      Autocorrelation_.L.ADC Tendency_cooc.L.ADC Shade_.L.ADC
## [1,]             -0.7196121           0.6709820    1.4150181
## [2,]              0.5781359          -0.7529954   -1.1793911
## [3,]             -1.9136712           1.1793911    2.2371600
## [4,]             -0.3917753          -0.6394275   -0.3780645
## [5,]             -0.2971722          -0.6084963   -0.4473933
## [6,]              0.6238874           1.3812290   -1.5696804
##      Prominence_cooc.L.ADC  IC1_.L.ADC  IC2_.L.ADC Coarseness_vdif_.L.ADC
## [1,]             1.1298434 -0.93476628  0.50442967             0.47571994
## [2,]            -0.6238874  0.60849632 -0.28389090             0.06370943
## [3,]             2.2371600 -0.07647307  0.20515797            -0.17921668
## [4,]            -0.9152468  0.16629268 -0.06370859            -0.31050595
## [5,]            -0.6084963  0.70321822 -0.33734270            -0.05095386
## [6,]             1.1793911 -0.37806448  0.44739330            -0.07008883
##      Contrast_vdif_.L.ADC Busyness_vdif_.L.ADC Complexity_vdif_.L.ADC
## [1,]            1.1060782           -1.0603294              0.5631547
## [2,]           -0.3105060           -0.9955879             -0.8586682
## [3,]            0.3373427            0.2443353              0.8586682
## [4,]           -0.9546481            0.1662927             -1.0603294
## [5,]           -0.1533960           -0.5044297             -0.6551233
## [6,]            0.8404111           -0.7700043              0.6870110
```

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##      Strength_vdif_.L.ADC SRE_align.L.ADC LRE_align.L.ADC GLNU_align.L.ADC
## [1,]            1.3812290      0.01910130     -0.51894110       -1.3180073
## [2,]            0.6238874     -0.02546860     -0.43336550       -0.5932479
## [3,]            0.8404111     -0.31050614     -0.06370859       -0.2838909
## [4,]           -0.7032182     -0.57813649      0.15339601        0.2706594
## [5,]            0.2838909      0.05095499     -0.49002356       -0.5189411
## [6,]            0.5932479      0.20515874     -0.87721561       -0.7872387
##      RLNU_align.L.ADC RP_align.L.ADC LGRE_align.L.ADC HGRE_align.L.ADC
## [1,]       -1.5275205     0.05095448      -0.06370859       -0.3644242
## [2,]       -0.7529954    -0.02546898      -0.39177534        0.4194224
## [3,]       -0.2838909    -0.28389090       0.10204149       -1.9997211
## [4,]        0.2971722    -0.59324787      -0.12767671       -0.4757183
## [5,]       -0.5781359     0.03820863      -0.23123752       -0.3508513
## [6,]       -0.5189411     0.24433531      -0.40556015        0.6551233
##      LGSRE_align.L.ADC HGSRE_align.L.ADC LGHRE_align.L.ADC HGLRE_align.L.ADC
## [1,]       -0.06370884        -0.2574751       -0.10204149        -0.4900236
## [2,]       -0.39177578         0.4194224       -0.40556015         0.4194224
## [3,]        0.07647290        -1.9997211        0.08924999        -1.9997211
## [4,]       -0.14052504        -0.4757183       -0.08924999        -0.3780645
## [5,]       -0.23123786        -0.3105060       -0.24433531        -0.3508513
## [6,]       -0.40556060         0.6709820       -0.41942235         0.6238874
##      GLNU_norm_align.L.ADC RLNU_norm_align.L.ADC GLVAR_align.L.ADC
## [1,]           -0.11484968            0.05095457         0.8586682
## [2,]           -0.08924999           -0.05095441        -0.5482987
## [3,]           -0.21817922           -0.29717219         0.8960694
## [4,]           -0.12767671           -0.67098206        -0.8047097
## [5,]           -0.24433531            0.03820873        -0.3644242
## [6,]           -0.75299544            0.29717236         1.0603294
##      RLVAR_align.L.ADC Entropy_align.L.ADC  SZSE.L.ADC  LZSE.L.ADC LGLZE.L.ADC
## [1,]       -0.43336634          -0.4194224  0.24433538 -0.87721561 -0.07647307
## [2,]       -0.41942318          -0.8586682 -0.03820862 -0.59324787 -0.39177534
## [3,]       -0.07647358           0.1921714 -0.89606958  0.23123752  0.11484968
## [4,]        0.21817897          -0.3644242 -0.51894119 -0.02546898 -0.19217136
## [5,]       -0.36442500          -0.3780645 -0.29717224 -0.10204149 -0.20515797
## [6,]       -0.78723983           0.6238874  0.20515804 -1.20528514 -0.40556015
##      HGLZE.L.ADC SZLGE.L.ADC SZHGE.L.ADC LZLGE.L.ADC LZHGE.L.ADC
## [1,]  -0.2838909 -0.06370838  -0.1662927 -0.14052487  -0.9955879
## [2,]   0.4194224 -0.37806447   0.3373427 -0.47571848   0.2971722
## [3,]  -1.9997211  0.08925030  -1.9997211  0.50442973  -1.6635205
## [4,]  -0.4900236 -0.25747501  -0.6551233 -0.06370868  -0.4333655
## [5,]  -0.4473933 -0.19217124  -0.4473933 -0.27065957  -0.3917753
## [6,]   0.6238874 -0.40556016   0.6238874 -0.50442988   0.3780645
##      GLNU_area.L.ADC ZSNU.L.ADC   ZSP.L.ADC GLNU_norm.L.ADC ZSNU_norm.L.ADC
## [1,]      -1.3180073 -1.4879098  0.25747509     -0.11484983       0.2971730
## [2,]      -0.5482987 -0.9546481  0.03820863     -0.08925014      -0.0764728
## [3,]      -0.3917753 -0.4615096 -0.97491405     -0.32389548      -1.1793926
## [4,]       0.2971722  0.3508513 -0.51894110     -0.12767687      -0.6870117
## [5,]      -0.5335625 -0.6394275 -0.33734270     -0.25747529      -0.3105061
## [6,]      -0.7529954 -0.4900236  0.33734270     -0.71961240       0.2312383
##      GLVAR_area.L.ADC ZSVAR.L.ADC Entropy_area.L.ADC Max_cooc.H.ADC
## [1,]        0.8772156 -0.80470972         -0.7529954    -0.11484998
## [2,]       -0.5631547 -0.63942746         -1.2882802    -0.27065984
## [3,]        0.8224296  0.44739330          0.5781359     0.07647291
## [4,]       -0.8586682  0.06370859         -0.2051580    -0.12767702
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## [5,]       -0.3373427  0.01273346         -0.1276767    -0.39865881
## [6,]        1.0603294 -1.25964848          0.5932479    -0.07647334
##      Average_cooc.H.ADC Variance_cooc.H.ADC Entropy_cooc.H.ADC DAVE_cooc.H.ADC
## [1,]         -1.2052851          -0.9546481         0.49002356      0.10204149
## [2,]          0.5781359          -0.8047097        -0.70321822      0.01273346
## [3,]         -0.8047097           0.6394275        -0.23123752     -0.67098197
## [4,]         -0.5631547          -0.9955879         0.12767671     -1.23201233
## [5,]         -0.1792170          -1.7165060        -0.06370859     -0.03820863
## [6,]         -0.8404111           0.5631547        -0.75299544     -1.20528514
##      DVAR_cooc.H.ADC DENT_cooc.H.ADC SAVE_cooc.H.ADC SVAR_cooc.H.ADC
## [1,]      0.07647307      0.01273556      -1.2052851      -0.8404111
## [2,]     -0.36442422     -0.03820676       0.5781359      -0.4900236
## [3,]     -0.35085134     -0.57813651      -0.7872387       0.3508513
## [4,]     -1.28828023     -1.25965212      -0.5932479       0.1020415
## [5,]     -0.23123752     -0.02546706      -0.1792170      -0.8224296
## [6,]     -0.80470972     -1.12984646      -0.8404111       0.4615096
##      SENT_cooc.H.ADC ASM_cooc.H.ADC Contrast_cooc.H.ADC
## [1,]       0.2838909     0.02548452          0.06370859
## [2,]      -1.7165060    -0.20515786         -0.05095448
## [3,]       0.1405248    -0.08285155         -0.62388738
## [4,]      -0.1662927    -0.29717824         -1.31800728
## [5,]      -0.5631547    -0.25090274         -0.06370859
## [6,]      -0.6870110    -0.05094405         -1.10607816
##      Dissimilarity_cooc.H.ADC Inv_diff_cooc.H.ADC Inv_diff_norm_cooc.H.ADC
## [1,]               0.10204149          -0.3780651              -0.50442967
## [2,]               0.01273346          -0.6238881              -0.40556015
## [3,]              -0.67098197           0.1792168               0.01273346
## [4,]              -1.23201233           0.2574749               0.28389090
## [5,]              -0.03820863          -0.2838914              -0.32389526
## [6,]              -1.20528514           0.3917753               0.31050605
##      IDM_cooc.H.ADC IDM_norm_cooc.H.ADC Inv_var_cooc.H.ADC
## [1,]     -0.3373427         -0.41942235         -0.2312376
## [2,]     -0.6870110         -0.29717220         -0.7032184
## [3,]      0.2051580         -0.06370859          0.2051580
## [4,]      0.1921714          0.27065942          0.1792170
## [5,]     -0.2971722         -0.28389090         -0.3644243
## [6,]      0.3508513          0.23123752          0.3644243
##      Correlation_cooc.H.ADC Autocorrelation_cooc.H.ADC Tendency_cooc.H.ADC
## [1,]             -0.7529954              -1.487910e+00          -0.8404111
## [2,]             -0.4473933               5.932479e-01          -0.4900236
## [3,]              0.2051580              -2.574751e-01           0.3508513
## [4,]              0.4900236              -5.421149e-17           0.1020415
## [5,]             -0.5482987              -4.055602e-01          -0.8224296
## [6,]              0.5044297              -1.273346e-02           0.4615096
##      Shade_cooc.H.ADC Prominence_cooc.H.ADC IC1_d.H.ADC IC2_d.H.ADC
## [1,]        0.5482987           -0.93476628  -1.1793914  0.50442967
## [2,]       -1.6635205           -0.78723867   0.2971724 -0.01273346
## [3,]        1.2596485            0.51894110   0.1020416  0.14052475
## [4,]       -0.1276767           -0.01273346   0.4757185 -0.15339601
## [5,]       -0.8960694           -0.91524677   0.3644245 -0.03820863
## [6,]       -0.7872387            0.28389090  -0.4757183  0.37806448
##      Coarseness_vdif.H.ADC Contrast_vdif.H.ADC Busyness_vdif.H.ADC
## [1,]          6.709821e-01          0.03820863          -1.6635205
## [2,]          3.820853e-02         -0.08924999          -0.7362013
```

```
## [3,]         -1.276769e-01         -1.06032943          -0.3105060
## [4,]         -3.238955e-01         -1.34894519           0.2181792
## [5,]         -7.647320e-02         -0.01273346          -0.5044297
## [6,]         -1.147554e-07         -1.28828023          -0.6394275
##      Complexity_vdif.H.ADC Strength_vdif.H.ADC SRE_align.H.ADC LRE_align.H.ADC
## [1,]          5.095448e-02           1.3180073      0.05095439      -0.6709820
## [2,]         -1.405248e-01           0.7362013      0.02546889      -0.6551233
## [3,]         -1.038266e+00           0.1662927     -0.41248158       0.2181792
## [4,]         -1.348945e+00          -0.5335625     -0.53356273       0.2574751
## [5,]         -5.421149e-17           0.2971722     -0.14052490      -0.3373427
## [6,]         -1.259648e+00           0.6394275     -0.35085154      -0.1405248
##      GLNU_align.H.ADC RLNU_align.H.ADC RP_align.H.ADC LGRE_align.H.ADC
## [1,]       -1.4505021       -1.4505021     0.14052483       0.01273851
## [2,]       -0.7529954       -0.7529954     0.08925006      -0.12767341
## [3,]       -0.2971722       -0.3105060    -0.46150963       0.05096001
## [4,]        0.3373427        0.3373427    -0.56315481      -0.36442388
## [5,]       -0.5781359       -0.5781359    -0.08924997      -0.21817705
## [6,]       -0.5189411       -0.5189411    -0.28389092      -0.23123551
##      HGRE_align.H.ADC LGSRE_align.H.ADC HGSRE_align.H.ADC LGHRE_align.H.ADC
## [1,]        0.3105060        0.03821309        0.41942235     -3.917756e-01
## [2,]       -0.6551233       -0.07646978       -0.07647307     -3.780647e-01
## [3,]       -2.4286392        0.06371331       -2.42863924     -2.706596e-01
## [4,]       -0.2181792       -0.37806428       -0.50442967      5.095454e-02
## [5,]       -0.4194224       -0.25747366       -0.12767671     -2.574752e-01
## [6,]        0.2312375       -0.31050515       -0.01273346      2.756749e-08
##      HGLRE_align.H.ADC GLNU_norm_align.H.ADC RLNU_norm_align.H.ADC
## [1,]        -0.8047097           -0.03821078          2.838911e-01
## [2,]        -0.8224296           -0.14696808          2.051581e-01
## [3,]         0.6084963           -0.22472047         -4.473934e-01
## [4,]        -0.1020415           -0.47575501         -6.551235e-01
## [5,]        -0.5482987           -0.14696808          6.658463e-08
## [6,]        -0.5335625           -0.30385552         -2.838910e-01
##      GLVAR_align.H.ADC RLVAR_align.H.ADC Entropy_align.H.ADC  SZSE.H.ADC
## [1,]         0.3508513       -0.59324787         -1.20528537  0.24433561
## [2,]         0.2051580       -0.54829867         -0.82242969  0.08925023
## [3,]        -1.4879098        0.21817922         -0.05095444 -0.85866834
## [4,]        -0.3644242        0.05095448          0.31050617 -0.39177532
## [5,]         0.1792170       -0.35085134         -0.54829874 -0.16629256
## [6,]        -0.4473933       -0.15339601         -0.23123752 -0.65512338
##       LZSE.H.ADC LGLZE.H.ADC HGLZE.H.ADC   SZLGE.H.ADC SZHGE.H.ADC LZLGE.H.ADC
## [1,] -0.85875773  0.19217133  -0.2971722  2.377814e-01   0.1405248 -0.75299544
## [2,] -0.80479542  0.03820853  -0.2051580  6.370858e-02   0.1148497 -0.60849632
## [3,]  0.62390401 -0.12126089  -2.8041692 -2.181794e-01  -2.1037376  0.06370859
## [4,] -0.05098619 -0.21817945  -0.2838909 -3.105063e-01  -0.4055602 -0.12767671
## [5,] -0.17925794 -0.08925016  -1.3812290 -4.875143e-08  -1.2052851 -0.14052475
## [6,]  0.14050676 -0.41248169   0.3105060 -3.917756e-01  -0.5044297  0.54829867
##      LZHGE.H.ADC GLNU_area.H.ADC ZSNU.H.ADC  ZSP.H.ADC GLNU_norm.H.ADC
## [1,] -0.78723867      -1.4505021 -1.4879695  0.3105064    0.0001161525
## [2,] -0.95464809      -0.7529954 -0.7530320  0.2181795   -0.2838687582
## [3,]  0.70321822      -0.3105060 -0.3239184 -1.2320127   -0.0126215246
## [4,] -0.02546898       0.3373427  0.3238925 -0.4333655   -0.4264086264
## [5,]  0.11484968      -0.5781359 -0.5932795 -0.1921713   -0.1533306504
## [6,] -0.10204149      -0.5335625 -0.5335922 -0.6238875   -0.2116180558
##      ZSNU_norm.H.ADC GLVAR_area.H.ADC   ZSVAR.H.ADC Entropy_area.H.ADC
```

```
## [1,]      0.28389119      -0.03820863 -6.870142e-01        -1.41501808
## [2,]      0.17921729       0.44739330 -7.362047e-01        -0.85866816
## [3,]     -1.25964882      -2.42863924  1.716510e+00         0.41942235
## [4,]     -0.41942234      -0.51894110 -1.336426e-06         0.07647307
## [5,]     -0.08924985      -0.01273346 -1.273483e-02        -0.53356248
## [6,]     -0.80470987      -1.20528514  2.706588e-01         0.01273346
##      Max_cooc.W.ADC Average_cooc.W.ADC Variance_cooc.W.ADC DAVE_cooc.W.ADC
## [1,]      0.1662977      -8.772156e-01           0.3644242      0.28389090
## [2,]     -0.1986587       4.473933e-01          -0.2181792     -0.05095448
## [3,]     -0.2312360      -9.152468e-01           1.4150181      0.44739330
## [4,]     -0.4900243       3.508513e-01           0.6551233      0.23123752
## [5,]     -0.2971712      -5.421149e-17           0.1533960      0.33734270
## [6,]     -0.3508508       7.529954e-01           1.8398097      1.01669574
##      DVAR_cooc.W.ADC DENT_cooc.W.ADC SAVE_cooc.W.ADC SVAR_cooc.W.ADC
## [1,]      0.85866816       0.1405248     -0.87721561      0.15339601
## [2,]     -0.05095448      -0.1020415      0.46150957     -0.23123752
## [3,]      1.45050212       0.3780645     -0.91524677      1.41501808
## [4,]      0.32389526       0.1792170      0.39177534      0.73620133
## [5,]      0.29717220       0.2574751      0.01273346      0.06370859
## [6,]      1.52752054       0.6394275      0.70321822      1.83980971
##      SENT_cooc.W.ADC ASM_cooc.W.ADC Contrast_cooc.W.ADC
## [1,]      -0.2312375     0.03821171          0.62388738
## [2,]      -1.3489452    -0.13409891          0.02546898
## [3,]       0.5932479    -0.17921903          1.25964848
## [4,]       0.1792170    -0.41248879          0.32389526
## [5,]       0.1148497    -0.24433882          0.46150957
## [6,]      -0.8772156    -0.36443054          1.61482620
##      Dissimilarity_cooc.W.ADC Inv_diff_cooc.W.ADC Inv_diff_norm_cooc.W.ADC
## [1,]               0.28389090           0.2706595              -0.67098197
## [2,]              -0.05095448          -0.3508514              -0.05095448
## [3,]               0.44739330          -0.2312375              -0.36442422
## [4,]               0.23123752          -0.3373427               0.29717220
## [5,]               0.33734270          -0.6551234              -0.16629268
## [6,]               1.01669574          -0.9955881              -0.68701098
##      IDM_cooc.W.ADC IDM_norm_cooc.W.ADC Inv_var_cooc.W.ADC
## [1,]      0.2706595         -0.87721561          0.2443353
## [2,]     -0.5482988         -0.06370859         -0.5631547
## [3,]     -0.2838910         -0.51894110         -0.2312375
## [4,]     -0.3917754          0.19217136         -0.4757183
## [5,]     -0.5932480         -0.16629268         -0.7362013
## [6,]     -0.9152469         -0.65512329         -0.8960694
##      Correlation_cooc.W.ADC Autocorrelation_cooc.W.ADC Tendency_cooc.W.ADC
## [1,]             -0.8586682                -0.8224296          0.15339601
## [2,]             -0.5781359                 0.6084963         -0.23123752
## [3,]              0.4900236                -0.8047097          1.41501808
## [4,]              0.4615096                 0.6551233          0.73620133
## [5,]             -0.6084963                 0.1148497          0.06370859
## [6,]              0.5932479                 1.2320123          1.83980971
##      Shade_cooc.W.ADC Prominence_cooc.W.ADC IC1_d.W.ADC IC2_d.W.ADC
## [1,]       1.15426355             0.4055621  -1.0829209   0.4900236
## [2,]      -1.31800728            -0.1020407  -0.2181792   0.1921714
## [3,]       2.80416916             2.1037436  -0.4055602   0.2838909
## [4,]       0.47571828             0.7362041   0.4055602  -0.1148497
## [5,]       0.06370859             0.2706611  -0.3917753   0.2574751
```

```
## [6,]      -1.66352051             1.6635255  -1.2320123   0.6084963
##      Coarseness_vdif.W.ADC Contrast_vdif.W.ADC Busyness_vdif.W.ADC
## [1,]            0.35085134           1.8398097         -0.41942260
## [2,]            0.06370850           0.2312375         -0.82242999
## [3,]           -0.19217154           0.7362013         -0.05095456
## [4,]           -0.31050626          -0.2574751         -0.39177558
## [5,]           -0.03820876           0.4615096         -0.63942781
## [6,]           -0.07647320           1.2320123         -0.84041153
##      Complexity_vdif.W.ADC Strength_vdif.W.ADC SRE_align.W.ADC LRE_align.W.ADC
## [1,]            -0.5482987          1.34894519     -0.40556015      -0.1662927
## [2,]            -0.2051580          0.71961205     -0.02546898      -0.6084963
## [3,]             0.6870110          1.28828023     -0.17921704      -0.3373427
## [4,]             0.5189411          0.05095448     -0.29717220      -0.2971722
## [5,]             0.1662927          0.65512329     -0.03820863      -0.4900236
## [6,]             1.1793911          1.23201233      0.10204149      -0.8772156
##      GLNU_align.W.ADC RLNU_align.W.ADC RP_align.W.ADC LGRE_align.W.ADC
## [1,]       -1.4505021       -1.5275205    -0.39177534       0.01273328
## [2,]       -0.8586682       -0.7529954     0.01273346      -0.34408956
## [3,]       -0.4333655       -0.2971722    -0.16629268      -0.32389562
## [4,]        0.1020415        0.3373427    -0.25747509      -0.07647329
## [5,]       -0.8772156       -0.5781359    -0.02546898      -0.39177575
## [6,]       -1.2052851       -0.5189411     0.10204149      -0.42638400
##      HGRE_align.W.ADC LGSRE_align.W.ADC HGSRE_align.W.ADC LGHRE_align.W.ADC
## [1,]       -0.7362013        0.01273324        -0.7362013      3.295782e-06
## [2,]        0.4615096       -0.33734313         0.4615096     -3.508505e-01
## [3,]       -0.7700043       -0.32389568        -0.7700043     -3.238942e-01
## [4,]        0.7529954       -0.08925027         0.7529954     -1.273025e-02
## [5,]        0.1405248       -0.39177581         0.1405248     -3.917748e-01
## [6,]        1.2320123       -0.42638406         1.2882802     -4.333653e-01
##      HGLRE_align.W.ADC GLNU_norm_align.W.ADC RLNU_norm_align.W.ADC
## [1,]        -0.7362013            0.08924981           -0.37806451
## [2,]         0.4473933           -0.07647338            0.05095455
## [3,]        -0.7700043           -0.19217177           -0.08924996
## [4,]         0.7700043           -0.43336611           -0.23123751
## [5,]         0.1405248           -0.29717269            0.03820870
## [6,]         1.2052851           -0.53356317            0.21817933
##      GLVAR_align.W.ADC RLVAR_align.W.ADC Entropy_align.W.ADC  SZSE.W.ADC
## [1,]         0.4333655        -0.1405238           0.2312375  0.37806457
## [2,]        -0.2181792        -0.4473935          -0.3238953 -0.47571838
## [3,]         1.1060782        -0.2181786          -0.1662927  0.41942244
## [4,]         0.7196121        -0.2051573           0.4473933  0.12767674
## [5,]         0.3644242        -0.3238950           0.2706594 -0.07647308
## [6,]         1.7747932        -0.5631553           0.6084963  0.29717226
##      LZSE.W.ADC LGLZE.W.ADC HGLZE.W.ADC SZLGE.W.ADC SZHGE.W.ADC LZLGE.W.ADC
## [1,] -1.2052851  0.02546896  -0.7362013  0.05095473  -0.7362013 -0.03820863
## [2,] -0.4194224 -0.33734299   0.4615096 -0.33734264   0.4757183 -0.39177534
## [3,]  0.2443353 -0.32389553  -0.7700043 -0.32389519  -0.7700043 -0.31050605
## [4,] -0.6870110 -0.24433553   0.7529954 -0.25747499   0.7529954 -0.01273346
## [5,] -0.1533960 -0.39177567   0.1405248 -0.39177531   0.1405248 -0.41942235
## [6,] -1.0166957 -0.41942269   1.2320123 -0.41942233   1.2320123 -0.46150957
##      LZHGE.W.ADC GLNU_area.W.ADC ZSNU.W.ADC   ZSP.W.ADC GLNU_norm.W.ADC
## [1,]  -0.7872387      -1.4505021 -1.3812290  0.49002356      0.03820875
## [2,]   0.4473933      -0.8404111 -0.7529954 -0.32389526     -0.11484963
## [3,]  -0.7362013      -0.4615096 -0.2838909  0.29717220      0.29717244
```

```
## [4,]   0.6709820       0.1148497  0.3780645  0.25747509     -0.43336560
## [5,]   0.1662927      -0.9347663 -0.5781359 -0.06370859      0.33061178
## [6,]   1.2052851      -1.1793911 -0.5189411  0.44739330     -0.51894124
##      ZSNU_norm.W.ADC GLVAR_area.W.ADC ZSVAR.W.ADC Entropy_area.W.ADC
## [1,]      0.43336550        0.4333655  -0.8047097        -1.66352051
## [2,]     -0.16629268       -0.2181792  -0.4055602        -0.39177534
## [3,]     -0.57813595        1.0603294   0.4194224         0.25747509
## [4,]      0.17921704        0.7196121  -0.4473933         0.39177534
## [5,]     -0.02546898        0.3644242  -0.1533960         0.03820863
## [6,]      0.35085134        1.7747932  -0.7032182         0.56315472
```

```
sum(is.na(model3fdata))
```

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

1. K-Means Clustering

K-Means Clustering is one of the most well-known and commonly used clustering algorithms for partitioning observations into a set of k groups.

The primary objective of k-means clustering is to make clusters within-cluster variation that is minimized. We will perform K-means clustering with 3 clusters, 100 maximum number of iterations, and 100 n start.

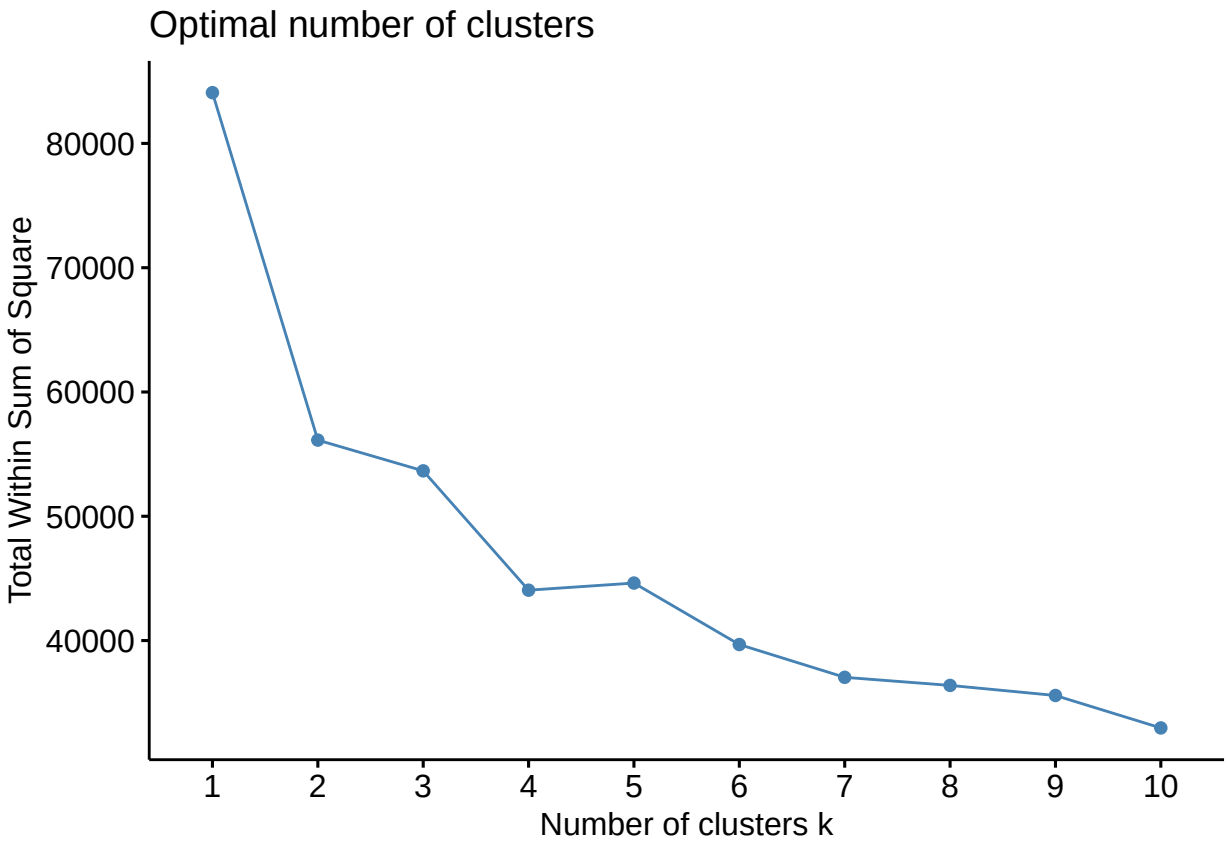
K-MEANS CLUSTERING

```
dataclust <- kmeans(model3fdata, centers = 3, iter.max = 100, nstart = 100)
```

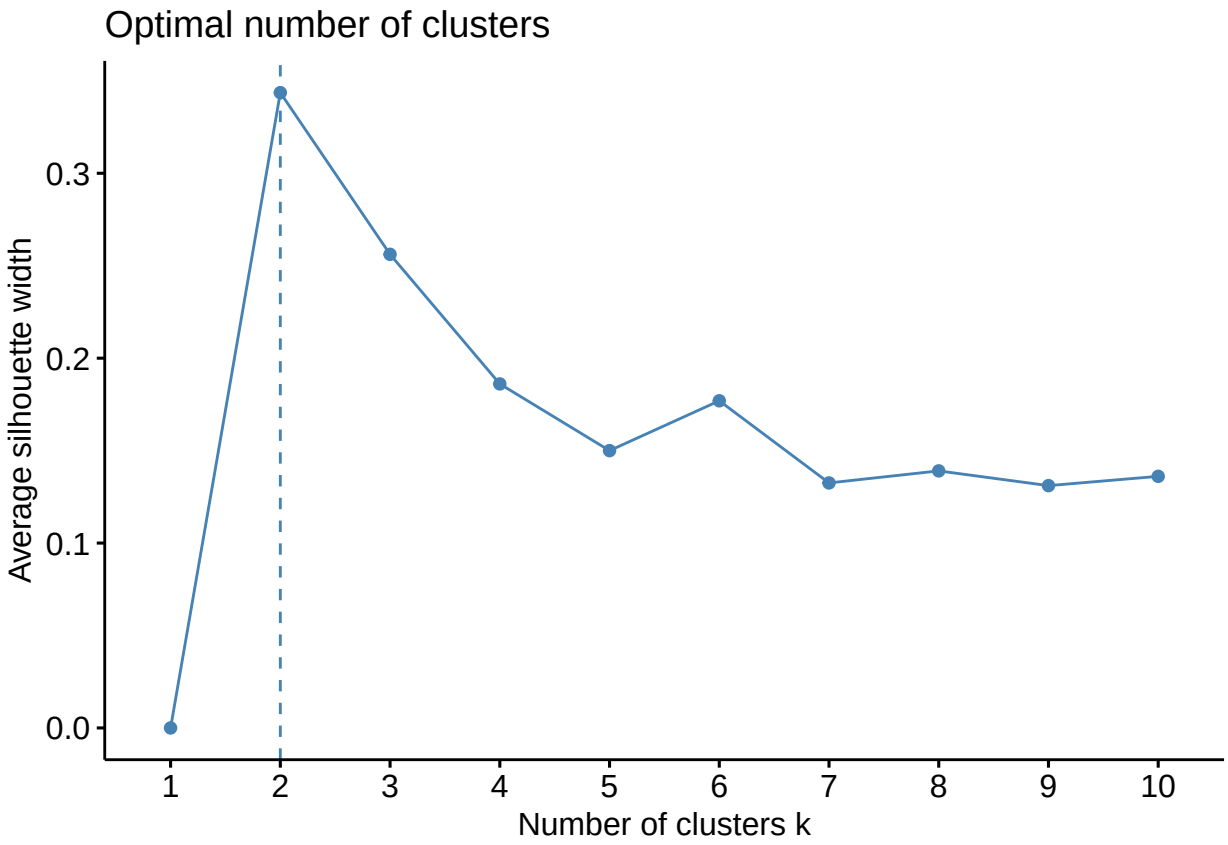
Also, we need to determine and visualize optimal number of clusters.

Another method to ascertain the most favorable value of the K number of clusters is by using *Within Sum of Squares*, *Silhouette* and *gap_stat* plots. This advise us with 2 clusters. To plot the 2 clusters, we can use *fviz_cluster()* function.

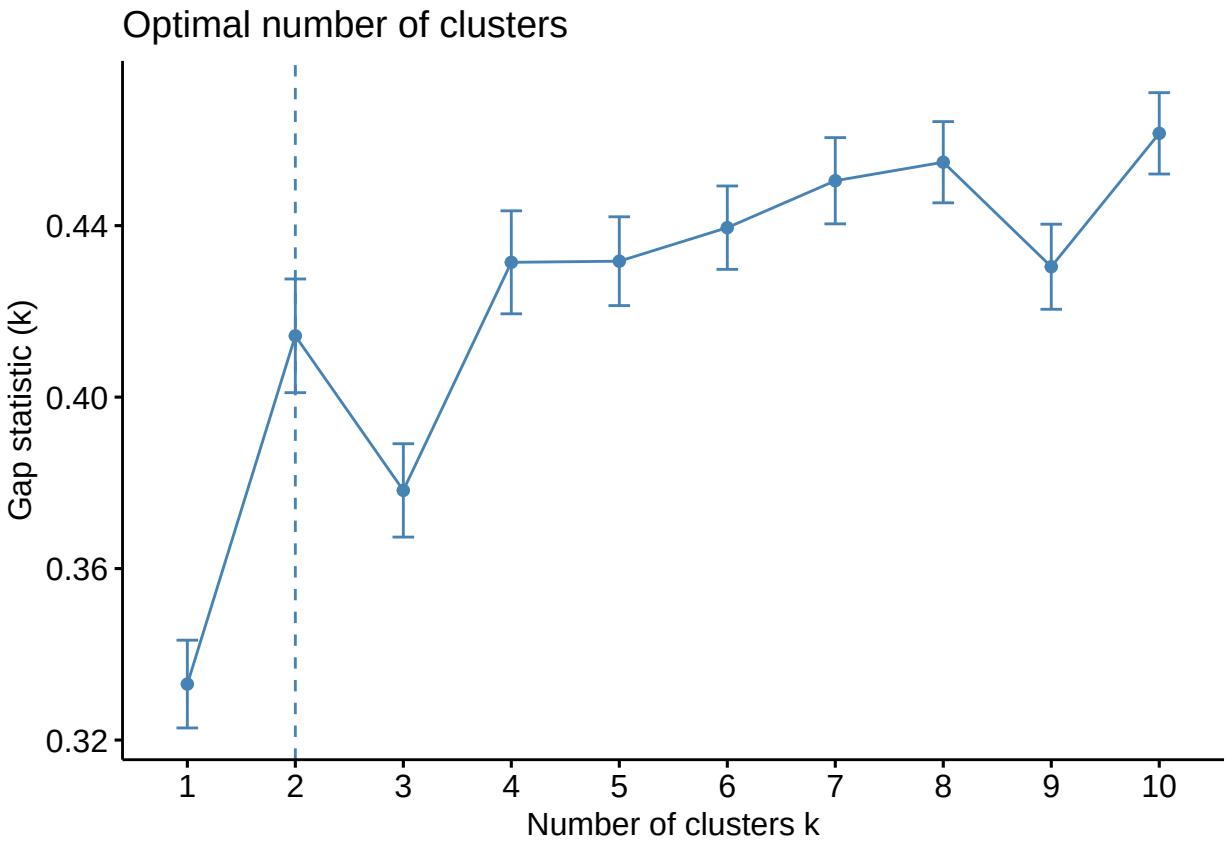
```
fviz_nbclust(model3fdata, kmeans, method = "wss")
```



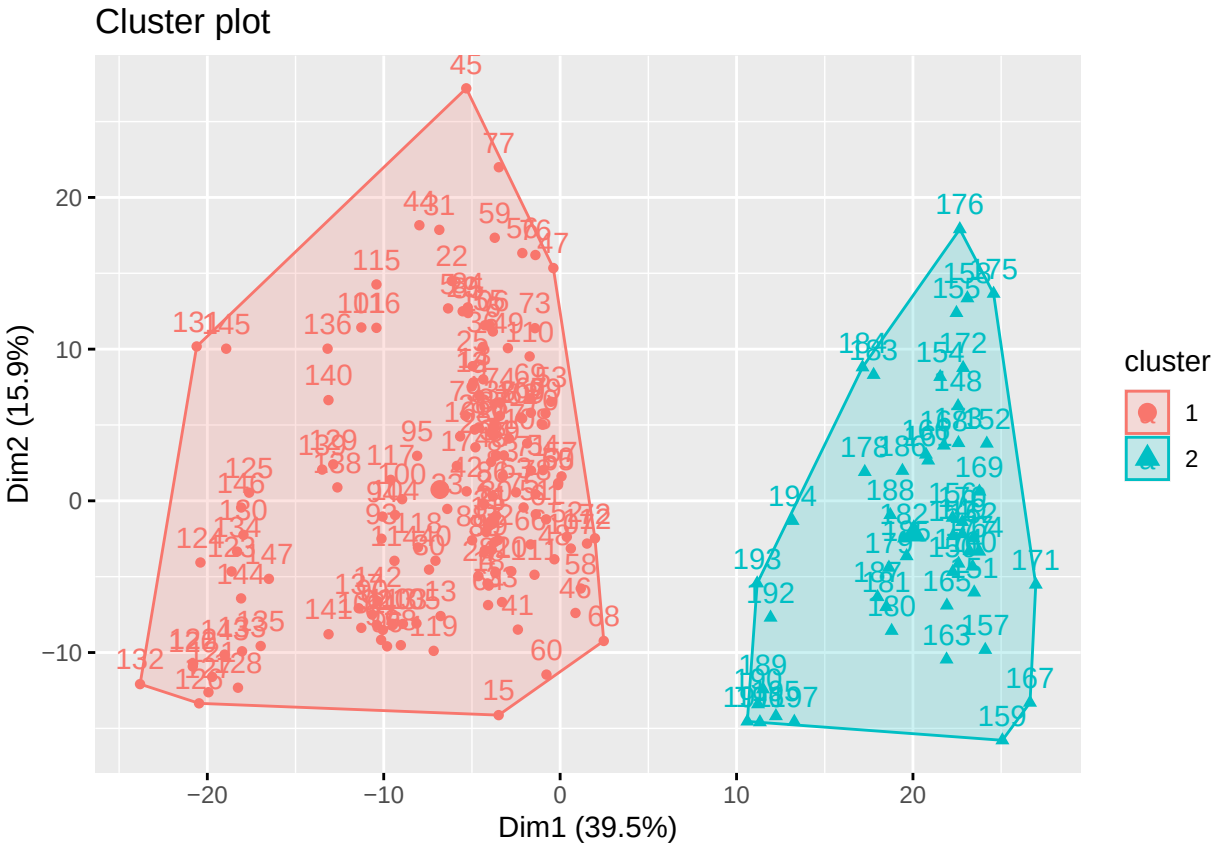

```
fviz_nbclust(model3fdata, kmeans, method = "silhouette")
```




```
fviz_nbclust(model3fdata, kmeans, method = "gap_stat")
```




```
dataclust <- kmeans(model3fdata, centers = 2, iter.max = 100, nstart = 100)
fviz_cluster(kmeans(model3fdata, centers = 2, iter.max = 100, nstart = 100), data = model3fdata)
```



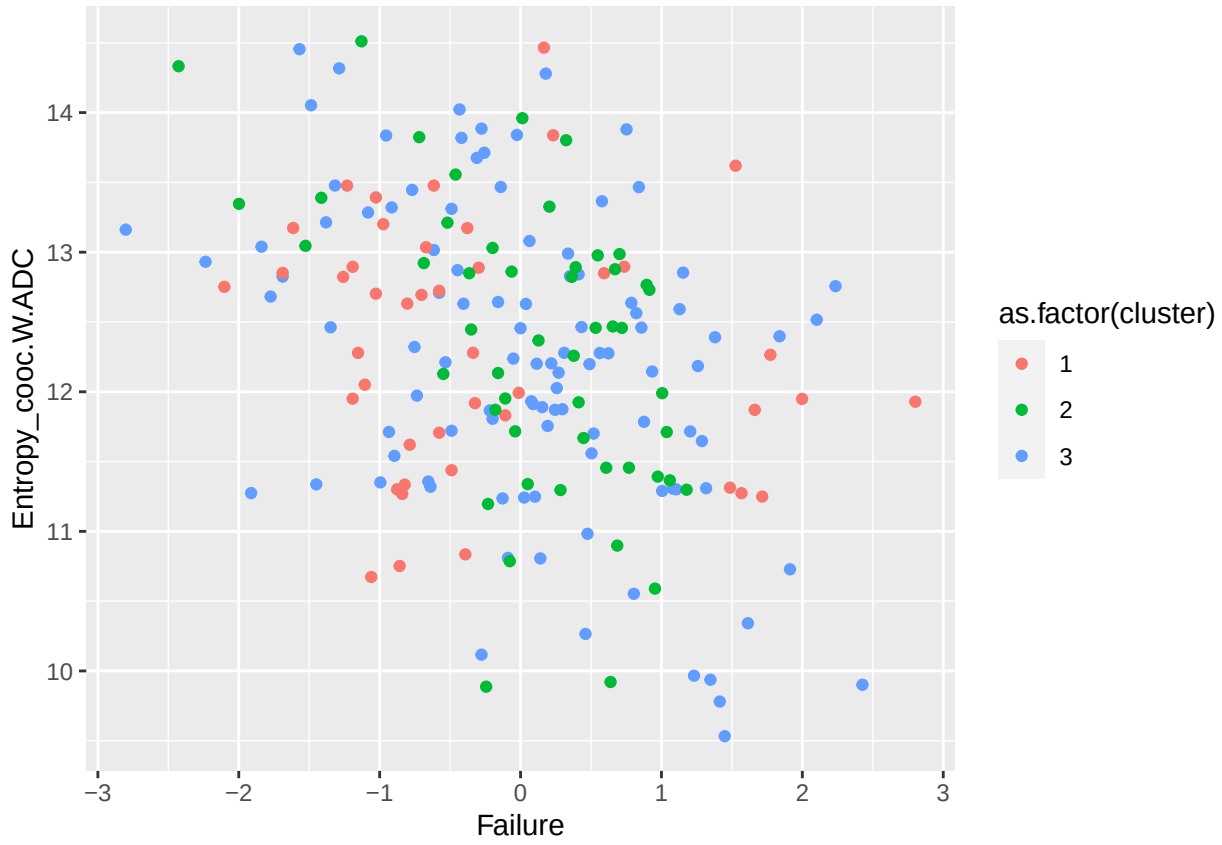
The quality of the k-means partition is gauged by the **SSwithin**, and we want it to be as little as possible. Hence, we have 33.2%.

```
dataclust$betweenss / dataclust$totss
```

```
## [1] 0.3324795
```

Lastly, we can visualize clusters using the original variables where **x is Failure** and **y is Entropy_cooc.W.ADC**

```
dataclust <- kmeans(model3fdata, centers = 3, iter.max = 100, nstart = 100)
model3data <- model3data |> mutate(cluster = dataclust$cluster)
model3data |> ggplot(aes(x = Failure, y = Entropy_cooc.W.ADC, col = as.factor(cluster))) + geom_point()
```



2.Hierarchical Clustering

In identifying the groupings in a data set, hierarchical clustering is a backup alternative to k-means clustering. Unlike k-means, in hierarchical clustering the number of clusters does not need to be preset, since this method can build hierarchy of clusters.

Also, before building a clustering model, a standardization of the data is prerequisite.

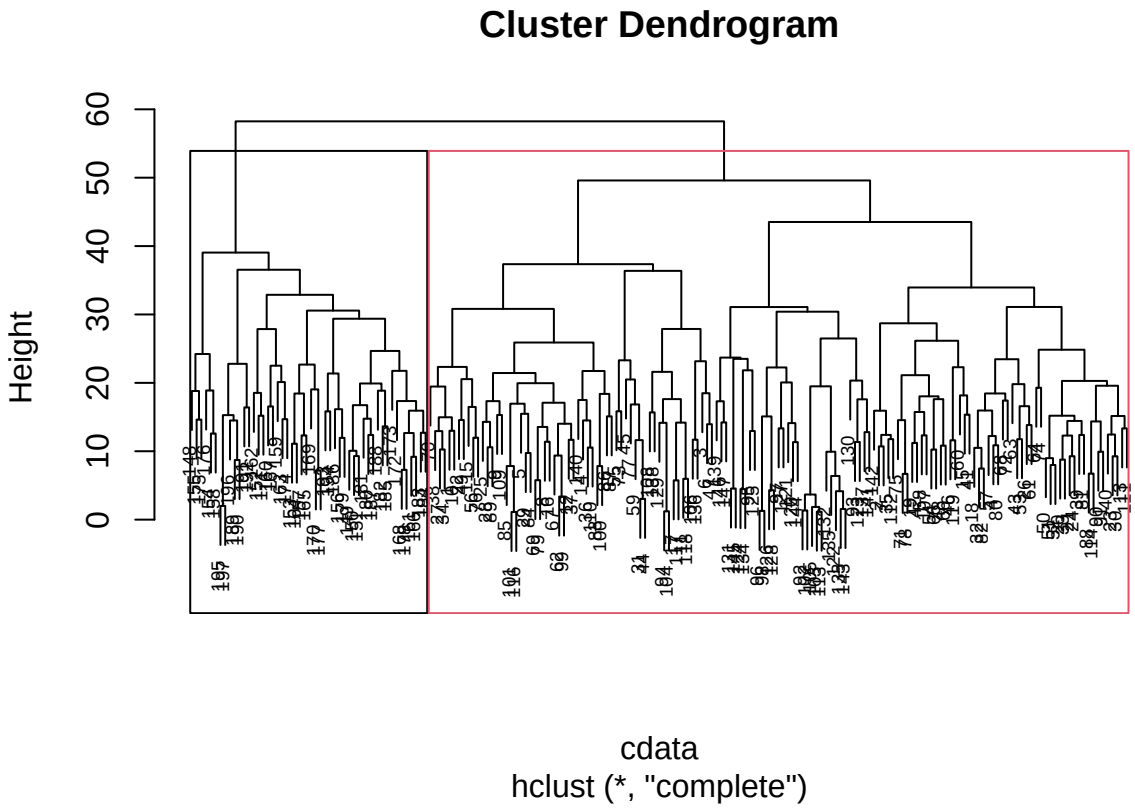
```
fdata <- model3data%>%
  select_if(is.numeric) %>%  # select numeric columns
  select(-Failure.binary) %>%    # remove target column
  mutate_all(as.double) %>%  # coerce to double type
  scale()
```

Hierarchical clustering using Complete Linkage

Resembling to k-means, we evaluate first the dissimilarity of observations using distance measures to get the agglomeration coefficient (AC). For us to sustain these values and specify the agglomeration method to be used either *"complete", "average", "single", or "ward.D2"*, is by using *hclust() function.*

```
cdata <- dist(fdata, method = "euclidean") #dissimiliraty matrix

heirclustA <- hclust(cdata, method = "complete")
plot(heirclustA, cex = 0.6)
rect.hclust(heirclustA, k = 2, border = 1:4)
```



AGNES

We can also use agnes() function.

```
set.seed(123)
heirclustB <- agnes(fdata, method = "complete")
heirclustB$ac
```

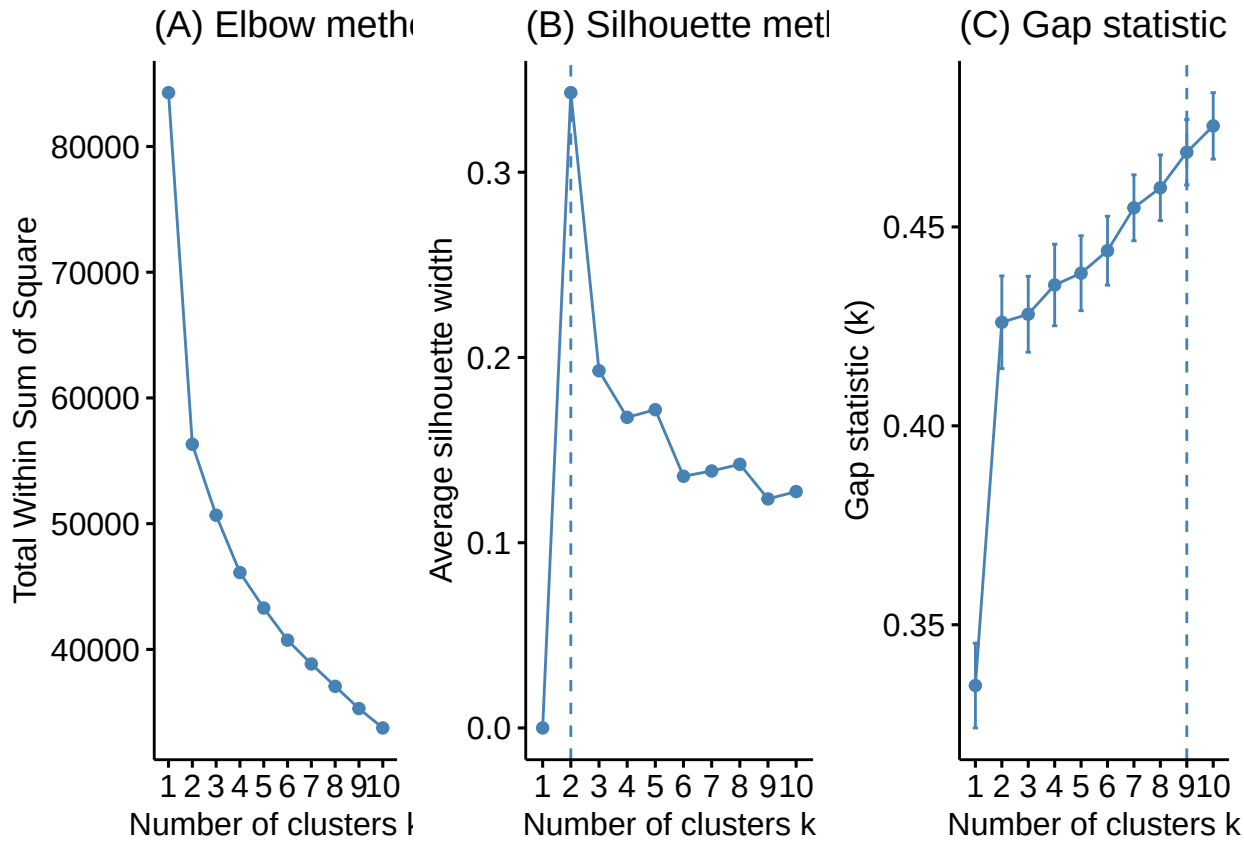
```
## [1] 0.8072963
```

DIANA

```
heirclustC <- diana(fdata)
heirclustC$dc
```

```
## [1] 0.7915983
```

```
dianaA <- fviz_nbclust(fdata, FUN = hcut, method = "wss",
                       k.max = 10) +
  ggtitle("(A) Elbow method")
dianaB <- fviz_nbclust(fdata, FUN = hcut, method = "silhouette",
                       k.max = 10) +
  ggtitle("(B) Silhouette method")
dianaC <- fviz_nbclust(fdata, FUN = hcut, method = "gap_stat",
                       k.max = 10) +
  ggtitle("(C) Gap statistic")
gridExtra::grid.arrange(dianaA, dianaB, dianaC, nrow = 1)
```



Ward's method

```
heirclustD <- hclust(cdata, method = "ward.D2" )
resgroup <- cutree(heirclustD, k = 8)
table(resgroup)
```

```
## resgroup
##  1  2  3  4  5  6  7  8
## 71 33 12 21 10 19 22  9
```

3.Model Based

Next is model-based clustering. Unlike the previous clustering methods, model-based clustering automatically ascertains the favorable number of clusters. Also, the Gaussian mixture models is applied.

We may use the **Mclust() function, *which will leave* G = NULL* to necessitate the Mclust() to evaluate 1–9 clusters and select the optimal number of components based on BIC.

```
modelB1 <- Mclust(model3fdata[,1:10], G=3)
summary(modelB1)
```

```
## ----------------------------------------------------
## Gaussian finite mixture model fitted by EM algorithm
## ----------------------------------------------------
##
## Mclust VEE (ellipsoidal, equal shape and orientation) model with 3 components:
##
##  log-likelihood   n df       BIC      ICL
##       -1074.583 197 89 -2619.371 -2638.94
```

```
##
## Clustering table:
##   1   2   3
## 111  50  36
```

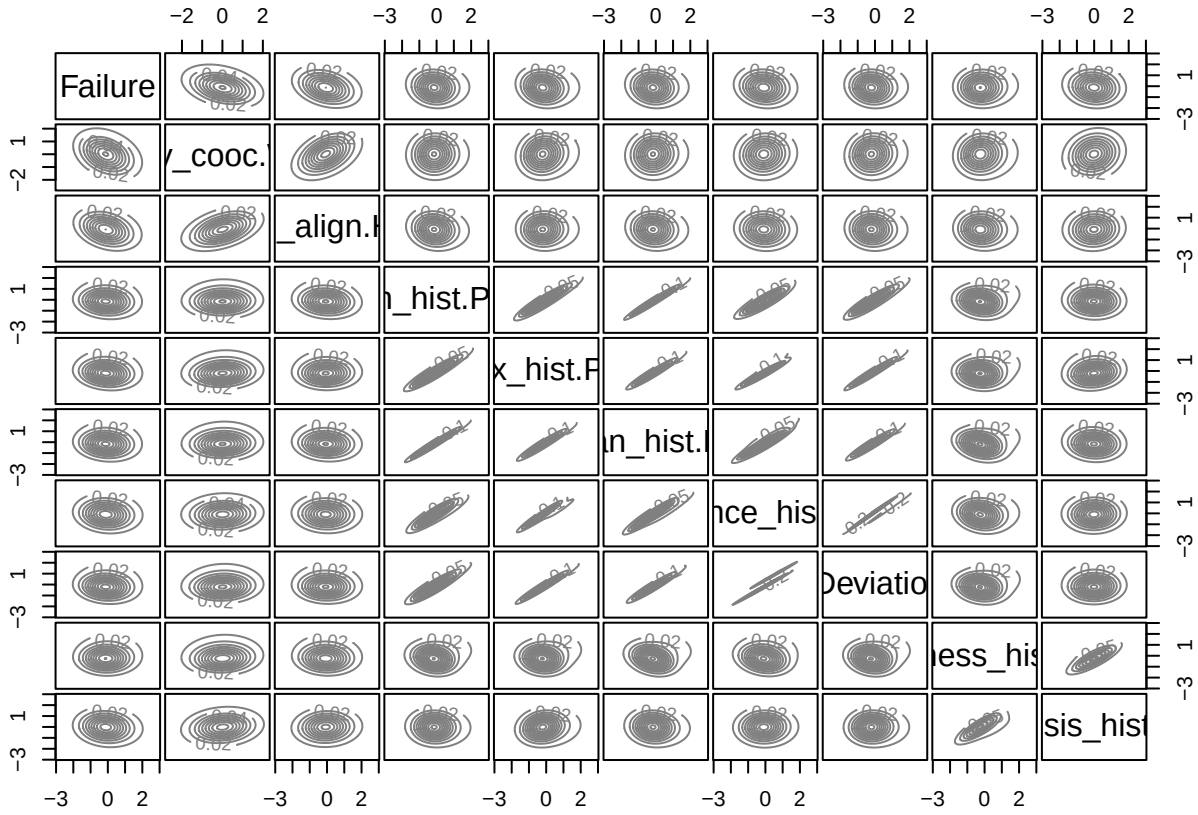
```
modelB2 = Mclust(model3fdata, 1:9) #from sir lecture

#Error in plot.new() : figure margins too large
summary(modelB2)
```

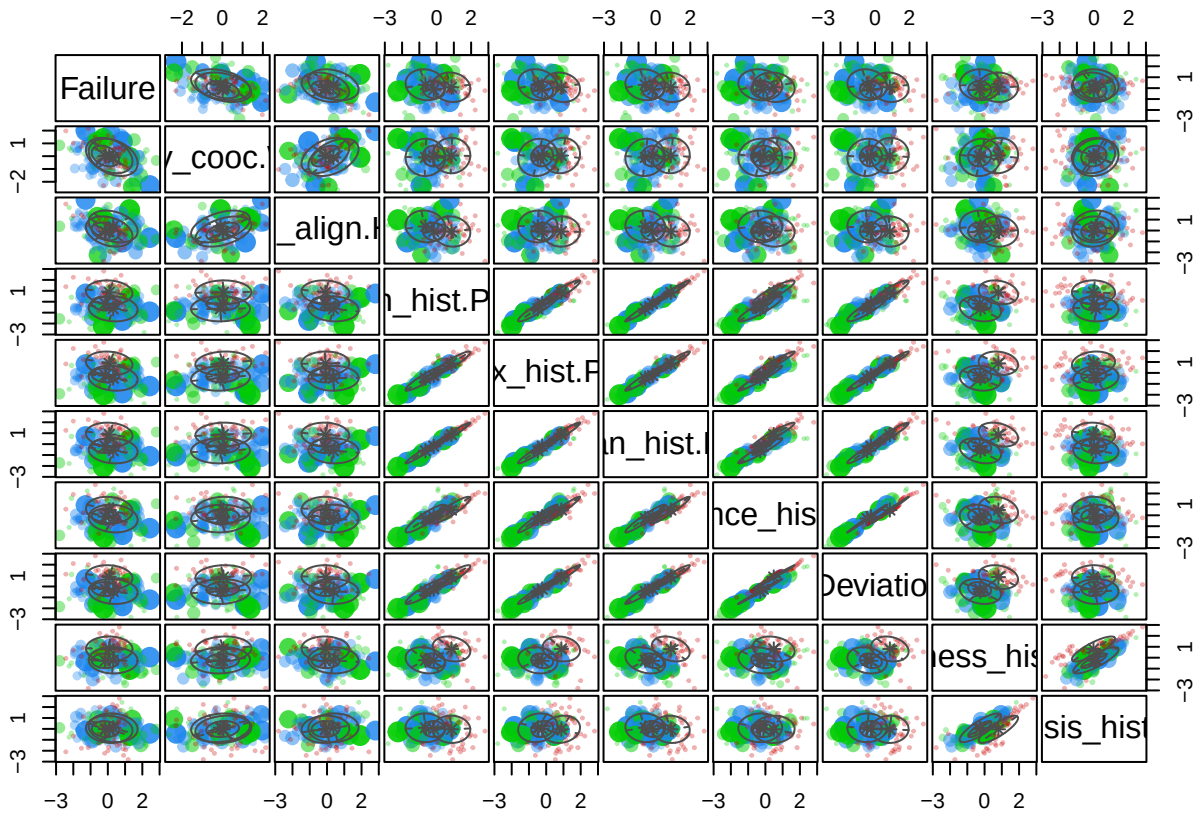
```
## ----------------------------------------------------
## Gaussian finite mixture model fitted by EM algorithm
## ----------------------------------------------------
##
## Mclust VEI (diagonal, equal shape) model with 9 components:
##
##  log-likelihood   n   df       BIC       ICL
##       -77829.42 197 4306 -178408.3 -178408.3
##
## Clustering table:
##  1  2  3  4  5  6  7  8  9
## 32 29 25 11 21 41 19 10  9
```

Plot results

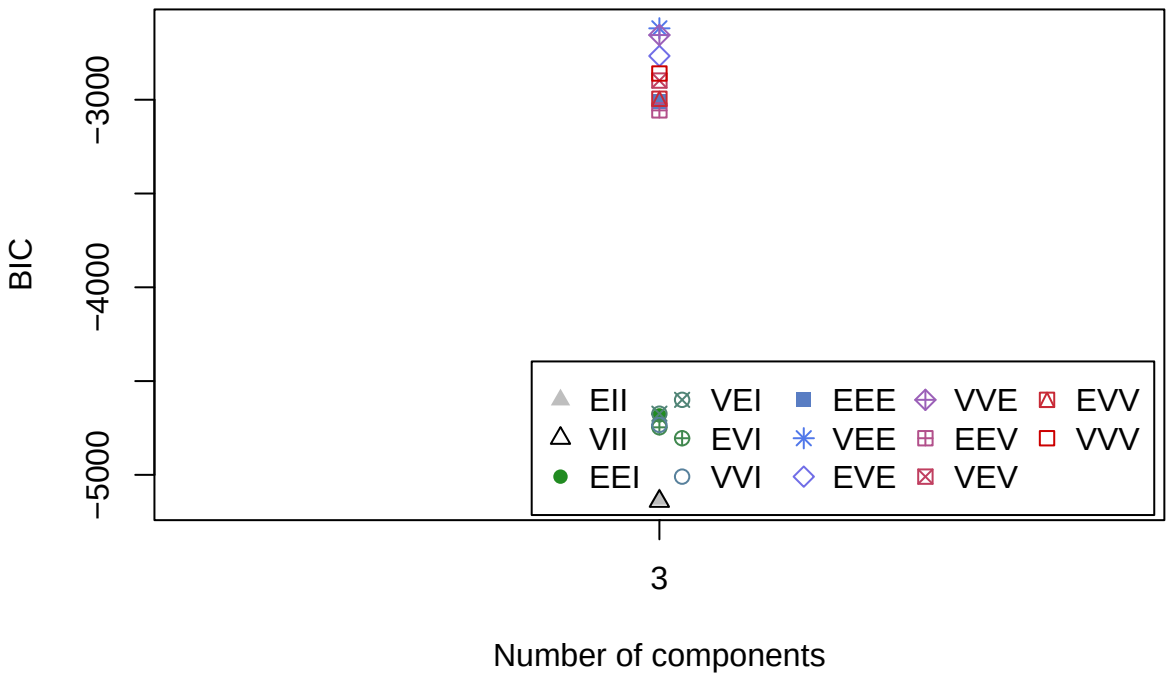
```
plot(modelB1, what = "density") #cannot plot 1:428 #dugay pag 1:10
```



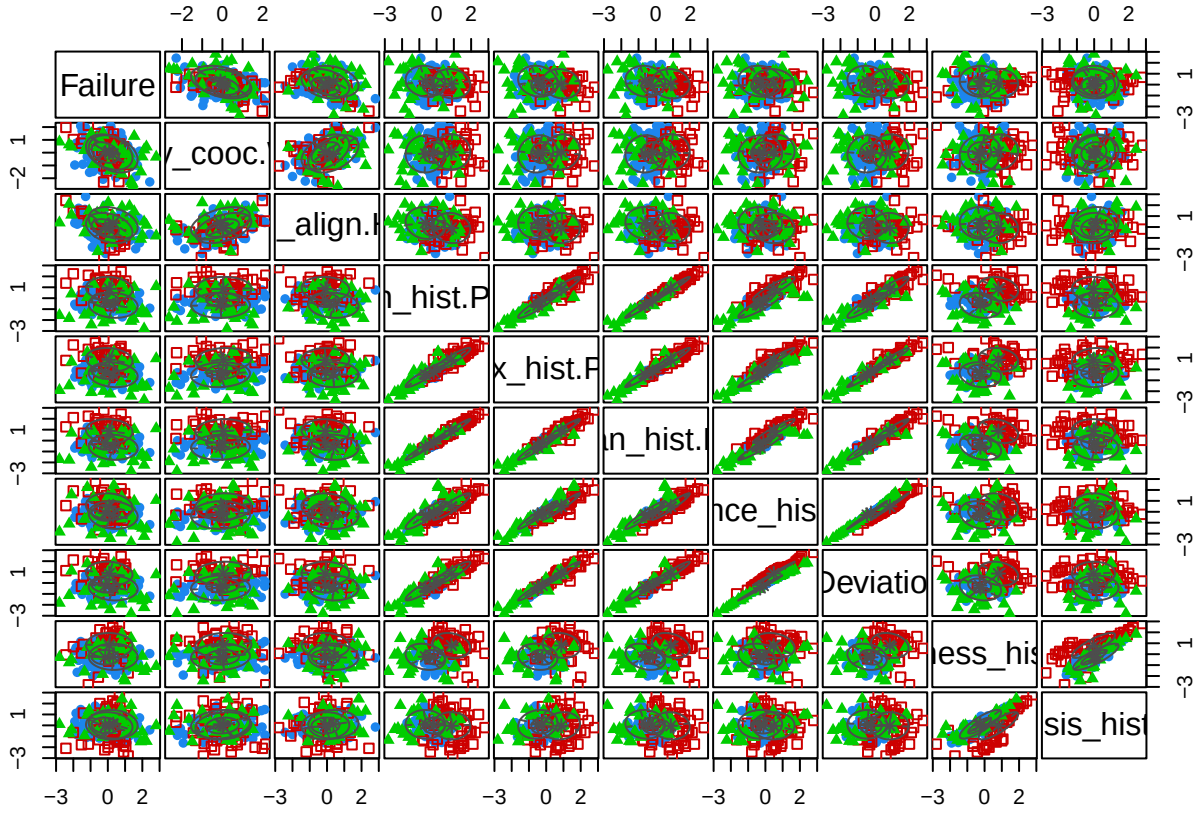
```
plot(modelB1, what = "uncertainty")
```



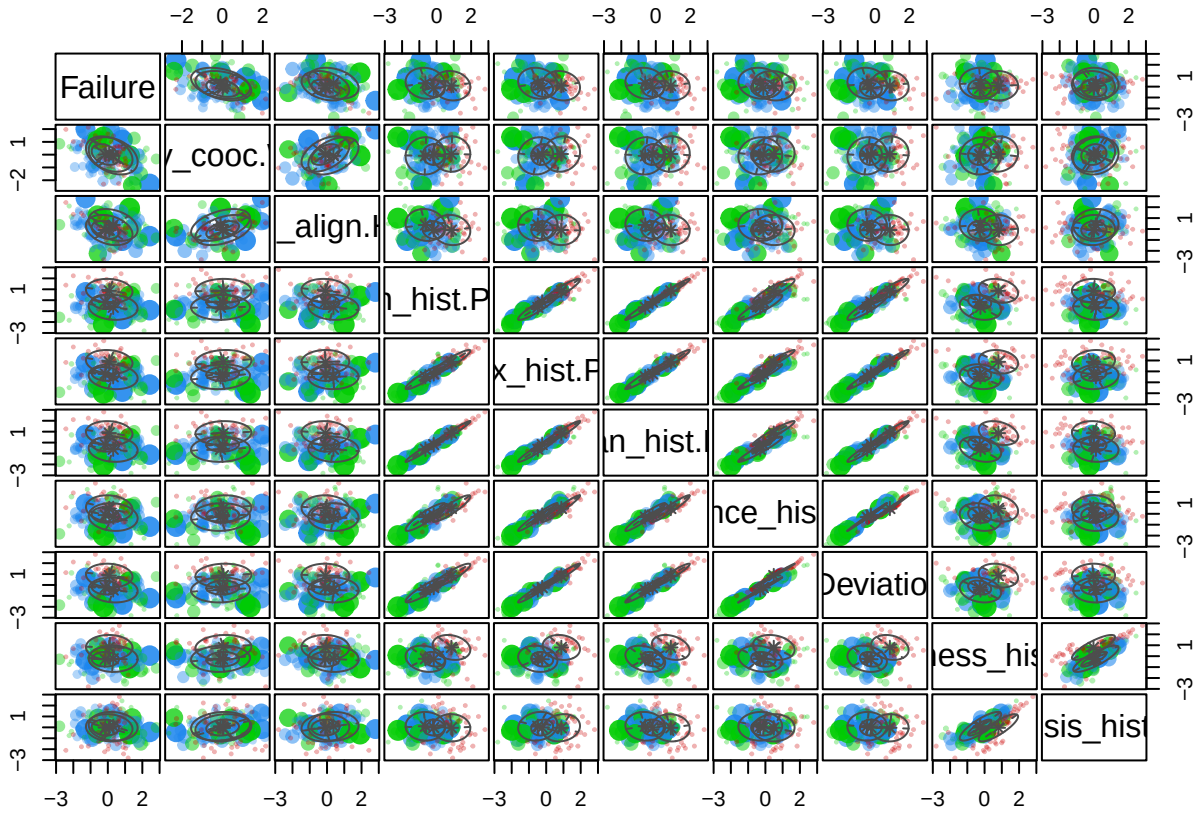

```
legargs <- list(x = "bottomright", ncol = 5)
plot(modelB1, what = 'BIC', legendArgs = legargs)
```




```
plot(modelB1, what = 'classification')
```




```
plot(modelB1, what = 'uncertainty')
```

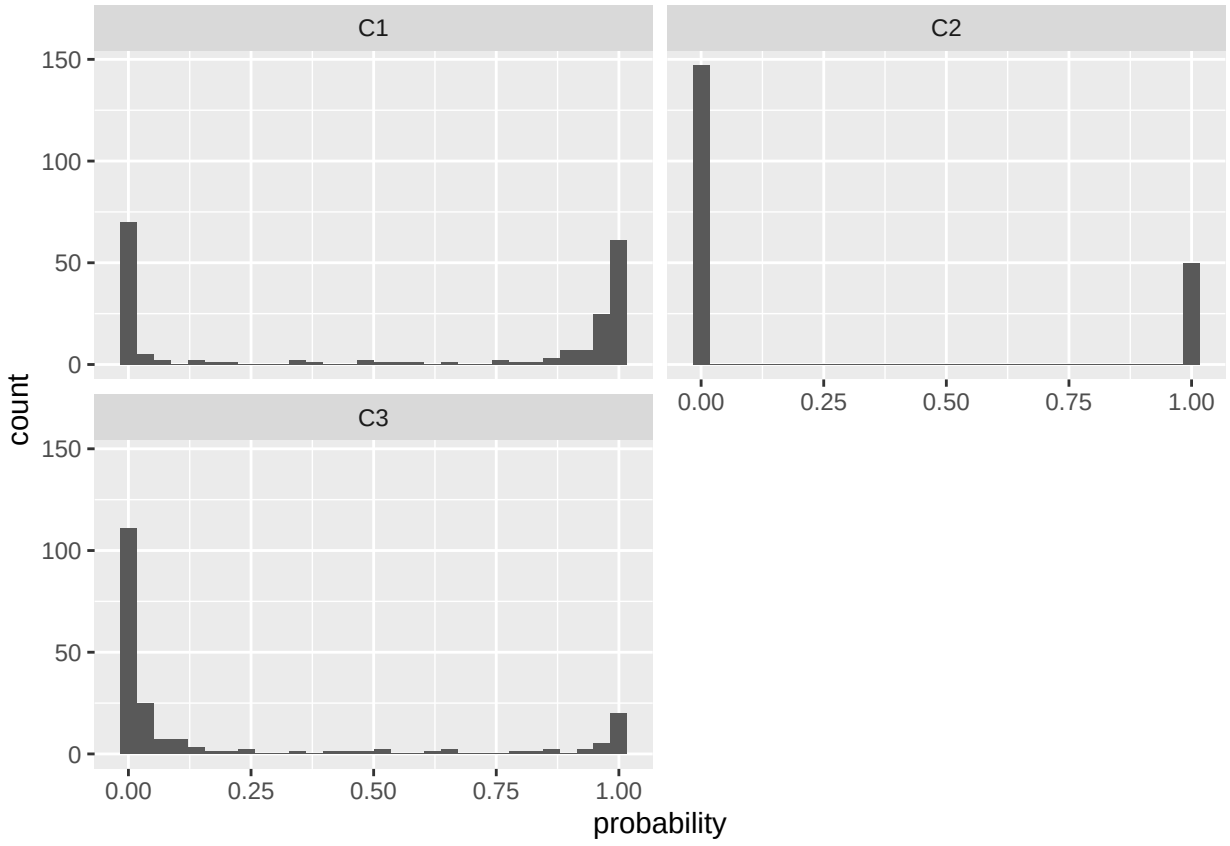



```
prbblts <- modelB1$z
colnames(prbblts) <- paste0('C', 1:3)

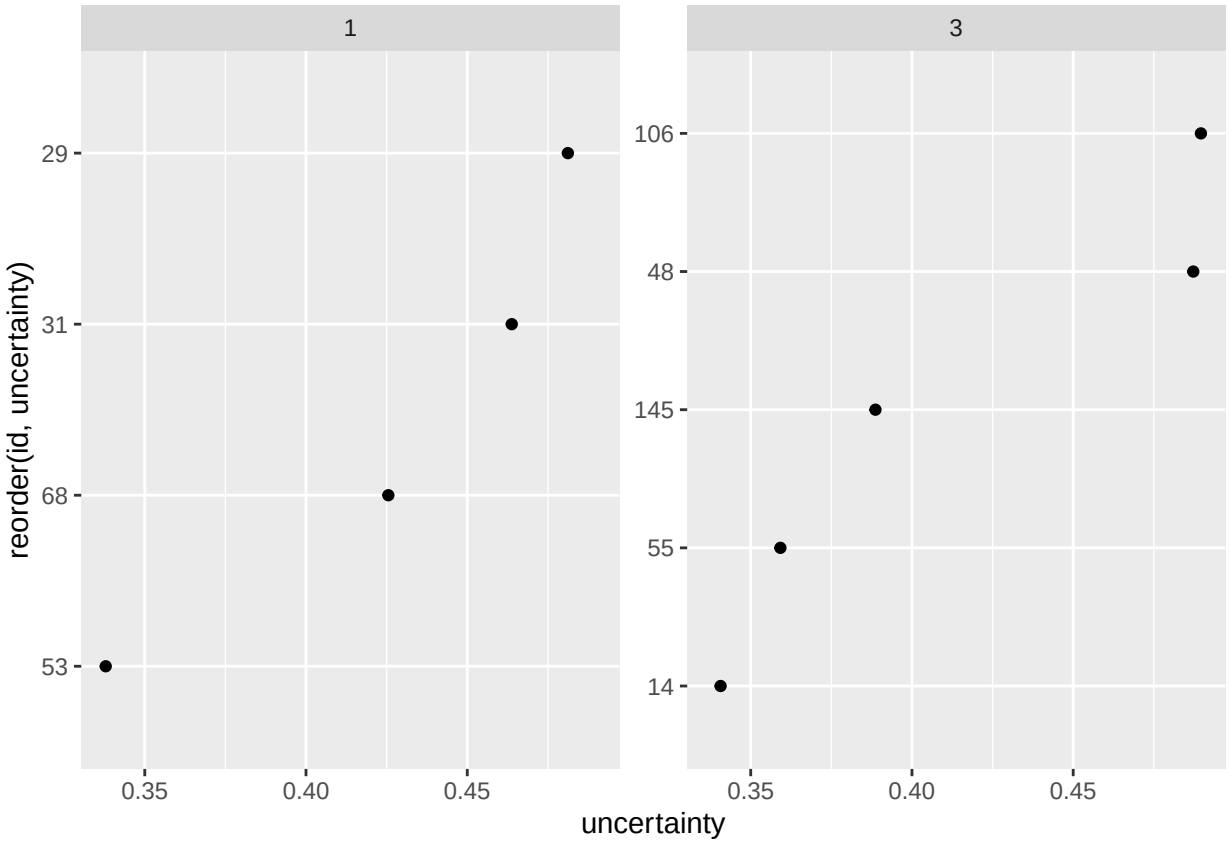
prbblts <- prbblts %>%
  as.data.frame() %>%
  mutate(id = row_number()) %>%
  tidyr::gather(cluster, probability, -id)

ggplot(prbblts, aes(probability)) +
  geom_histogram() +
  facet_wrap(~ cluster, nrow = 2)
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

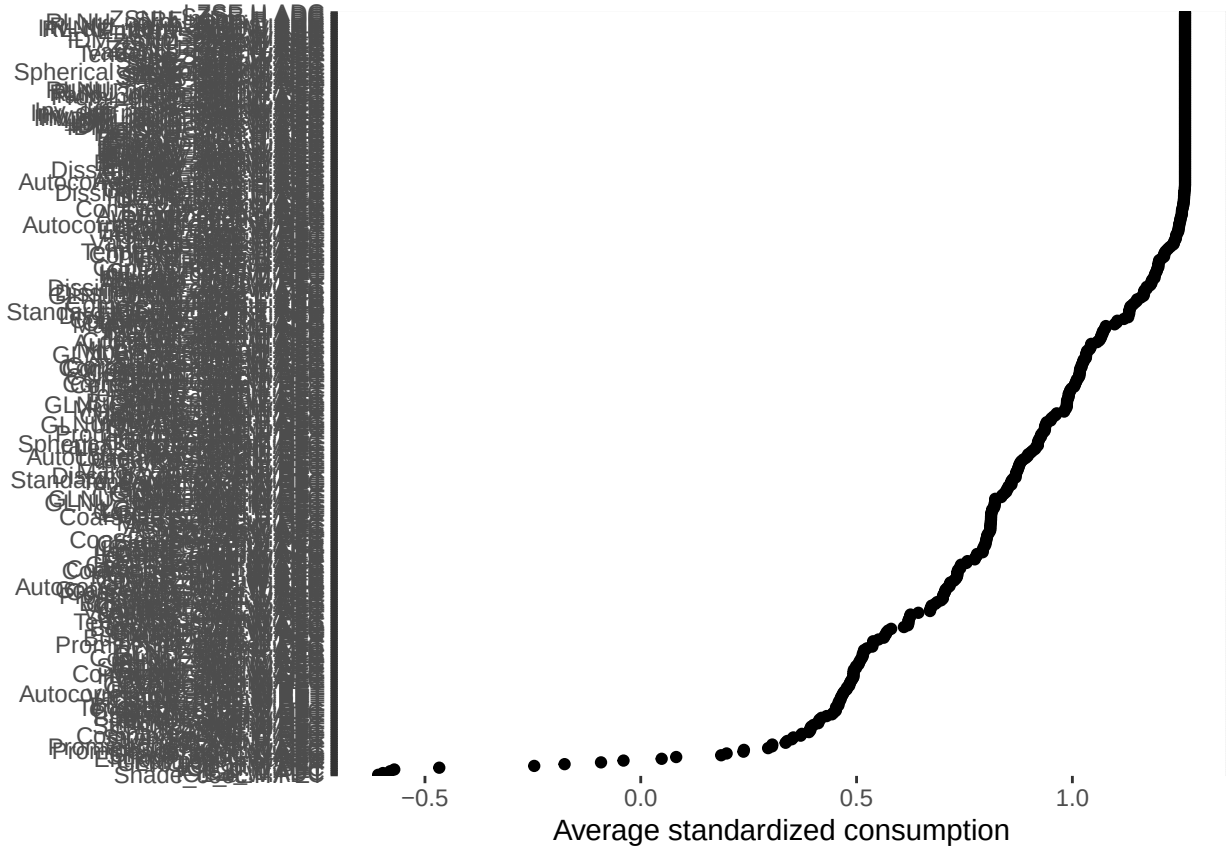



```
uncertainty <- data.frame(
  id = 1:nrow(model3fdata),
  dataficlust = modelB1$classification,
  uncertainty = modelB1$uncertainty
)
uncertainty %>%
  group_by(dataficlust) %>%
  filter(uncertainty > 0.25) %>%
  ggplot(aes(uncertainty, reorder(id, uncertainty))) +
  geom_point() +
  facet_wrap(~ dataficlust, scales = 'free_y', nrow = 1)
```




```
dataficlustB <- model3fdata %>%
  scale() %>%
  as.data.frame() %>%
  mutate(cluster = modelB1$classification) %>%
  filter(cluster == 2) %>%
  select(-cluster)

dataficlustB %>%
  tidyr::gather(product, std_count) %>%
  group_by(product) %>%
  summarize(avg = mean(std_count)) %>%
  ggplot(aes(avg, reorder(product, avg))) +
  geom_point() +
  labs(x = "Average standardized consumption", y = NULL)
```



Conclusion

By the results we can, therefore say that, using k-means clustering the best number of clusters is 2 with SSwithin = 33.2%. Also Hierarchical, gap statistics suggest 9 clusters with 84.90% AC and 84.29%. Lastly, model-based suggest 3 optimal number of clusters with BIC -2632.206.