Modern Data Mining, HW 2

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Due: 11:59 PM, Sunday, 02/25

Contents

Overview

Principle Component Analysis is widely used in data exploration, dimension reduction, data visualization. The aim is to transform original data into uncorrelated linear combinations of the original data while keeping the information contained in the data. High dimensional data tends to show clusters in lower dimensional view.

Clustering Analysis is another form of EDA. Here we are hoping to group data points which are close to each other within the groups and far away between different groups. Clustering using PC's can be effective. Clustering analysis can be very subjective in the way we need to summarize the properties within each group.

Both PCA and Clustering Analysis are so called unsupervised learning. There is no response variables involved in the process.

For supervised learning, we try to find out how does a set of predictors relate to some response variable of the interest. Multiple regression is still by far, one of the most popular methods. We use a linear model as a working model for its simplicity and interpretability. It is important that we use domain knowledge as much as we can to determine the form of the response as well as the function format of the factors on the other hand.

Important Notice: This homework encompasses material from three modules. You will have a period of three weeks to complete it. Please manage your time accordingly.

0.1 Objectives

- PCA
- SVD
- Clustering Analysis
- Linear Regression

0.2 Review materials

- Study Module 2: PCA
- Study Module 3: Clustering Analysis
- Study Module 4: Multiple regression (Including Simple regression as well)

0.3 Data needed

- `NLSY79.csv`
- `brca_subtype.csv`
- `brca_x_patient.csv`

1 Case study 1: Self-esteem

Self-esteem generally describes a person's overall sense of self-worthiness and personal value. It can play significant role in one's motivation and success throughout the life. Factors that influence self-esteem can be inner thinking, health condition, age, life experiences etc. We will try to identify possible factors in our data that are related to the level of self-esteem.

In the well-cited National Longitudinal Study of Youth (NLSY79), it follows about 13,000 individuals and numerous individual-year information has been gathered through surveys. The survey data is open to public here. Among many variables we assembled a subset of variables including personal demographic variables in different years, household environment in 79, ASVAB test Scores in 81 and Self-Esteem scores in 81 and 87 respectively.

The data is store in `NLSY79.csv`.

Here are the description of variables:

Personal Demographic Variables

- Gender: a factor with levels "female" and "male"
- Education05: years of education completed by 2005
- HeightFeet05, HeightInch05: height measurement. For example, a person of 5'10 will be recorded as HeightFeet05=5, HeightInch05=10.
- Weight05: weight in lbs.
- Income87, Income05: total annual income from wages and salary in 2005.
- Job87 (missing), Job05: job type in 1987 and 2005, including Protective Service Occupations, Food Preparation and Serving Related Occupations, Cleaning and Building Service Occupations, Entertainment Attendants and Related Workers, Funeral Related Occupations, Personal Care and Service Workers, Sales and Related Workers, Office and Administrative Support Workers, Farming, Fishing and Forestry Occupations, Construction Trade and Extraction Workers, Installation, Maintenance and Repairs Workers, Production and Operating Workers, Food Preparation Occupations, Setters, Operators and Tenders, Transportation and Material Moving Workers

Household Environment

- Imagazine: a variable taking on the value 1 if anyone in the respondent's household regularly read magazines in 1979, otherwise 0
- Inewspaper: a variable taking on the value 1 if anyone in the respondent's household regularly read newspapers in 1979, otherwise 0
- Ilibrary: a variable taking on the value 1 if anyone in the respondent's household had a library card in 1979, otherwise 0
- MotherEd: mother's years of education
- FatherEd: father's years of education
- FamilyIncome78

Variables Related to ASVAB test Scores in 1981

Test	Description
AFQT	percentile score on the AFQT intelligence test in 1981
Coding	score on the Coding Speed test in 1981
Auto	score on the Automotive and Shop test in 1981
Mechanic	score on the Mechanic test in 1981
Elec	score on the Electronics Information test in 1981
Science	score on the General Science test in 1981
Math	score on the Math test in 1981
Arith	score on the Arithmetic Reasoning test in 1981
Word	score on the Word Knowledge Test in 1981
Parag	score on the Paragraph Comprehension test in 1981
Numer	score on the Numerical Operations test in 1981

Self-Esteem test 81 and 87

We have two sets of self-esteem test, one in 1981 and the other in 1987. Each set has same 10 questions. They are labeled as `Esteem81` and `Esteem87` respectively followed by the question number. For example, `Esteem81_1` is Esteem question 1 in 81.

The following 10 questions are answered as 1: strongly agree, 2: agree, 3: disagree, 4: strongly disagree

- Esteem 1: "I am a person of worth"
- Esteem 2: "I have a number of good qualities"
- Esteem 3: "I am inclined to feel like a failure"
- Esteem 4: "I do things as well as others"
- Esteem 5: "I do not have much to be proud of"
- Esteem 6: "I take a positive attitude towards myself and others"
- Esteem 7: "I am satisfied with myself"
- Esteem 8: "I wish I could have more respect for myself"
- Esteem 9: "I feel useless at times"
- Esteem 10: "I think I am no good at all"

1.1 Data preparation

Load the data. Do a quick EDA to get familiar with the data set. Pay attention to the unit of each variable. Are there any missing values?

Answer: There are no missing values as there are no null values.

```
## 'data.frame':    2431 obs. of  46 variables:
##  $ Subject       : int  2 6 7 8 9 13 16 17 18 20 ...
##  $ Gender        : chr  "female" "male" "male" "female" ...
##  $ Education05   : int  12 16 12 14 14 16 13 13 13 17 ...
##  $ Income87      : int  16000 18000 0 9000 15000 2200 27000 20000 28000 27000 ...
##  $ Job05         : chr  "4700 TO 4960: Sales and Related Workers" "10 TO 430: Executive, Administrat
##  $ Income05      : int  5500 65000 19000 36000 65000 8000 71000 43000 120000 64000 ...
##  $ Weight05      : int  160 187 175 246 180 235 160 188 173 130 ...
##  $ HeightFeet05  : int  5 5 5 5 5 6 5 5 5 5 ...
##  $ HeightInch05  : int  2 5 9 3 6 0 4 10 9 4 ...
##  $ Imagazine     : int  1 0 1 1 1 1 1 1 1 1 ...
##  $ Inewspaper    : int  1 1 1 1 1 1 1 1 1 1 ...
##  $ Ilibrary      : int  1 1 1 1 1 1 1 1 1 1 ...
##  $ MotherEd      : int  5 12 12 9 12 12 12 12 12 12 ...
##  $ FatherEd      : int  8 12 12 6 10 16 12 15 16 18 ...
##  $ FamilyIncome78: int  20000 35000 8502 7227 17000 20000 48000 15000 4510 50000 ...
##  $ Science       : int  6 23 14 18 17 16 13 19 22 21 ...
##  $ Arith         : int  8 30 14 13 21 30 17 29 30 17 ...
##  $ Word          : int  15 35 27 35 28 29 30 33 35 28 ...
##  $ Parag         : int  6 15 8 12 10 13 12 13 14 14 ...
##  $ Number        : int  29 45 32 24 40 36 49 35 48 39 ...
##  $ Coding        : int  52 68 35 48 46 30 58 58 61 54 ...
##  $ Auto          : int  9 21 13 11 13 21 11 18 21 18 ...
##  $ Math          : int  6 23 11 4 13 24 17 21 23 20 ...
##  $ Mechanic      : int  10 21 9 12 13 19 11 19 16 20 ...
##  $ Elec          : int  5 19 11 12 15 16 10 16 17 13 ...
##  $ AFQT          : num  6.84 99.39 47.41 44.02 59.68 ...
##  $ Esteem81_1    : int  1 2 2 1 1 1 2 2 2 1 ...
##  $ Esteem81_2    : int  1 1 1 1 1 1 2 2 2 1 ...
##  $ Esteem81_3    : int  4 4 3 3 4 4 3 3 3 3 ...
##  $ Esteem81_4    : int  1 2 2 2 1 1 2 2 2 1 ...
##  $ Esteem81_5    : int  3 4 3 3 1 4 3 3 3 3 ...
##  $ Esteem81_6    : int  3 2 2 2 1 1 2 2 2 2 ...
```

```
##  $ Esteem81_7    : int  1 2 2 3 1 1 3 2 2 1 ...
##  $ Esteem81_8    : int  3 4 2 3 4 4 3 3 3 3 ...
##  $ Esteem81_9    : int  3 3 3 3 4 4 3 3 3 3 ...
##  $ Esteem81_10   : int  3 4 3 3 4 4 3 3 3 3 ...
##  $ Esteem87_1    : int  2 1 2 1 1 1 1 2 1 1 ...
##  $ Esteem87_2    : int  1 1 2 1 1 1 1 2 1 1 ...
##  $ Esteem87_3    : int  4 4 4 3 4 4 4 3 4 4 ...
##  $ Esteem87_4    : int  1 1 2 1 1 1 2 2 1 4 ...
##  $ Esteem87_5    : int  2 4 4 4 4 4 4 3 4 4 ...
##  $ Esteem87_6    : int  2 1 2 2 1 1 2 2 1 1 ...
##  $ Esteem87_7    : int  2 2 2 1 1 2 2 2 2 1 ...
##  $ Esteem87_8    : int  3 3 4 2 4 4 4 3 4 3 ...
##  $ Esteem87_9    : int  3 2 3 2 4 4 3 3 3 4 ...
##  $ Esteem87_10   : int  4 4 4 2 4 4 4 3 4 4 ...

##     Subject         Gender           Education05      Income87    
##  Min.   :    2   Length:2431        Min.   : 6.0   Min.   :   -2  
##  1st Qu.: 1592   Class :character   1st Qu.:12.0   1st Qu.: 4500  
##  Median : 3137   Mode  :character   Median :13.0   Median :12000  
##  Mean   : 3504                      Mean   :13.9   Mean   :13399  
##  3rd Qu.: 4668                      3rd Qu.:16.0   3rd Qu.:19000  
##  Max.   :12140                      Max.   :20.0   Max.   :59387  
##     Job05              Income05        Weight05    HeightFeet05  
##  Length:2431        Min.   :    63   Min.   : 81   Min.   :-4.00  
##  Class :character   1st Qu.: 22650   1st Qu.:150   1st Qu.: 5.00  
##  Mode  :character   Median : 38500   Median :180   Median : 5.00  
##                     Mean   : 49415   Mean   :183   Mean   : 5.18  
##                     3rd Qu.: 61350   3rd Qu.:209   3rd Qu.: 5.00  
##                     Max.   :703637   Max.   :380   Max.   : 8.00  
##   HeightInch05     Imagazine       Inewspaper       Ilibrary       MotherEd   
##  Min.   : 0.00   Min.   :0.000   Min.   :0.000   Min.   :0.00   Min.   : 0.0  
##  1st Qu.: 2.00   1st Qu.:0.000   1st Qu.:1.000   1st Qu.:1.00   1st Qu.:11.0  
##  Median : 5.00   Median :1.000   Median :1.000   Median :1.00   Median :12.0  
##  Mean   : 5.32   Mean   :0.718   Mean   :0.861   Mean   :0.77   Mean   :11.7  
##  3rd Qu.: 8.00   3rd Qu.:1.000   3rd Qu.:1.000   3rd Qu.:1.00   3rd Qu.:12.0  
##  Max.   :11.00   Max.   :1.000   Max.   :1.000   Max.   :1.00   Max.   :20.0  
##     FatherEd    FamilyIncome78     Science         Arith           Word     
##  Min.   : 0.0   Min.   :    0   Min.   : 0.0   Min.   : 0.0   Min.   : 0.0  
##  1st Qu.:10.0   1st Qu.:11167   1st Qu.:13.0   1st Qu.:13.0   1st Qu.:23.0  
##  Median :12.0   Median :20000   Median :17.0   Median :19.0   Median :28.0  
##  Mean   :11.8   Mean   :21252   Mean   :16.3   Mean   :18.6   Mean   :26.6  
##  3rd Qu.:14.0   3rd Qu.:27500   3rd Qu.:20.0   3rd Qu.:25.0   3rd Qu.:32.0  
##  Max.   :20.0   Max.   :75001   Max.   :25.0   Max.   :30.0   Max.   :35.0  
##      Parag          Number         Coding          Auto           Math     
##  Min.   : 0.0   Min.   : 0.0   Min.   : 0.0   Min.   : 0.0   Min.   : 0.0  
##  1st Qu.:10.0   1st Qu.:29.0   1st Qu.:38.0   1st Qu.:10.0   1st Qu.: 9.0  
##  Median :12.0   Median :36.0   Median :48.0   Median :14.0   Median :14.0  
##  Mean   :11.2   Mean   :35.5   Mean   :47.1   Mean   :14.3   Mean   :14.3  
##  3rd Qu.:14.0   3rd Qu.:44.0   3rd Qu.:57.0   3rd Qu.:18.0   3rd Qu.:20.0  
##  Max.   :15.0   Max.   :50.0   Max.   :84.0   Max.   :25.0   Max.   :25.0  
##     Mechanic         Elec           AFQT         Esteem81_1     Esteem81_2  
##  Min.   : 0.0   Min.   : 0.0   Min.   :  0.0   Min.   :1.00   Min.   :1.00  
##  1st Qu.:11.0   1st Qu.: 9.0   1st Qu.: 31.9   1st Qu.:1.00   1st Qu.:1.00  
##  Median :14.0   Median :12.0   Median : 57.0   Median :1.00   Median :1.00  
```

```
##  Mean   :14.4   Mean   :11.6   Mean   : 54.7   Mean   :1.42   Mean   :1.42
##  3rd Qu.:18.0   3rd Qu.:15.0   3rd Qu.: 78.2   3rd Qu.:2.00   3rd Qu.:2.00
##  Max.   :25.0   Max.   :20.0   Max.   :100.0   Max.   :4.00   Max.   :4.00
##    Esteem81_3     Esteem81_4     Esteem81_5     Esteem81_6     Esteem81_7
##  Min.   :1.00   Min.   :1.00   Min.   :1.00   Min.   :1.00   Min.   :1.00
##  1st Qu.:3.00   1st Qu.:1.00   1st Qu.:3.00   1st Qu.:1.00   1st Qu.:1.00
##  Median :4.00   Median :2.00   Median :4.00   Median :2.00   Median :2.00
##  Mean   :3.51   Mean   :1.57   Mean   :3.46   Mean   :1.62   Mean   :1.75
##  3rd Qu.:4.00   3rd Qu.:2.00   3rd Qu.:4.00   3rd Qu.:2.00   3rd Qu.:2.00
##  Max.   :4.00   Max.   :4.00   Max.   :4.00   Max.   :4.00   Max.   :4.00
##    Esteem81_8     Esteem81_9    Esteem81_10    Esteem87_1     Esteem87_2
##  Min.   :1.00   Min.   :1.00   Min.   :1.0   Min.   :1.00   Min.   :1.0
##  1st Qu.:3.00   1st Qu.:3.00   1st Qu.:3.0   1st Qu.:1.00   1st Qu.:1.0
##  Median :3.00   Median :3.00   Median :3.0   Median :1.00   Median :1.0
##  Mean   :3.13   Mean   :3.16   Mean   :3.4   Mean   :1.38   Mean   :1.4
##  3rd Qu.:4.00   3rd Qu.:4.00   3rd Qu.:4.0   3rd Qu.:2.00   3rd Qu.:2.0
##  Max.   :4.00   Max.   :4.00   Max.   :4.0   Max.   :4.00   Max.   :4.0
##    Esteem87_3     Esteem87_4    Esteem87_5     Esteem87_6     Esteem87_7
##  Min.   :1.00   Min.   :1.0   Min.   :1.00   Min.   :1.00   Min.   :1.00
##  1st Qu.:3.00   1st Qu.:1.0   1st Qu.:3.00   1st Qu.:1.00   1st Qu.:1.00
##  Median :4.00   Median :1.0   Median :4.00   Median :2.00   Median :2.00
##  Mean   :3.58   Mean   :1.5   Mean   :3.53   Mean   :1.59   Mean   :1.72
##  3rd Qu.:4.00   3rd Qu.:2.0   3rd Qu.:4.00   3rd Qu.:2.00   3rd Qu.:2.00
##  Max.   :4.00   Max.   :4.0   Max.   :4.00   Max.   :4.00   Max.   :4.00
##    Esteem87_8    Esteem87_9    Esteem87_10
##  Min.   :1.0   Min.   :1.00   Min.   :1.00
##  1st Qu.:3.0   1st Qu.:3.00   1st Qu.:3.00
##  Median :3.0   Median :3.00   Median :3.00
##  Mean   :3.1   Mean   :3.06   Mean   :3.37
##  3rd Qu.:4.0   3rd Qu.:4.00   3rd Qu.:4.00
##  Max.   :4.0   Max.   :4.00   Max.   :4.00
```

```
##  [1] ""
##  [2] "10 TO 430: Executive, Administrative and Managerial Occupations"
##  [3] "1000 TO 1240: Mathematical and Computer Scientists"
##  [4] "1300 TO 1560: Engineers, Architects, Surveyers, Engineering and Related Technicians"
##  [5] "1600 TO 1760: Physical Scientists"
##  [6] "1800 TO 1860: Social Scientists and Related Workers"
##  [7] "1900 TO 1960: Life, Physical and Social Science Technicians"
##  [8] "2000 TO 2060: Counselors, Sociala and Religious Workers"
##  [9] "2100 TO 2150: Lawyers, Judges and Legal Support Workers"
## [10] "2200 TO 2340: Teachers"
## [11] "2400 TO 2550: Education, Training and Library Workers"
## [12] "2600 TO 2760: Entertainers and Performers, Sports and Related Workers"
## [13] "2800 TO 2960: Media and Communications Workers"
## [14] "3000 TO 3260: Health Diagnosing and Treating Practitioners"
## [15] "3300 TO 3650: Health Care Technical and Support Occupations"
## [16] "3700 TO 3950: Protective Service Occupations"
## [17] "4000 TO 4160: Food Preparation and Serving Related Occupations"
## [18] "4200 TO 4250: Cleaning and Building Service Occupations"
## [19] "4300 TO 4430: Entertainment Attendants and Related Workers"
## [20] "4500 TO 4650: Personal Care and Service Workers"
## [21] "4700 TO 4960: Sales and Related Workers"
## [22] "500 TO 950: Management Related Occupations"
```

```
## [23] "5000 TO 5930: Office and Administrative Support Workers"
## [24] "6000 TO 6130: Farming, Fishing and Forestry Occupations"
## [25] "6200 TO 6940: Construction Trade and Extraction Workers"
## [26] "7000 TO 7620: Installation, Maintenance and Repairs Workers"
## [27] "7700 TO 7750: Production and Operating Workers"
## [28] "7800 TO 7850: Food Preparation Occupations"
## [29] "7900 TO 8960: Setters, Operators and Tenders"
## [30] "9000 TO 9750: Transportation and Material Moving Workers"
## [31] "9990: Uncodeable"

##
##
##                                                                                     56
##                      10 TO 430: Executive, Administrative and Managerial Occupations
##                                                                                    377
##                                   1000 TO 1240: Mathematical and Computer Scientists
##                                                                                     64
## 1300 TO 1560: Engineers, Architects, Surveyers, Engineering and Related Technicians
##                                                                                     53
##                                                    1600 TO 1760: Physical Scientists
##                                                                                      4
##                                  1800 TO 1860: Social Scientists and Related Workers
##                                                                                      6
##                          1900 TO 1960: Life, Physical and Social Science Technicians
##                                                                                      7
##                              2000 TO 2060: Counselors, Sociala and Religious Workers
##                                                                                     41
##                              2100 TO 2150: Lawyers, Judges and Legal Support Workers
##                                                                                     15
##                                                               2200 TO 2340: Teachers
##                                                                                    120
##                                 2400 TO 2550: Education, Training and Library Workers
##                                                                                     29
##                 2600 TO 2760: Entertainers and Performers, Sports and Related Workers
##                                                                                     24
##                                        2800 TO 2960: Media and Communications Workers
##                                                                                     13
##                           3000 TO 3260: Health Diagnosing and Treating Practitioners
##                                                                                     74
##                          3300 TO 3650: Health Care Technical and Support Occupations
##                                                                                     99
##                                          3700 TO 3950: Protective Service Occupations
##                                                                                     54
##                       4000 TO 4160: Food Preparation and Serving Related Occupations
##                                                                                     68
##                              4200 TO 4250: Cleaning and Building Service Occupations
##                                                                                     67
##                             4300 TO 4430: Entertainment Attendants and Related Workers
##                                                                                     10
##                                         4500 TO 4650: Personal Care and Service Workers
##                                                                                     42
##                                                 4700 TO 4960: Sales and Related Workers
##                                                                                    205
##                                             500 TO 950: Management Related Occupations
```

```
##                                                                   108
##                       5000 TO 5930: Office and Administrative Support Workers
##                                                                   360
##                       6000 TO 6130: Farming, Fishing and Forestry Occupations
##                                                                     9
##                       6200 TO 6940: Construction Trade and Extraction Workers
##                                                                   135
##                    7000 TO 7620: Installation, Maintenance and Repairs Workers
##                                                                   108
##                             7700 TO 7750: Production and Operating Workers
##                                                                    49
##                                8000 TO 7850: Food Preparation Occupations
##                                                                     4
##                              7900 TO 8960: Setters, Operators and Tenders
##                                                                   112
##                     9000 TO 9750: Transportation and Material Moving Workers
##                                                                   117
##                                                      9990: Uncodeable
##                                                                     1
```

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

1.2 Self esteem evaluation

Let concentrate on Esteem scores evaluated in 87.

0. First do a quick summary over all the `Esteem` variables. Pay attention to missing values, any peculiar numbers etc. How do you fix problems discovered if there is any? Briefly describe what you have done for the data preparation.

Answer: For all of the Esteem variables, the minimum value is 1 and the maximum value is 4, which is as expected. There are no missing values. There is nothing to fix.

```
##    Esteem87_1     Esteem87_2    Esteem87_3     Esteem87_4    Esteem87_5
##  Min.   :1.00   Min.   :1.0   Min.   :1.00   Min.   :1.0   Min.   :1.00
##  1st Qu.:1.00   1st Qu.:1.0   1st Qu.:3.00   1st Qu.:1.0   1st Qu.:3.00
##  Median :1.00   Median :1.0   Median :4.00   Median :1.0   Median :4.00
##  Mean   :1.38   Mean   :1.4   Mean   :3.58   Mean   :1.5   Mean   :3.53
##  3rd Qu.:2.00   3rd Qu.:2.0   3rd Qu.:4.00   3rd Qu.:2.0   3rd Qu.:4.00
##  Max.   :4.00   Max.   :4.0   Max.   :4.00   Max.   :4.0   Max.   :4.00
##    Esteem87_6     Esteem87_7     Esteem87_8    Esteem87_9     Esteem87_10
##  Min.   :1.00   Min.   :1.00   Min.   :1.0   Min.   :1.00   Min.   :1.00
##  1st Qu.:1.00   1st Qu.:1.00   1st Qu.:3.0   1st Qu.:3.00   1st Qu.:3.00
##  Median :2.00   Median :2.00   Median :3.0   Median :3.00   Median :3.00
##  Mean   :1.59   Mean   :1.72   Mean   :3.1   Mean   :3.06   Mean   :3.37
##  3rd Qu.:2.00   3rd Qu.:2.00   3rd Qu.:4.0   3rd Qu.:4.00   3rd Qu.:4.00
##  Max.   :4.00   Max.   :4.00   Max.   :4.0   Max.   :4.00   Max.   :4.00
```

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

1. Please note that higher scores on Esteem questions 1, 2, 4, 6, and 7 indicate higher self-esteem, whereas higher scores on the remaining questions suggest lower self-esteem. To maintain consistency,

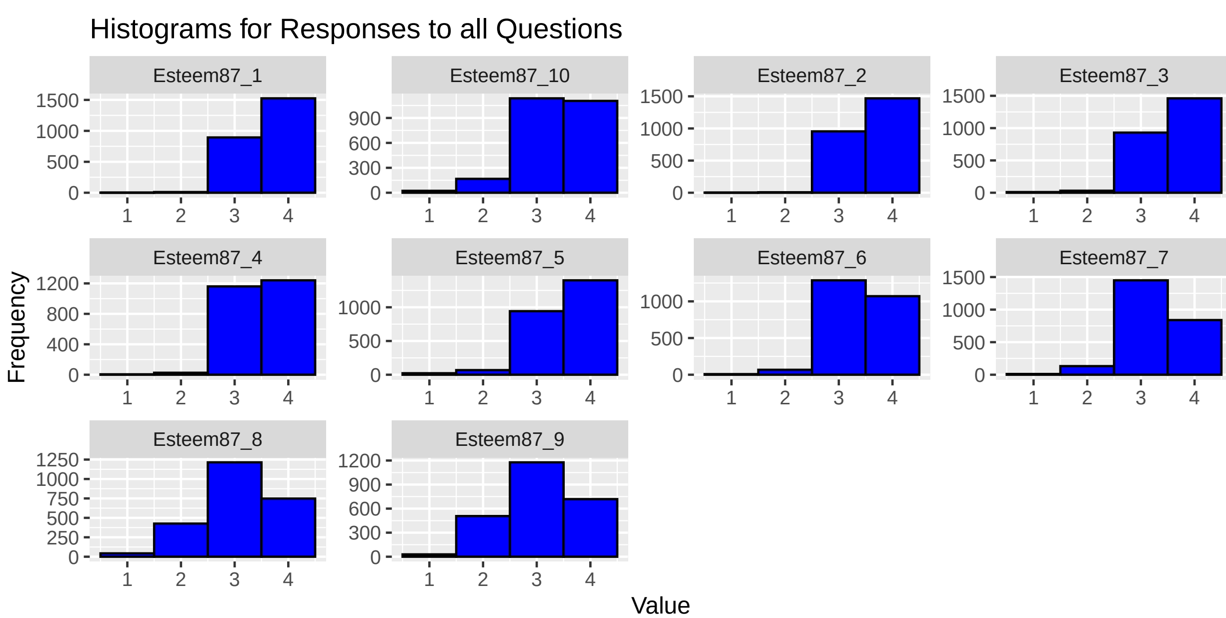
consider reversing the scores of certain Esteem questions. For example, if the esteem data is stored in `data.esteem`, you can use the code `data.esteem[, c(1, 2, 4, 6, 7)] <- 5 - data.esteem[, c(1, 2, 4, 6, 7)]` to invert the scores.

Answer: See .rmd document.

2. Write a brief summary with necessary plots about the 10 esteem measurements.

Answer: After correcting the responses such that higher scores correspond to higher self-esteem, we see that all of the questions have more weight towards the right, meaning that most participants gave responses that indicate higher self-esteem. However, questions 6 through 9 have a mass that is more centered around the middle, indicating that respondents have slightly lower self-esteem for these questions.

```
##    Esteem87_1     Esteem87_2     Esteem87_3     Esteem87_4     Esteem87_5
##  Min.   :1.00   Min.   :1.0   Min.   :1.00   Min.   :1.0   Min.   :1.00
##  1st Qu.:3.00   1st Qu.:3.0   1st Qu.:3.00   1st Qu.:3.0   1st Qu.:3.00
##  Median :4.00   Median :4.0   Median :4.00   Median :4.0   Median :4.00
##  Mean   :3.62   Mean   :3.6   Mean   :3.58   Mean   :3.5   Mean   :3.53
##  3rd Qu.:4.00   3rd Qu.:4.0   3rd Qu.:4.00   3rd Qu.:4.0   3rd Qu.:4.00
##  Max.   :4.00   Max.   :4.0   Max.   :4.00   Max.   :4.0   Max.   :4.00
##    Esteem87_6     Esteem87_7     Esteem87_8     Esteem87_9     Esteem87_10
##  Min.   :1.00   Min.   :1.00   Min.   :1.0   Min.   :1.00   Min.   :1.00
##  1st Qu.:3.00   1st Qu.:3.00   1st Qu.:3.0   1st Qu.:3.00   1st Qu.:3.00
##  Median :3.00   Median :3.00   Median :3.0   Median :3.00   Median :3.00
##  Mean   :3.41   Mean   :3.28   Mean   :3.1   Mean   :3.06   Mean   :3.37
##  3rd Qu.:4.00   3rd Qu.:4.00   3rd Qu.:4.0   3rd Qu.:4.00   3rd Qu.:4.00
##  Max.   :4.00   Max.   :4.00   Max.   :4.0   Max.   :4.00   Max.   :4.00
```

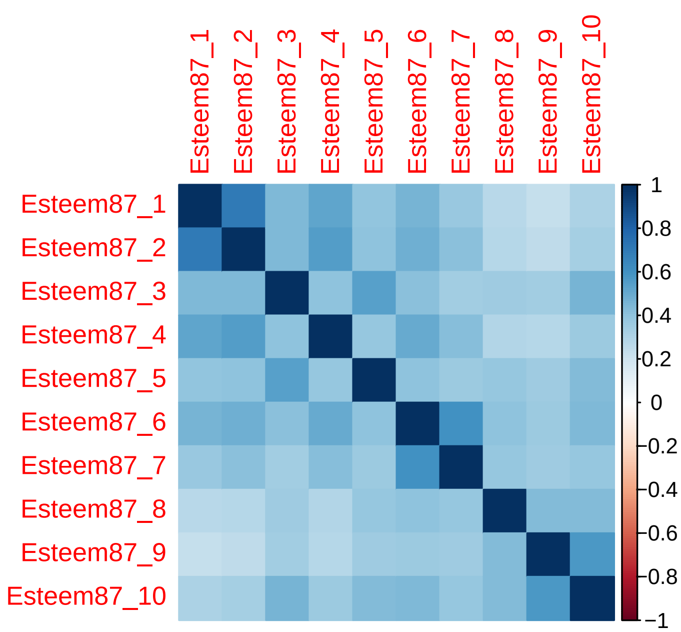


3. Do esteem scores all positively correlated? Report the pairwise correlation table and write a brief summary.

Answer: All esteem scores are positively correlated; the minimum value in each row is positive. Questions that are adjacent to each other (e.g., questions 1 and 2 or questions 6 and 7) tend to have stronger correlations than questions that are further away from each other.

```
##  Esteem87_1  Esteem87_2  Esteem87_3  Esteem87_4  Esteem87_5  Esteem87_6
##       0.236       0.259       0.343       0.287       0.354       0.364
##  Esteem87_7  Esteem87_8  Esteem87_9 Esteem87_10
##       0.343       0.273       0.236       0.312
```

```
##    Esteem87_1      Esteem87_2      Esteem87_3      Esteem87_4
##  Min.   :0.236   Min.   :0.259   Min.   :0.343   Min.   :0.287
##  1st Qu.:0.328   1st Qu.:0.348   1st Qu.:0.365   1st Qu.:0.369
##  Median :0.424   Median :0.427   Median :0.427   Median :0.415
##  Mean   :0.474   Mean   :0.486   Mean   :0.476   Mean   :0.475
##  3rd Qu.:0.512   3rd Qu.:0.534   3rd Qu.:0.457   3rd Qu.:0.523
##  Max.   :1.000   Max.   :1.000   Max.   :1.000   Max.   :1.000
##    Esteem87_5      Esteem87_6      Esteem87_7      Esteem87_8
##  Min.   :0.354   Min.   :0.364   Min.   :0.343   Min.   :0.273
##  1st Qu.:0.381   1st Qu.:0.409   1st Qu.:0.372   1st Qu.:0.309
##  Median :0.401   Median :0.453   Median :0.389   Median :0.385
##  Mean   :0.468   Mean   :0.508   Mean   :0.465   Mean   :0.425
##  3rd Qu.:0.428   3rd Qu.:0.502   3rd Qu.:0.419   3rd Qu.:0.425
##  Max.   :1.000   Max.   :1.000   Max.   :1.000   Max.   :1.000
##    Esteem87_9     Esteem87_10
##  Min.   :0.236   Min.   :0.312
##  1st Qu.:0.303   1st Qu.:0.372
##  Median :0.353   Median :0.437
##  Mean   :0.421   Mean   :0.475
##  3rd Qu.:0.414   3rd Qu.:0.456
##  Max.   :1.000   Max.   :1.000
```



4. PCA on 10 esteem measurements. (centered but no scaling)

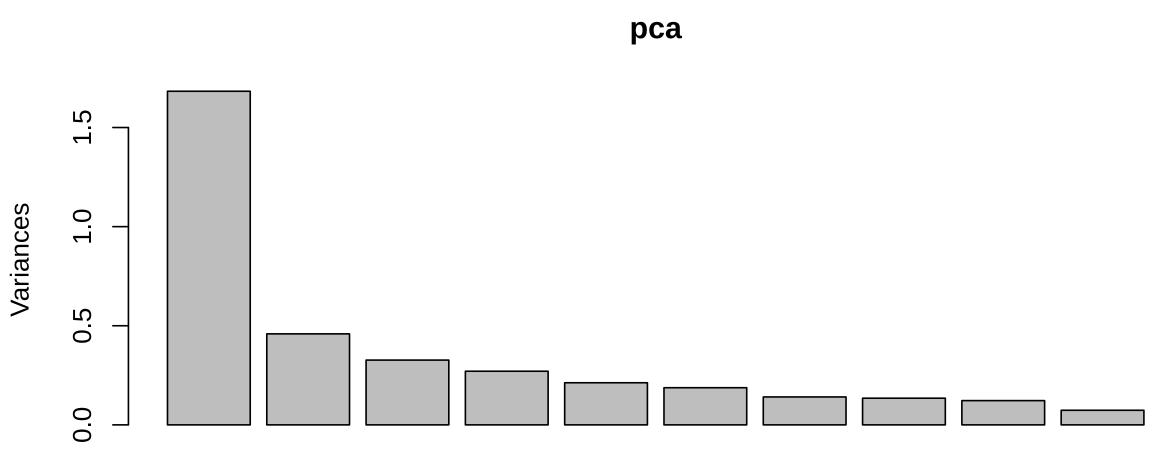
a) Report the PC1 and PC2 loadings. Are they unit vectors? Are they orthogonal?

Answer: The PC1 loading is (-0.235, -0.244, 0.279, -0.261, 0.312, -0.313, -0.299, 0.393, 0.398, 0.376). The PC2 loading is (0.374, 0.367, -0.149, 0.321, -0.131, 0.209, 0.163, 0.332, 0.578, 0.260). As shown in the table below, PC1 and PC2 both are unit vectors and are orthogonal to each other.

```
## [1] "sdev"     "rotation" "center"   "scale"    "x"
```

	PC1	PC2
Esteem87_1	0.235	-0.374
Esteem87_2	0.244	-0.367
Esteem87_3	0.279	-0.149
Esteem87_4	0.261	-0.321
Esteem87_5	0.312	-0.131
Esteem87_6	0.313	-0.209
Esteem87_7	0.299	-0.163
Esteem87_8	0.393	0.332
Esteem87_9	0.398	0.578
Esteem87_10	0.376	0.260

	PC1	PC2
PC1	1	0
PC2	0	1



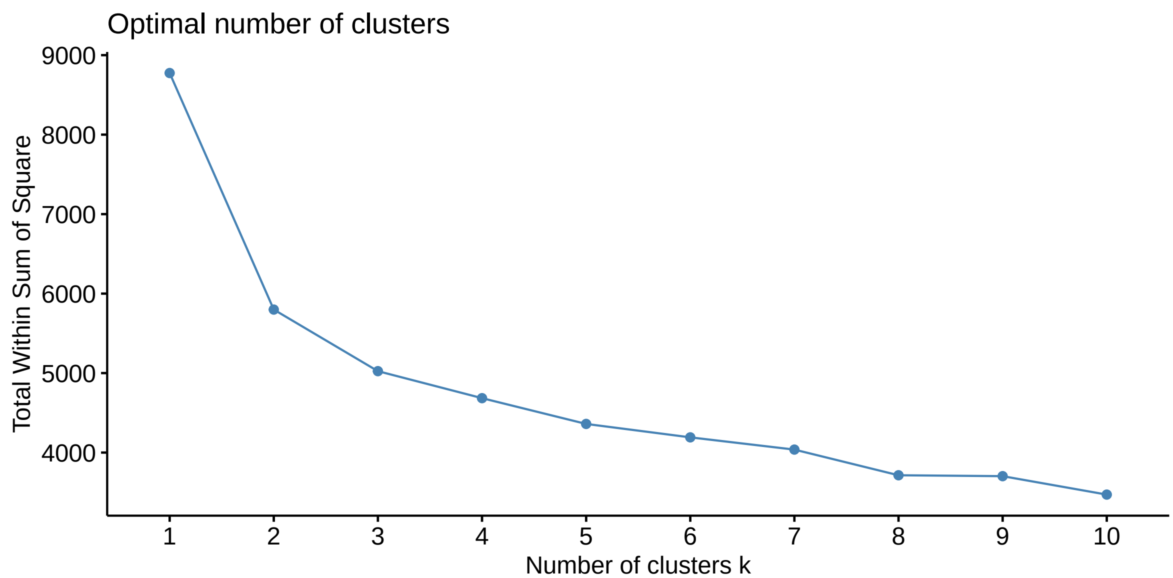

```
b) Are there good interpretations for PC1 and PC2? (If loadings are all negative, take the positive loa

TODO: can someone see if they can interpet PC2...

 \textcolor{red}{\textbf{Answer:}} We can interpret PC1 as the difference between the total score for Qu
```

```
c) How is the PC1 score obtained for each subject? Write down the formula.

 \textcolor{red}{\textbf{Answer:}} $$PC1 = -0.235 \times (Q1_score) + -0.244 \times (Q2_score) + 0.279 \

d) Are PC1 scores and PC2 scores in the data uncorrelated?

\textcolor{red}{\textbf{Answer:}} Yes, the PC1 and PC2 scores are uncorrelated. As shown in the table, t


|    |  PC1|   PC2|
|:---|----:|-----:|
|PC1 | 1.68| 0.000|
|PC2 | 0.00| 0.459|

e) Plot PVE (Proportion of Variance Explained) and summarize the plot.

\textcolor{red}{\textbf{Answer:}} The plot shows that PC1 explains almost 50% of the variation and PC2 e

![](hw2_sp2024_files/figure-latex/unnamed-chunk-8-1.pdf)<!-- -->

f) Also plot CPVE (Cumulative Proportion of Variance Explained). What proportion of the variance in the

\textcolor{red}{\textbf{Answer:}} Approximately 60% of variance in the data is explained by the first 2

![](hw2_sp2024_files/figure-latex/unnamed-chunk-9-1.pdf)<!-- -->

g) PC's provide us with a low dimensional view of the self-esteem scores. Use a biplot with the first tw

TODO: PC2 interpretation???

\textcolor{red}{\textbf{Answer:}} The biplot shows that PC1 roughly corresponds to the difference betwe

![](hw2_sp2024_files/figure-latex/unnamed-chunk-10-1.pdf)<!-- -->
```

5. Apply k-means to cluster subjects on the original esteem scores

   a) Find a reasonable number of clusters using within sum of squared with elbow rules.

   Answer: Using the elbow method, it appears that 2 is a reasonable number of clusters.



b) Can you summarize common features within each cluster?

Answer: Cluster 1 is characterized by higher scores for questions 3, 5, 8, 9, and 10. Cluster 2 is characterized by higher scores for questions 1, 2, 4, 6, and 7. This seems to roughly correspond to PC1, which can be interpreted as the approximate difference betwen the total score for questions 3, 5, 8, 9, and 10 and the total score for questions 1, 2, 4, 6, and 7.

```
##        Esteem87_1 Esteem87_2 Esteem87_3 Esteem87_4 Esteem87_5 Esteem87_6
## 1               3          4          4          4          2          3
## 2               4          4          4          4          4          4
## 3               3          3          4          3          4          3
## 4               4          4          3          4          4          3
## 5               4          4          4          4          4          4
## 6               4          4          4          4          4          4
## 7               4          4          4          3          4          3
## 8               3          3          3          3          3          3
## 9               4          4          4          4          4          4
## 10              4          4          4          1          4          4
## 11              4          4          4          4          4          4
## 12              3          3          2          2          3          2
## 13              4          4          4          4          4          4
## 14              4          4          4          4          4          4
## 15              3          3          4          3          4          3
## 16              3          3          4          3          4          3
## 17              4          4          4          4          4          4
## 18              4          4          4          4          4          4
## 19              3          3          3          3          3          3
## 20              3          3          3          3          4          3
## 21              3          3          4          3          3          3
## 22              3          3          3          3          3          3
## 23              4          4          4          4          1          4
## 24              4          4          4          4          4          4
## 25              4          4          4          4          4          4
## 26              4          4          4          4          4          4
## 27              4          4          4          4          4          3
```

```
## 28           3     3     3     3     3     3
## 29           4     3     4     4     4     4
## 30           3     3     3     3     3     3
## 31           4     4     4     4     4     3
## 32           4     4     4     3     4     3
## 33           4     4     4     4     4     3
## 34           4     4     4     4     3     1
## 35           4     4     4     4     4     4
## 36           4     4     4     4     4     4
## 37           3     3     4     4     4     4
## 38           4     3     4     4     3     3
## 39           4     4     4     4     4     4
## 40           4     4     4     4     4     4
## 41           4     4     4     4     4     4
## 42           4     4     4     4     4     4
## 43           4     4     4     4     4     4
## 44           4     4     3     3     4     3
## 45           4     4     4     4     4     4
## 46           4     4     4     4     4     4
## 47           3     3     3     3     3     3
## 48           3     3     3     3     3     3
## 49           4     4     4     4     4     4
## 50           4     4     4     4     4     3
## 51           4     4     4     4     4     4
## 52           4     4     4     4     4     4
## 53           4     4     4     3     4     3
## 54           4     3     4     3     4     2
## 55           4     4     4     4     4     4
## 56           3     3     3     3     3     3
## 57           4     3     4     4     4     3
## 58           3     3     3     3     3     3
## 59           4     4     4     3     4     4
## 60           4     4     4     4     4     4
## 61           4     4     4     4     4     4
## 62           4     4     4     4     4     4
## 63           3     4     4     3     4     3
## 64           4     4     4     4     4     4
## 65           3     3     4     4     4     4
## 66           4     3     3     3     4     3
## 67           3     3     4     3     4     3
## 68           3     3     2     3     4     3
## 69           4     4     4     4     4     4
## 70           3     3     3     3     3     3
## 71           3     3     3     3     3     3
## 72           4     4     4     4     4     4
## 73           4     4     4     4     4     4
## 74           3     3     3     3     3     3
## 75           4     4     4     4     4     4
## 76           4     4     4     4     4     4
## 77           4     4     4     4     3     3
## 78           3     3     4     3     4     3
## 79           3     3     3     3     2     3
## 80           4     4     4     4     4     4
## 81           3     3     3     3     3     3
```

```
## 82     4  4  4  4  4  4
## 83     4  4  4  4  4  4
## 84     4  4  3  3  4  4
## 85     4  4  4  4  4  4
## 86     3  3  3  3  3  3
## 87     4  4  4  4  4  4
## 88     4  4  4  4  4  3
## 89     4  4  4  4  4  4
## 90     4  4  4  3  4  3
## 91     4  3  4  4  2  3
## 92     4  4  3  3  3  3
## 93     3  3  3  3  3  4
## 94     3  3  3  3  3  3
## 95     4  4  3  3  3  4
## 96     4  4  4  4  4  4
## 97     3  4  4  4  4  4
## 98     3  4  4  4  4  4
## 99     4  4  3  3  3  3
## 100    4  4  4  4  4  3
## 101    4  4  4  4  4  4
## 102    4  4  4  4  4  4
## 103    4  4  4  4  4  4
## 104    4  4  4  4  4  4
## 105    3  3  3  3  3  3
## 106    4  4  4  3  4  3
## 107    4  4  4  4  2  4
## 108    4  3  3  3  3  3
## 109    4  4  4  4  4  4
## 110    3  3  4  4  4  4
## 111    3  3  3  3  3  3
## 112    3  4  4  4  4  4
## 113    4  4  4  4  4  4
## 114    4  4  3  4  4  4
## 115    4  4  4  4  4  4
## 116    3  3  3  3  3  3
## 117    4  4  4  4  4  4
## 118    4  4  4  4  4  4
## 119    3  3  4  3  4  3
## 120    3  3  4  3  4  4
## 121    4  4  4  4  4  4
## 122    4  4  4  4  4  4
## 123    4  4  4  4  4  4
## 124    4  4  4  4  4  4
## 125    4  4  3  3  3  3
## 126    4  4  4  4  4  4
## 127    4  4  4  4  4  4
## 128    4  4  4  4  4  4
## 129    4  4  4  4  4  4
## 130    4  3  3  3  3  3
## 131    4  4  4  4  4  4
## 132    3  3  3  3  3  3
## 133    4  4  4  4  4  4
## 134    4  4  4  3  3  3
## 135    3  3  3  3  3  3
```

```
## 136          3       3       3       3       3       3
## 137          3       3       4       3       3       3
## 138          4       4       4       4       3       4
## 139          4       4       4       4       4       4
## 140          3       4       4       4       4       4
## 141          4       3       4       3       3       3
## 142          3       3       4       3       4       1
## 143          3       3       4       3       3       3
## 144          4       4       4       4       4       4
## 145          4       4       3       4       4       4
## 146          4       4       4       4       4       4
## 147          4       4       3       4       4       4
## 148          3       3       3       3       3       3
## 149          3       3       4       3       4       3
## 150          4       4       4       4       3       3
## 151          4       4       4       4       4       3
## 152          4       4       4       4       4       4
## 153          4       3       4       4       1       3
## 154          4       4       4       4       4       4
## 155          4       3       3       4       3       3
## 156          4       4       3       4       3       4
## 157          4       4       4       4       4       4
## 158          3       3       3       3       3       3
## 159          3       3       3       3       3       3
## 160          3       3       3       4       4       3
## 161          3       3       4       3       4       3
## 162          4       4       4       4       4       4
## 163          3       3       4       3       3       3
## 164          4       4       4       4       4       4
## 165          4       4       4       4       4       4
## 166          4       4       4       4       4       4
## 167          4       4       4       4       4       4
## 168          4       4       4       4       4       3
## 169          4       4       4       4       4       4
## 170          4       4       4       4       4       4
## 171          4       4       4       4       4       3
## 172          4       4       4       4       4       4
## 173          3       3       4       3       4       3
## 174          4       4       4       3       4       3
## 175          4       3       3       4       4       3
## 176          4       4       4       4       4       4
## 177          4       4       3       4       3       3
## 178          4       4       4       4       4       3
## 179          3       3       3       3       3       3
## 180          4       4       4       4       4       4
## 181          4       4       4       4       4       4
## 182          3       3       3       4       4       3
## 183          3       4       3       4       4       4
## 184          4       4       4       4       4       4
## 185          4       4       4       4       2       4
## 186          4       4       3       3       4       3
## 187          4       4       3       4       4       4
## 188          4       3       4       3       4       3
## 189          3       3       4       4       4       3
```

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## 190        4        4        4        4        4        4
## 191        4        4        4        4        4        4
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## 196        3        3        4        3        4        3
## 197        4        4        4        4        4        4
## 198        4        3        4        3        4        3
## 199        4        4        4        4        4        4
## 200        4        4        3        3        3        3
## 201        4        4        4        4        4        3
## 202        4        4        4        4        4        4
## 203        4        3        4        4        4        4
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## 205        4        4        4        4        4        3
## 206        4        4        4        4        4        4
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## 208        4        4        4        3        4        4
## 209        4        4        3        4        3        4
## 210        4        4        4        4        4        3
## 211        4        4        4        4        4        4
## 212        4        4        3        3        3        3
## 213        4        4        4        4        1        4
## 214        4        4        4        4        4        4
## 215        3        3        3        3        3        3
## 216        4        4        4        4        4        4
## 217        4        3        3        3        3        3
## 218        4        4        4        3        3        3
## 219        4        3        4        4        2        4
## 220        4        4        4        4        4        4
## 221        4        4        4        4        4        4
## 222        4        4        3        3        3        4
## 223        3        3        3        3        3        3
## 224        4        4        4        3        4        4
## 225        4        3        4        3        4        3
## 226        4        3        4        4        4        4
## 227        3        3        3        3        3        3
## 228        3        3        3        3        3        3
## 229        4        4        4        4        4        4
## 230        4        4        4        4        4        4
## 231        3        3        3        3        3        3
## 232        4        4        4        4        4        4
## 233        4        4        4        4        4        4
## 234        4        4        4        4        4        4
## 235        4        4        4        4        4        3
## 236        4        4        3        4        3        4
## 237        4        4        4        3        3        4
## 238        4        4        4        1        4        4
## 239        4        4        4        3        4        4
## 240        3        3        3        3        3        3
## 241        4        4        4        4        4        4
## 242        4        4        4        4        4        4
## 243        3        4        3        3        3        3
```

```
## 244                3            4            4            4            4            1
## 245                4            4            3            4            3            4
## 246                3            3            3            3            3            3
## 247                4            4            3            4            3            3
## 248                3            3            3            3            3            3
## 249                4            4            4            4            4            4
## 250                4            4            4            4            4            4
## 251                3            3            3            3            4            3
## 252                3            3            4            3            4            3
## 253                4            4            3            3            3            3
## 254                4            4            4            4            4            4
## 255                4            3            4            3            4            3
## 256                4            4            4            4            3            4
## 257                3            3            4            3            4            3
## 258                3            3            4            3            4            3
## 259                4            3            4            2            3            3
## 260                3            3            4            3            4            3
## 261                3            3            3            3            3            3
## 262                3            3            4            3            3            3
## 263                3            3            3            3            3            3
## 264                4            4            4            4            4            3
## 265                3            3            3            3            3            3
## 266                3            3            3            3            3            3
## 267                4            4            4            3            3            4
## 268                3            3            3            3            3            3
## 269                3            4            3            3            3            3
## 270                3            3            3            3            3            3
## 271                3            3            3            3            3            3
## 272                3            3            3            3            3            3
## 273                3            3            4            3            4            3
## 274                3            4            3            3            3            3
## 275                3            3            3            3            2            3
## 276                4            4            4            3            4            3
## 277                4            4            4            4            4            4
## 278                4            3            3            3            3            2
## 279                4            4            4            4            4            3
## 280                4            4            4            4            4            3
## 281                4            4            3            3            3            4
## 282                4            4            3            3            3            3
## 283                4            4            4            4            4            4
## 284                4            4            4            4            4            4
## 285                4            4            4            4            4            4
## 286                4            3            3            3            3            3
## 287                4            4            4            4            4            4
## 288                3            3            3            3            3            3
## 289                4            4            4            4            4            4
## 290                4            4            4            4            4            4
## 291                4            4            4            4            4            4
## 292                4            4            4            4            4            4
## 293                4            4            4            3            4            4
## 294                4            4            4            4            4            4
## 295                4            4            3            3            3            3
## 296                3            3            3            3            4            2
## 297                3            3            2            3            2            2
```

```
## 298            4           4           4           4           4           4
## 299            3           3           3           3           3           3
## 300            3           3           3           3           3           4
## 301            4           4           4           4           4           4
## 302            3           2           3           3           2           2
## 303            3           3           3           3           3           3
## 304            4           4           3           3           3           3
## 305            3           4           3           3           4           4
## 306            3           3           3           3           3           3
## 307            3           3           4           4           4           3
## 308            3           4           3           3           3           3
## 309            4           4           4           4           4           4
## 310            3           3           3           3           3           3
## 311            3           3           4           3           3           3
## 312            3           3           3           3           3           3
## 313            4           4           4           4           4           4
## 314            4           4           4           3           4           4
## 315            4           4           4           4           4           4
## 316            4           4           4           4           4           4
## 317            4           4           4           4           3           4
## 318            4           4           4           4           4           4
## 319            4           4           4           3           3           3
## 320            3           4           3           3           3           3
## 321            4           4           3           3           3           4
## 322            4           3           3           3           4           4
## 323            3           4           4           4           4           4
## 324            4           4           4           4           4           4
## 325            3           3           2           3           2           3
## 326            4           4           3           3           3           3
## 327            4           4           3           3           3           3
## 328            4           4           4           4           4           4
## 329            3           3           3           3           3           3
## 330            4           4           3           3           4           3
## 331            4           4           4           4           4           4
## 332            4           4           4           4           4           3
## 333            3           3           3           3           3           3
## 334            3           4           4           4           4           4
## 335            4           3           4           3           3           3
## 336            4           3           4           4           4           3
## 337            4           4           4           4           4           4
## 338            4           4           4           4           4           4
## 339            4           4           3           4           4           4
## 340            4           4           4           4           4           3
## 341            3           4           3           3           3           3
## 342            4           4           4           4           4           4
## 343            4           3           4           3           3           3
## 344            4           4           4           4           4           4
## 345            3           3           4           3           4           3
## 346            4           4           3           4           4           3
## 347            4           4           3           4           4           3
## 348            3           3           3           3           3           3
## 349            4           4           4           4           4           4
## 350            4           4           4           3           4           4
## 351            4           4           4           4           4           4
```

```
## 352           3           3           3           3           3           3
## 353           3           3           3           3           3           3
## 354           4           4           4           4           4           4
## 355           4           4           4           4           3           3
## 356           4           3           4           3           4           3
## 357           4           4           4           4           3           4
## 358           4           4           3           4           3           4
## 359           3           3           3           3           3           3
## 360           4           4           4           4           4           4
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## 2387	4	4	4	4	4	4
## 2388	4	4	4	4	4	4
## 2389	3	3	3	3	4	3
## 2390	3	3	4	3	4	3
## 2391	3	3	4	3	4	3
## 2392	3	4	4	4	4	4
## 2393	3	3	3	3	2	3
## 2394	4	4	4	4	4	4
## 2395	4	4	4	4	4	4
## 2396	4	4	3	4	3	4
## 2397	3	3	3	3	3	3
## 2398	4	4	4	3	4	3
## 2399	3	3	3	3	3	3
## 2400	3	3	3	3	3	3
## 2401	4	4	4	4	4	4
## 2402	4	4	4	4	4	4
## 2403	4	4	3	3	4	3

```
## 2404          4          4          3          4          3          4
## 2405          3          3          3          3          3          3
## 2406          3          3          3          3          3          3
## 2407          4          4          4          4          4          4
## 2408          4          4          3          4          4          3
## 2409          4          4          4          4          4          4
## 2410          4          4          4          4          4          4
## 2411          4          3          3          3          3          3
## 2412          3          3          3          3          3          3
## 2413          3          3          3          3          3          3
## 2414          4          4          3          4          3          4
## 2415          4          4          4          4          4          4
## 2416          3          3          4          3          4          3
## 2417          4          4          3          3          3          3
## 2418          3          3          4          3          4          3
## 2419          4          4          4          4          4          4
## 2420          4          4          4          4          4          4
## 2421          4          4          4          4          4          4
## 2422          3          3          3          3          3          3
## 2423          4          4          3          3          3          3
## 2424          3          4          4          3          4          4
## 2425          4          4          3          4          3          4
## 2426          4          4          4          3          4          4
## 2427          4          4          3          4          4          4
## 2428          3          3          2          3          3          3
## 2429          4          4          4          4          4          4
## 2430          4          4          4          3          4          3
## 2431          2          3          1          3          3          1
##      Esteem87_7 Esteem87_8 Esteem87_9 Esteem87_10 cluster
## 1             3          3          3           4       2
## 2             3          3          2           4       1
## 3             3          4          3           4       1
## 4             4          2          2           2       2
## 5             4          4          4           4       1
## 6             3          4          4           4       1
## 7             3          4          3           4       1
## 8             3          3          3           3       2
## 9             3          4          3           4       1
## 10            4          3          4           4       1
## 11            3          3          4           4       1
## 12            3          2          3           3       2
## 13            4          4          4           4       1
## 14            4          3          3           3       1
## 15            3          4          4           4       1
## 16            3          3          2           3       2
## 17            4          4          4           4       1
## 18            3          4          1           1       2
## 19            3          3          3           3       2
## 20            3          3          3           3       2
## 21            3          3          3           3       2
## 22            3          3          3           3       2
## 23            4          1          1           1       2
## 24            3          3          4           4       1
## 25            4          4          4           4       1
```

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## 27            3          2          3           4       1
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## 31            3          3          4           4       1
## 32            3          2          2           3       2
## 33            3          4          3           4       1
## 34            1          2          3           3       2
## 35            4          4          4           4       1
## 36            4          4          3           4       1
## 37            2          3          3           4       1
## 38            3          3          3           3       2
## 39            4          4          4           4       1
## 40            4          3          3           4       1
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## 42            4          4          4           4       1
## 43            4          3          3           4       1
## 44            3          3          3           3       2
## 45            4          3          3           4       1
## 46            4          4          4           4       1
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## 48            3          3          2           2       2
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## 50            4          4          3           4       1
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## 57            3          3          3           3       2
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## 61            4          4          4           4       1
## 62            4          4          4           4       1
## 63            3          3          3           3       2
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## 65            4          3          3           4       1
## 66            3          3          3           4       2
## 67            3          4          2           3       2
## 68            3          4          4           4       2
## 69            4          4          4           4       1
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## 71            3          3          2           3       2
## 72            4          4          4           4       1
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## 75            3          1          2           4       2
## 76            4          4          4           4       1
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## 78            3          3          3           4       2
## 79            3          3          3           3       2
```

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## 91            3          2          3           3        2
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## 95            3          3          3           4        2
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## 101           4          4          4           4        1
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## 104           4          4          4           4        1
## 105           3          3          3           3        2
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## 107           4          2          3           4        1
## 108           3          2          2           3        2
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## 113           4          4          3           3        1
## 114           3          3          2           4        1
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## 116           3          3          3           3        2
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## 119           3          4          3           4        1
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## 122           4          4          4           4        1
## 123           4          4          3           3        1
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## 126           4          4          3           4        1
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## 128           3          4          4           4        1
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## 133           3          3          3           3        1
```

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## 140                 3           3           3            4        1
## 141                 4           1           3            4        2
## 142                 3           4           2            4        2
## 143                 3           3           3            3        2
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## 145                 4           3           3            4        1
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## 147                 3           4           3            3        1
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## 149                 3           3           3            3        2
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## 159                 3           3           3            4        2
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## 175                 4           3           3            3        2
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## 187                 4           4           4            4        1
```

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## 194              4          4          4           4       1
## 195              3          3          3           3       2
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## 205              3          3          2           3       2
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## 223              3          3          3           3       2
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## 241              3          4          4           4       1
```

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## 295            3          3          3          3       2
```

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```

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```

```
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## 457          2         2         2         3      2
```

```
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## 511          3         3         2          3       2
```

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## 536          3       3       3        3     2
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## 540          3       3       2        3     2
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## 545          4       3       4        4     1
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## 558          3       4       3        4     1
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## 560          4       2       3        4     1
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## 563          3       2       3        3     2
## 564          3       3       3        3     2
## 565          1       4       4        4     1
```

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## 566          4        4         2          3      1
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## 577          4        2         3          3      2
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## 580          3        4         3          4      1
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## 582          2        3         2          3      2
## 583          3        3         2          2      2
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## 592          3        3         3          3      2
## 593          3        3         3          4      2
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## 597          4        2         2          2      2
## 598          4        3         4          4      1
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## 600          3        3         3          4      1
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## 602          3        3         3          3      2
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## 610          3        2         2          3      2
## 611          3        3         2          3      2
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## 614          3        3         3          3      2
## 615          4        3         4          4      1
## 616          3        3         2          4      2
## 617          4        3         3          4      1
## 618          4        4         4          4      1
## 619          3        3         3          3      2
```

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## 625          3          2          3          3          2
## 626          3          3          3          3          2
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## 639          4          4          1          4          1
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## 642          3          3          3          3          2
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## 645          3          4          3          3          1
## 646          4          4          4          4          1
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## 648          4          4          4          4          1
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## 670          3          3          2          3          2
## 671          4          3          3          4          1
## 672          3          2          3          2          2
## 673          4          3          4          4          1
```

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## 683                 3           3           2            3        2
## 684                 3           3           3            3        2
## 685                 3           3           4            4        1
## 686                 4           4           3            4        1
## 687                 3           3           2            3        2
## 688                 3           2           4            4        1
## 689                 4           4           4            4        1
## 690                 4           4           3            4        1
## 691                 4           4           2            3        1
## 692                 3           3           3            3        2
## 693                 3           3           3            3        2
## 694                 4           2           4            4        1
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## 696                 3           3           2            3        2
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## 710                 4           4           4            4        1
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## 714                 3           3           3            3        2
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## 717                 3           3           2            3        2
## 718                 4           4           3            2        1
## 719                 4           4           4            2        1
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## 721                 4           4           4            4        1
## 722                 2           2           2            2        2
## 723                 2           3           3            3        2
## 724                 4           4           4            4        1
## 725                 4           3           3            3        2
## 726                 3           4           4            4        1
## 727                 4           4           4            4        1
```

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## 728                 4           4           3            4        1
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## 731                 3           4           3            3        1
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## 733                 4           4           4            4        1
## 734                 3           3           3            3        2
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## 736                 4           4           4            4        1
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## 738                 4           4           4            4        1
## 739                 4           4           4            4        1
## 740                 3           2           3            3        2
## 741                 3           2           4            4        1
## 742                 3           3           3            3        2
## 743                 3           3           2            2        2
## 744                 2           2           3            2        2
## 745                 4           3           2            4        1
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## 747                 4           3           3            4        1
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## 755                 4           4           4            4        1
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## 763                 4           3           2            2        2
## 764                 3           3           2            3        2
## 765                 3           3           4            4        1
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## 768                 3           1           4            4        2
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## 772                 3           3           3            3        2
## 773                 3           3           2            3        2
## 774                 3           4           4            4        1
## 775                 3           3           3            3        2
## 776                 4           4           4            4        1
## 777                 4           3           3            4        1
## 778                 4           2           2            2        2
## 779                 4           4           4            4        1
## 780                 3           4           4            4        1
## 781                 3           3           3            3        2
```

```
## 782          3     2     2     3     2
## 783          3     3     3     3     2
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## 785          3     3     3     3     2
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## 787          3     2     3     3     2
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## 789          3     3     3     3     2
## 790          4     2     3     3     2
## 791          3     3     3     3     2
## 792          3     4     2     3     1
## 793          3     3     3     3     2
## 794          3     4     4     4     1
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## 796          3     2     2     3     2
## 797          4     4     4     4     1
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## 806          4     3     3     3     1
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## 808          3     3     3     4     2
## 809          3     3     2     3     2
## 810          3     2     2     2     2
## 811          4     4     4     4     1
## 812          3     3     2     3     2
## 813          4     4     4     4     1
## 814          4     4     4     4     1
## 815          4     4     4     4     1
## 816          4     4     4     4     1
## 817          3     2     2     3     2
## 818          3     3     3     4     2
## 819          3     2     3     3     2
## 820          3     3     3     3     2
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## 823          2     3     3     3     2
## 824          3     3     3     3     2
## 825          3     3     4     4     1
## 826          3     3     3     3     2
## 827          3     3     3     3     2
## 828          4     4     4     4     1
## 829          3     3     3     3     2
## 830          4     3     4     4     1
## 831          4     3     3     4     1
## 832          3     3     3     3     2
## 833          2     3     3     3     2
## 834          3     4     4     4     1
## 835          2     3     3     3     2
```

```
## 836    4    4    4    4    1
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## 839    2    3    3    3    2
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## 841    3    1    2    3    2
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## 843    3    3    2    3    2
## 844    4    3    3    3    1
## 845    4    3    3    4    1
## 846    4    4    4    4    1
## 847    2    3    2    2    2
## 848    3    3    2    3    2
## 849    3    2    3    3    2
## 850    2    4    2    4    1
## 851    3    3    3    3    1
## 852    3    3    2    3    2
## 853    4    2    4    4    1
## 854    4    3    2    3    2
## 855    3    4    4    4    1
## 856    3    4    2    2    2
## 857    4    2    2    4    1
## 858    4    3    3    3    1
## 859    2    2    2    2    2
## 860    4    2    2    3    2
## 861    4    4    4    4    1
## 862    4    3    3    3    1
## 863    3    4    4    4    1
## 864    4    3    3    3    1
## 865    4    4    3    2    2
## 866    4    4    3    3    1
## 867    3    3    3    3    2
## 868    3    3    3    3    2
## 869    4    4    4    4    1
## 870    4    3    3    3    1
## 871    4    4    4    4    1
## 872    4    3    3    3    2
## 873    3    3    3    4    1
## 874    3    3    3    3    2
## 875    3    3    3    3    2
## 876    4    2    3    3    2
## 877    2    3    3    3    2
## 878    4    4    4    4    1
## 879    3    3    3    3    2
## 880    4    4    2    4    1
## 881    4    4    4    4    1
## 882    4    2    3    3    2
## 883    2    3    3    3    2
## 884    4    3    3    3    1
## 885    3    2    3    4    2
## 886    3    3    2    3    2
## 887    3    2    4    4    1
## 888    4    3    4    4    1
## 889    4    1    1    3    2
```

```
## 890                3           3           3            3        2
## 891                4           4           4            4        1
## 892                3           3           3            4        2
## 893                3           2           3            3        2
## 894                4           4           4            4        1
## 895                3           3           3            3        2
## 896                4           4           4            4        1
## 897                4           4           4            4        1
## 898                3           2           3            3        2
## 899                3           4           4            4        1
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## 901                2           2           2            2        2
## 902                3           3           3            3        2
## 903                4           4           3            4        1
## 904                4           4           4            4        1
## 905                4           4           4            4        1
## 906                3           4           4            4        1
## 907                3           3           3            3        2
## 908                4           4           4            4        1
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## 910                3           2           2            3        2
## 911                3           3           3            3        2
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## 914                4           4           4            4        1
## 915                4           4           3            4        1
## 916                3           2           4            4        2
## 917                3           3           2            3        2
## 918                4           4           4            4        1
## 919                3           4           4            4        1
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## 927                4           4           2            4        1
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## 931                4           4           3            4        1
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## 937                3           4           4            4        1
## 938                4           4           3            4        1
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## 940                4           3           2            3        1
## 941                3           3           3            3        1
## 942                4           4           4            4        1
## 943                3           3           2            3        2
```

```
## 944 3 3 3 3 2
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## 946 3 4 3 3 1
## 947 3 2 4 4 1
## 948 3 4 4 4 1
## 949 2 3 2 3 2
## 950 3 3 2 2 2
## 951 4 4 2 3 1
## 952 3 3 3 3 2
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## 954 3 3 4 2 2
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## 957 4 3 2 3 1
## 958 3 3 4 4 2
## 959 3 2 2 2 2
## 960 3 3 3 3 2
## 961 3 3 3 4 2
## 962 4 4 4 4 1
## 963 4 3 3 3 2
## 964 4 4 4 4 1
## 965 2 3 2 3 2
## 966 3 3 3 3 2
## 967 3 3 2 3 2
## 968 3 3 3 3 2
## 969 3 3 3 3 2
## 970 4 4 2 3 1
## 971 4 4 3 4 1
## 972 4 4 4 4 1
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## 974 3 3 2 3 2
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## 976 3 2 2 3 2
## 977 3 3 2 3 2
## 978 3 3 2 3 2
## 979 3 3 4 3 2
## 980 3 3 4 4 1
## 981 3 3 3 3 2
## 982 3 3 2 3 2
## 983 3 3 4 4 1
## 984 4 4 3 3 1
## 985 3 2 3 2 2
## 986 3 2 3 4 2
## 987 4 3 3 4 1
## 988 3 3 2 4 2
## 989 3 3 4 4 1
## 990 3 2 2 3 2
## 991 4 4 4 4 1
## 992 3 3 3 3 2
## 993 3 3 3 4 1
## 994 4 4 3 3 1
## 995 3 3 3 3 2
## 996 3 3 3 4 1
## 997 3 3 3 3 2
```

```
## 998     3 4 3 4 1
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## 1003    2 2 3 3 2
## 1004    3 3 3 3 2
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## 1007    4 3 2 3 1
## 1008    3 3 3 3 2
## 1009    3 4 4 4 1
## 1010    4 4 4 4 1
## 1011    3 3 3 4 1
## 1012    3 2 3 3 2
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## 1017    3 3 3 4 2
## 1018    4 4 4 4 1
## 1019    4 4 4 4 1
## 1020    3 3 2 3 2
## 1021    4 3 4 4 1
## 1022    3 4 4 4 1
## 1023    3 3 3 4 1
## 1024    2 3 3 3 2
## 1025    3 3 3 3 2
## 1026    3 2 2 4 2
## 1027    4 4 3 4 1
## 1028    4 4 4 4 1
## 1029    3 3 3 3 2
## 1030    3 4 4 4 1
## 1031    3 2 2 3 2
## 1032    2 2 2 2 2
## 1033    3 2 2 3 2
## 1034    3 3 2 3 2
## 1035    3 2 2 2 2
## 1036    3 3 2 3 2
## 1037    4 3 2 2 2
## 1038    4 1 3 3 2
## 1039    4 3 3 3 1
## 1040    4 4 4 4 1
## 1041    3 3 2 3 2
## 1042    4 4 4 4 1
## 1043    3 3 2 3 2
## 1044    3 3 2 3 2
## 1045    3 3 3 3 2
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## 1047    3 3 2 3 2
## 1048    3 3 3 3 2
## 1049    4 3 2 3 2
## 1050    3 3 2 3 2
## 1051    4 4 3 4 1
```

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## 1071         3       4       1       4     1
## 1072         3       4       3       3     1
## 1073         4       4       4       4     1
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## 1089         3       3       3       3     2
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## 1092         3       2       3       3     2
## 1093         3       3       3       3     2
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## 1097         4       2       3       3     2
## 1098         4       4       4       4     1
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## 1100         4       4       4       4     1
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## 1102         3       3       3       3     2
## 1103         3       3       3       3     2
## 1104         3       3       3       3     2
## 1105         4       4       3       3     1
```

```
## 1106              2           2           2           3        2
## 1107              3           3           3           3        2
## 1108              3           4           4           4        1
## 1109              4           4           3           3        1
## 1110              4           4           3           4        1
## 1111              4           4           2           4        1
## 1112              2           3           2           3        2
## 1113              3           2           3           4        2
## 1114              4           3           3           4        1
## 1115              4           3           3           3        1
## 1116              3           4           3           4        1
## 1117              3           3           3           4        1
## 1118              3           2           2           3        2
## 1119              4           4           2           4        1
## 1120              3           3           3           3        2
## 1121              4           3           3           3        1
## 1122              4           4           4           4        1
## 1123              4           3           3           4        1
## 1124              3           4           4           4        1
## 1125              3           3           3           3        2
## 1126              3           3           3           3        1
## 1127              3           2           2           3        2
## 1128              4           4           3           4        1
## 1129              3           2           3           4        1
## 1130              4           3           3           3        2
## 1131              4           4           4           4        1
## 1132              2           3           3           3        2
## 1133              3           3           3           4        1
## 1134              3           3           3           3        2
## 1135              3           3           3           4        2
## 1136              3           3           3           4        2
## 1137              3           3           3           3        2
## 1138              3           4           4           4        1
## 1139              3           4           3           4        1
## 1140              4           4           4           4        1
## 1141              4           4           2           3        1
## 1142              3           3           3           3        2
## 1143              3           2           2           3        2
## 1144              4           4           4           4        1
## 1145              2           2           2           2        2
## 1146              3           3           2           3        2
## 1147              4           4           4           4        1
## 1148              3           2           2           3        2
## 1149              4           4           4           4        1
## 1150              4           4           4           4        1
## 1151              4           4           4           4        1
## 1152              4           4           4           4        1
## 1153              3           2           3           3        2
## 1154              3           3           2           3        2
## 1155              3           3           3           4        2
## 1156              2           3           3           3        2
## 1157              3           2           2           4        2
## 1158              3           3           3           4        2
## 1159              3           3           3           3        2
```

```
## 1160    3    3    2    3    2
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## 1163    3    2    3    3    2
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## 1165    4    4    4    4    1
## 1166    3    4    3    4    1
## 1167    3    3    3    3    2
## 1168    4    4    4    4    1
## 1169    4    4    2    3    1
## 1170    4    3    2    4    1
## 1171    4    4    3    3    1
## 1172    4    4    4    4    1
## 1173    4    4    3    4    1
## 1174    3    2    4    4    1
## 1175    4    4    2    4    1
## 1176    3    3    4    3    2
## 1177    3    3    3    3    2
## 1178    3    3    3    3    2
## 1179    3    3    3    3    2
## 1180    3    4    4    4    1
## 1181    4    4    4    4    1
## 1182    3    3    2    4    2
## 1183    4    4    4    4    1
## 1184    4    4    4    4    1
## 1185    3    3    3    4    2
## 1186    3    2    3    3    2
## 1187    3    4    4    4    1
## 1188    3    3    3    3    2
## 1189    3    2    3    3    2
## 1190    4    4    4    4    1
## 1191    2    3    4    4    1
## 1192    1    2    1    2    2
## 1193    3    3    2    2    2
## 1194    3    3    3    2    2
## 1195    4    3    4    4    1
## 1196    3    3    3    3    2
## 1197    3    3    3    3    2
## 1198    3    2    3    3    2
## 1199    3    3    3    3    2
## 1200    4    4    4    4    1
## 1201    4    3    3    4    1
## 1202    2    3    3    3    2
## 1203    3    3    2    3    2
## 1204    4    3    4    4    1
## 1205    3    3    3    3    2
## 1206    4    3    3    3    1
## 1207    4    4    3    3    1
## 1208    3    3    3    3    2
## 1209    3    3    3    3    1
## 1210    4    3    3    3    1
## 1211    4    4    4    4    1
## 1212    4    4    4    4    1
## 1213    3    3    3    3    2
```

```
## 1214          3          3          3          4          2
## 1215          4          2          3          2          2
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## 1217          3          3          4          3          2
## 1218          3          2          3          3          2
## 1219          3          3          2          3          2
## 1220          3          4          3          4          1
## 1221          4          4          4          4          1
## 1222          4          4          4          4          1
## 1223          4          4          4          4          1
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## 1225          3          3          3          3          2
## 1226          4          2          4          4          1
## 1227          4          4          4          4          1
## 1228          3          3          3          3          2
## 1229          3          3          3          3          2
## 1230          3          3          3          4          1
## 1231          4          4          4          3          1
## 1232          3          3          3          4          2
## 1233          3          4          4          4          1
## 1234          4          3          3          4          1
## 1235          3          3          3          3          2
## 1236          3          3          2          2          2
## 1237          3          2          2          3          2
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## 1240          3          2          3          4          1
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## 1242          4          3          1          3          2
## 1243          3          3          2          3          2
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## 1245          3          2          3          4          1
## 1246          4          3          3          4          1
## 1247          3          3          4          4          1
## 1248          3          2          2          2          2
## 1249          4          4          3          4          1
## 1250          3          3          3          3          2
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## 1252          3          3          2          3          2
## 1253          3          3          3          3          2
## 1254          4          3          3          3          1
## 1255          4          4          4          3          1
## 1256          3          3          3          3          1
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## 1258          2          3          2          2          2
## 1259          3          3          2          3          2
## 1260          3          3          4          4          1
## 1261          3          4          4          4          1
## 1262          3          3          2          4          1
## 1263          3          3          2          2          2
## 1264          4          4          3          4          1
## 1265          3          4          3          4          1
## 1266          4          3          3          3          1
## 1267          4          4          2          3          1
```

```
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## 1269        3       3       3       3     2
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## 1273        3       2       4       4     1
## 1274        4       4       4       4     1
## 1275        3       3       4       4     2
## 1276        4       3       3       2     2
## 1277        4       4       4       4     1
## 1278        3       3       3       4     1
## 1279        3       3       3       4     2
## 1280        3       2       2       3     2
## 1281        4       4       2       4     1
## 1282        3       2       3       3     2
## 1283        4       4       3       4     1
## 1284        3       2       3       3     2
## 1285        4       4       4       4     1
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## 1287        3       3       3       3     2
## 1288        3       3       3       3     2
## 1289        3       4       2       3     1
## 1290        3       3       3       3     2
## 1291        3       4       3       4     1
## 1292        2       3       3       3     2
## 1293        3       4       2       4     2
## 1294        4       3       3       3     1
## 1295        4       4       4       4     1
## 1296        3       2       3       3     2
## 1297        3       2       4       4     1
## 1298        3       3       3       3     2
## 1299        3       3       3       3     2
## 1300        3       2       2       3     2
## 1301        3       3       3       4     2
## 1302        3       2       2       3     2
## 1303        4       4       4       4     1
## 1304        4       4       4       4     1
## 1305        3       2       2       2     2
## 1306        3       3       2       2     2
## 1307        3       2       3       3     2
## 1308        3       4       4       4     1
## 1309        3       4       3       4     1
## 1310        3       3       2       3     2
## 1311        3       4       4       4     1
## 1312        3       3       4       4     1
## 1313        4       4       4       4     1
## 1314        4       4       4       4     1
## 1315        3       3       2       3     2
## 1316        3       3       3       3     2
## 1317        2       3       3       4     1
## 1318        3       3       3       3     2
## 1319        3       3       3       4     1
## 1320        3       4       3       3     1
## 1321        3       3       3       3     2
```

```
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## 1323            4          3          4          4       1
## 1324            4          4          4          4       1
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## 1326            4          4          4          4       1
## 1327            4          4          4          4       1
## 1328            3          3          3          2       2
## 1329            3          3          3          4       2
## 1330            4          3          3          3       1
## 1331            2          3          3          4       2
## 1332            4          2          4          3       2
## 1333            4          4          4          4       1
## 1334            3          3          3          3       2
## 1335            3          3          3          3       2
## 1336            3          4          4          3       1
## 1337            4          4          2          2       1
## 1338            3          3          2          2       2
## 1339            3          3          3          3       2
## 1340            3          2          3          3       2
## 1341            4          4          3          4       1
## 1342            3          2          4          3       2
## 1343            4          4          3          4       1
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## 1345            3          4          2          3       2
## 1346            3          3          3          3       2
## 1347            3          2          3          2       2
## 1348            2          3          4          4       1
## 1349            4          4          4          4       1
## 1350            3          3          4          4       1
## 1351            3          4          4          4       1
## 1352            3          4          4          4       1
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## 1354            4          3          3          3       1
## 1355            4          4          4          4       1
## 1356            3          3          3          4       2
## 1357            3          3          3          3       2
## 1358            3          3          3          4       1
## 1359            3          3          4          3       1
## 1360            3          3          4          4       1
## 1361            3          3          3          4       2
## 1362            3          3          3          3       2
## 1363            2          2          2          3       2
## 1364            4          4          3          4       1
## 1365            4          4          3          3       1
## 1366            4          4          4          4       1
## 1367            3          3          3          4       2
## 1368            2          3          3          3       2
## 1369            3          3          3          2       2
## 1370            3          3          3          3       2
## 1371            4          2          4          3       1
## 1372            4          3          4          4       1
## 1373            4          4          4          4       1
## 1374            4          3          3          3       1
## 1375            3          3          3          3       2
```

```
## 1376          3          4          4           3        1
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## 1378          3          3          3           3        2
## 1379          4          3          3           3        1
## 1380          4          3          3           3        1
## 1381          3          4          4           4        1
## 1382          3          3          3           3        1
## 1383          4          3          3           3        2
## 1384          3          3          3           4        2
## 1385          3          3          3           4        2
## 1386          2          2          3           3        2
## 1387          3          2          2           3        2
## 1388          4          4          4           4        1
## 1389          4          4          4           4        1
## 1390          4          2          3           3        1
## 1391          3          3          3           3        1
## 1392          3          4          3           4        1
## 1393          2          2          2           3        2
## 1394          3          3          4           4        1
## 1395          4          4          4           4        1
## 1396          3          3          3           4        2
## 1397          3          3          2           4        1
## 1398          3          4          1           4        1
## 1399          3          3          3           4        1
## 1400          3          3          2           3        2
## 1401          3          3          3           4        1
## 1402          3          3          3           3        2
## 1403          3          2          2           3        2
## 1404          3          3          3           3        2
## 1405          3          2          2           3        2
## 1406          3          2          3           3        2
## 1407          3          3          3           3        2
## 1408          3          3          2           3        2
## 1409          3          3          3           3        2
## 1410          3          2          3           3        2
## 1411          3          3          4           3        2
## 1412          3          3          3           3        2
## 1413          3          3          3           4        1
## 1414          4          3          4           4        1
## 1415          3          3          3           3        2
## 1416          3          4          4           4        1
## 1417          3          4          4           4        1
## 1418          4          3          4           4        1
## 1419          3          3          3           4        2
## 1420          4          3          3           3        2
## 1421          3          3          3           3        2
## 1422          3          2          4           4        2
## 1423          3          3          3           3        2
## 1424          3          3          3           3        2
## 1425          3          3          3           3        2
## 1426          4          3          3           4        1
## 1427          3          3          3           3        2
## 1428          3          3          4           4        1
## 1429          4          4          4           4        1
```

```
## 1430    3    3    2    3    2
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## 1433    4    2    2    4    2
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## 1436    2    4    4    3    1
## 1437    4    4    4    4    1
## 1438    4    3    3    3    1
## 1439    4    4    4    4    1
## 1440    4    4    3    4    1
## 1441    4    4    4    4    1
## 1442    3    3    4    4    2
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## 1445    2    3    2    2    2
## 1446    3    3    3    3    2
## 1447    4    3    3    4    2
## 1448    3    1    2    4    2
## 1449    3    3    3    3    2
## 1450    3    4    4    4    1
## 1451    2    3    3    3    2
## 1452    4    4    4    4    1
## 1453    3    3    2    3    2
## 1454    3    3    2    3    2
## 1455    3    3    3    3    2
## 1456    3    3    4    4    1
## 1457    4    4    4    4    1
## 1458    3    2    3    3    2
## 1459    3    2    4    4    2
## 1460    4    3    3    4    1
## 1461    3    3    2    3    2
## 1462    4    3    3    4    1
## 1463    4    4    4    4    1
## 1464    3    4    3    4    1
## 1465    3    2    2    3    2
## 1466    2    2    1    2    2
## 1467    4    4    1    4    1
## 1468    2    3    2    2    2
## 1469    3    3    2    3    2
## 1470    3    2    3    3    2
## 1471    3    2    1    2    2
## 1472    3    4    4    4    1
## 1473    4    4    4    4    1
## 1474    3    2    4    4    2
## 1475    3    4    4    4    1
## 1476    3    3    3    3    2
## 1477    3    2    3    4    2
## 1478    3    3    3    2    2
## 1479    4    4    4    4    1
## 1480    3    3    2    3    2
## 1481    3    2    3    4    2
## 1482    4    4    4    4    1
## 1483    3    3    3    4    2
```

```
## 1484 3 3 3 3 1
## 1485 4 4 4 4 1
## 1486 3 3 3 4 2
## 1487 3 3 2 3 2
## 1488 3 4 3 4 1
## 1489 3 3 3 2 2
## 1490 3 3 2 3 1
## 1491 3 4 4 4 1
## 1492 3 3 2 3 2
## 1493 2 2 2 1 2
## 1494 3 3 3 3 1
## 1495 2 2 2 3 2
## 1496 4 3 4 4 1
## 1497 4 4 4 4 1
## 1498 3 3 3 3 2
## 1499 3 3 3 3 2
## 1500 3 2 2 3 2
## 1501 3 4 4 4 1
## 1502 4 4 1 4 1
## 1503 4 3 3 3 1
## 1504 3 3 3 3 2
## 1505 4 3 3 4 1
## 1506 4 3 4 4 1
## 1507 4 3 4 4 1
## 1508 4 3 3 3 1
## 1509 3 2 2 4 2
## 1510 4 4 4 4 1
## 1511 3 3 3 4 1
## 1512 3 2 4 4 1
## 1513 3 3 4 4 2
## 1514 4 3 2 4 2
## 1515 4 2 2 3 2
## 1516 3 2 4 3 2
## 1517 4 4 4 4 1
## 1518 3 3 3 3 2
## 1519 3 3 3 3 2
## 1520 3 2 4 4 1
## 1521 3 1 2 3 2
## 1522 3 3 2 3 2
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## 1524 4 4 3 4 1
## 1525 4 4 4 4 1
## 1526 3 3 4 4 2
## 1527 3 3 3 3 2
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## 1530 4 4 4 4 1
## 1531 3 3 3 3 2
## 1532 4 4 4 4 1
## 1533 3 3 3 4 1
## 1534 2 3 2 3 2
## 1535 3 3 3 2 2
## 1536 3 3 3 3 2
## 1537 4 2 3 3 1
```

```
## 1538          4          3          3          4        1
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## 1542          3          3          3          3        2
## 1543          4          4          4          4        1
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## 1545          3          3          3          4        1
## 1546          4          4          4          4        1
## 1547          3          3          2          3        2
## 1548          3          3          3          3        2
## 1549          3          2          2          2        2
## 1550          4          4          3          4        1
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## 1552          3          3          3          3        1
## 1553          3          3          3          3        2
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## 1557          4          4          4          4        1
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## 1559          4          4          4          4        1
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## 1562          3          3          3          3        2
## 1563          4          2          4          4        1
## 1564          3          4          3          4        1
## 1565          3          3          3          4        1
## 1566          3          2          3          4        2
## 1567          3          3          4          4        1
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## 1577          4          3          3          3        1
## 1578          4          4          4          4        1
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## 1580          3          3          4          4        1
## 1581          4          4          4          4        1
## 1582          3          3          3          3        2
## 1583          3          3          2          3        2
## 1584          4          4          4          4        1
## 1585          4          2          4          4        1
## 1586          3          4          2          2        2
## 1587          3          3          3          3        2
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## 1589          3          2          3          4        2
## 1590          4          3          2          3        2
## 1591          3          3          3          3        2
```

```
## 1592         3        3        3        3      2
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## 1594         4        4        4        4      1
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## 1596         2        3        2        3      2
## 1597         3        4        2        4      1
## 1598         4        4        3        4      1
## 1599         3        3        3        3      2
## 1600         3        3        2        4      2
## 1601         3        3        4        4      1
## 1602         3        3        3        3      2
## 1603         3        3        3        3      2
## 1604         3        3        3        3      2
## 1605         4        3        2        3      2
## 1606         4        4        3        4      1
## 1607         3        4        4        4      1
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## 1609         4        4        4        4      1
## 1610         4        3        4        4      1
## 1611         4        3        2        3      1
## 1612         4        4        3        4      1
## 1613         4        4        2        2      1
## 1614         3        2        3        3      2
## 1615         3        3        3        2      2
## 1616         3        2        3        3      2
## 1617         3        3        3        3      2
## 1618         2        3        3        3      2
## 1619         3        3        3        3      2
## 1620         4        4        4        4      1
## 1621         3        3        4        3      2
## 1622         3        2        3        3      2
## 1623         4        2        4        4      1
## 1624         4        3        4        4      1
## 1625         3        2        3        3      2
## 1626         4        3        3        3      1
## 1627         3        3        3        4      1
## 1628         4        4        4        4      1
## 1629         4        3        3        3      1
## 1630         4        2        2        3      2
## 1631         4        4        4        4      1
## 1632         4        1        4        4      1
## 1633         3        2        3        3      2
## 1634         4        4        4        4      1
## 1635         4        3        4        4      1
## 1636         3        3        3        4      2
## 1637         3        2        3        3      2
## 1638         2        2        2        2      2
## 1639         4        4        4        4      1
## 1640         3        3        3        3      2
## 1641         3        4        2        3      2
## 1642         3        3        3        3      2
## 1643         3        4        3        3      1
## 1644         4        3        3        4      1
## 1645         4        3        3        4      2
```

```
## 1646           3          4          2           4       1
## 1647           3          4          2           4       1
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## 1649           4          4          2           4       1
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## 1651           3          3          3           3       2
## 1652           3          3          4           4       1
## 1653           3          3          3           4       2
## 1654           2          2          2           3       2
## 1655           3          2          3           4       2
## 1656           3          2          2           3       2
## 1657           3          2          3           3       2
## 1658           4          3          4           4       1
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## 1672           3          3          3           3       2
## 1673           3          3          3           3       2
## 1674           4          4          1           4       1
## 1675           3          4          3           3       2
## 1676           4          4          3           4       1
## 1677           4          4          4           4       1
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## 1679           3          3          3           3       2
## 1680           4          3          4           4       1
## 1681           3          3          3           3       2
## 1682           3          3          4           4       1
## 1683           3          3          3           3       2
## 1684           3          4          4           4       1
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## 1688           3          3          2           3       2
## 1689           2          3          2           2       2
## 1690           3          4          4           3       1
## 1691           3          3          3           3       2
## 1692           3          3          3           4       1
## 1693           4          2          3           2       2
## 1694           4          4          4           4       1
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## 1697           4          4          4           4       1
## 1698           3          3          2           3       2
## 1699           3          3          2           2       2
```

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## 1725           4          4          4          4        1
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## 1736           3          3          3          3        2
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## 1740           4          4          4          4        1
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## 1742           4          4          4          4        1
## 1743           4          3          4          4        1
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## 1745           3          3          3          4        1
## 1746           3          4          2          4        1
## 1747           3          3          4          4        1
## 1748           4          3          3          3        1
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## 1750           3          2          3          4        2
## 1751           4          4          4          4        1
## 1752           3          4          4          4        1
## 1753           4          4          3          4        1
```

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## 1765            3           3           3            4        2
## 1766            3           3           3            3        2
## 1767            4           4           4            4        1
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## 1776            3           3           3            3        2
## 1777            3           3           3            3        2
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## 1781            3           3           2            3        2
## 1782            3           3           2            3        2
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## 1796            4           4           4            4        1
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## 1799            4           4           3            3        1
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## 1806            4           4           4            4        1
## 1807            4           2           4            4        1
```

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## 1825        3      3      3      3      2
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## 1835        3      1      4      4      1
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## 1837        3      4      3      4      1
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## 1855        3      3      2      3      2
## 1856        3      2      2      2      2
## 1857        3      3      3      3      2
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## 1860        3      3      3      3      2
## 1861        3      2      3      3      2
```

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```

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## 1969           4          3          3           3       1
```

```
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## 2021           4          4          4          4       1
## 2022           4          3          2          4       2
## 2023           4          3          3          3       1
```

```
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## 2075        3        3        4        4        1
## 2076        3        3        3        3        2
## 2077        3        3        3        4        2
```

```
## 2078    3    3    2    3    2
## 2079    3    3    3    3    2
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## 2083    3    3    3    3    2
## 2084    3    2    2    3    2
## 2085    4    2    3    3    2
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## 2087    3    3    4    4    1
## 2088    4    4    4    4    1
## 2089    3    3    3    4    1
## 2090    3    2    2    3    2
## 2091    3    3    2    2    2
## 2092    4    4    4    4    1
## 2093    4    3    3    3    2
## 2094    3    3    3    3    2
## 2095    4    2    3    4    1
## 2096    4    4    4    4    1
## 2097    4    3    2    3    2
## 2098    4    4    4    4    1
## 2099    3    2    3    4    1
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## 2101    2    3    3    3    2
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## 2108    4    4    4    4    1
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## 2130    4    3    3    3    1
## 2131    3    3    3    3    2
```

```
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## 2185       3       3       2       2     2
```

```
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## 2208          3          2          2          3       2
## 2209          3          3          2          2       2
## 2210          3          4          4          3       1
## 2211          3          3          2          3       2
## 2212          3          2          3          3       2
## 2213          3          2          3          3       2
## 2214          3          3          3          3       2
## 2215          4          2          2          3       2
## 2216          4          3          4          4       1
## 2217          4          3          4          4       1
## 2218          3          3          3          3       2
## 2219          3          2          3          3       2
## 2220          3          2          4          4       1
## 2221          3          3          3          3       2
## 2222          3          3          3          3       2
## 2223          4          4          3          3       1
## 2224          4          4          3          3       1
## 2225          3          3          2          3       2
## 2226          4          3          2          2       2
## 2227          3          3          3          3       2
## 2228          3          2          3          3       2
## 2229          3          3          2          3       2
## 2230          4          2          2          1       2
## 2231          4          3          2          3       1
## 2232          3          2          3          3       2
## 2233          3          3          3          3       2
## 2234          3          3          4          4       1
## 2235          3          3          3          3       2
## 2236          4          4          3          4       1
## 2237          3          3          3          3       2
## 2238          4          4          4          4       1
## 2239          3          1          4          4       1
```

```
## 2240          4          2          3          3          2
## 2241          4          4          4          4          1
## 2242          3          3          3          4          1
## 2243          3          3          3          4          1
## 2244          3          3          3          3          2
## 2245          4          4          4          4          1
## 2246          4          4          4          4          1
## 2247          4          3          4          4          1
## 2248          3          3          4          4          1
## 2249          3          2          2          1          2
## 2250          3          3          3          4          1
## 2251          3          3          3          3          2
## 2252          3          2          2          3          2
## 2253          3          3          4          4          1
## 2254          3          3          3          4          1
## 2255          4          2          3          4          1
## 2256          4          3          3          4          1
## 2257          3          3          3          3          2
## 2258          4          4          3          4          1
## 2259          3          3          3          4          2
## 2260          3          3          2          3          2
## 2261          2          1          3          2          2
## 2262          4          3          4          4          1
## 2263          4          4          4          4          1
## 2264          3          2          3          3          2
## 2265          1          3          3          3          2
## 2266          3          2          2          3          2
## 2267          4          3          2          4          1
## 2268          3          4          4          4          1
## 2269          3          2          4          4          1
## 2270          3          3          2          3          2
## 2271          4          2          2          2          2
## 2272          3          3          2          3          2
## 2273          3          3          3          3          2
## 2274          3          3          4          4          1
## 2275          3          4          4          4          1
## 2276          2          2          4          4          1
## 2277          4          4          4          4          1
## 2278          4          3          4          3          1
## 2279          3          3          2          2          2
## 2280          3          4          4          4          1
## 2281          3          4          4          4          1
## 2282          3          3          3          3          2
## 2283          4          4          4          4          1
## 2284          3          2          3          3          2
## 2285          4          4          4          4          1
## 2286          4          4          4          4          1
## 2287          3          3          3          3          1
## 2288          3          3          2          3          2
## 2289          2          4          4          4          1
## 2290          3          4          4          4          1
## 2291          4          4          4          4          1
## 2292          3          3          3          3          2
## 2293          4          4          3          4          1
```

```
## 2294    3    3    3    3    2
## 2295    1    4    4    4    1
## 2296    1    2    4    3    2
## 2297    3    2    2    2    2
## 2298    3    2    3    4    2
## 2299    4    3    3    4    1
## 2300    3    3    3    3    2
## 2301    3    2    2    4    1
## 2302    3    2    2    4    2
## 2303    4    3    3    3    2
## 2304    3    4    3    4    1
## 2305    4    4    4    4    1
## 2306    3    3    3    3    1
## 2307    4    3    3    3    1
## 2308    4    3    3    3    1
## 2309    4    4    4    4    1
## 2310    4    3    3    3    1
## 2311    3    3    3    3    2
## 2312    3    3    3    3    2
## 2313    4    2    4    4    1
## 2314    3    3    2    3    2
## 2315    2    2    2    2    2
## 2316    3    4    3    4    1
## 2317    3    2    4    4    1
## 2318    3    1    1    2    2
## 2319    3    2    3    3    2
## 2320    4    2    2    4    1
## 2321    4    3    4    3    1
## 2322    4    3    4    4    1
## 2323    3    2    2    2    2
## 2324    3    3    3    3    1
## 2325    3    3    3    3    1
## 2326    4    4    4    4    1
## 2327    4    4    2    4    1
## 2328    3    3    3    3    1
## 2329    3    3    4    4    1
## 2330    4    4    4    3    1
## 2331    4    3    3    4    1
## 2332    3    2    3    3    2
## 2333    3    4    3    3    1
## 2334    4    3    4    4    1
## 2335    3    3    2    3    2
## 2336    3    3    2    3    2
## 2337    3    4    4    2    1
## 2338    3    2    3    3    2
## 2339    2    3    3    3    2
## 2340    3    3    2    2    2
## 2341    4    4    4    4    1
## 2342    3    2    3    3    2
## 2343    3    3    3    3    2
## 2344    3    3    3    3    2
## 2345    3    3    3    3    2
## 2346    4    4    3    4    1
## 2347    4    3    2    3    2
```

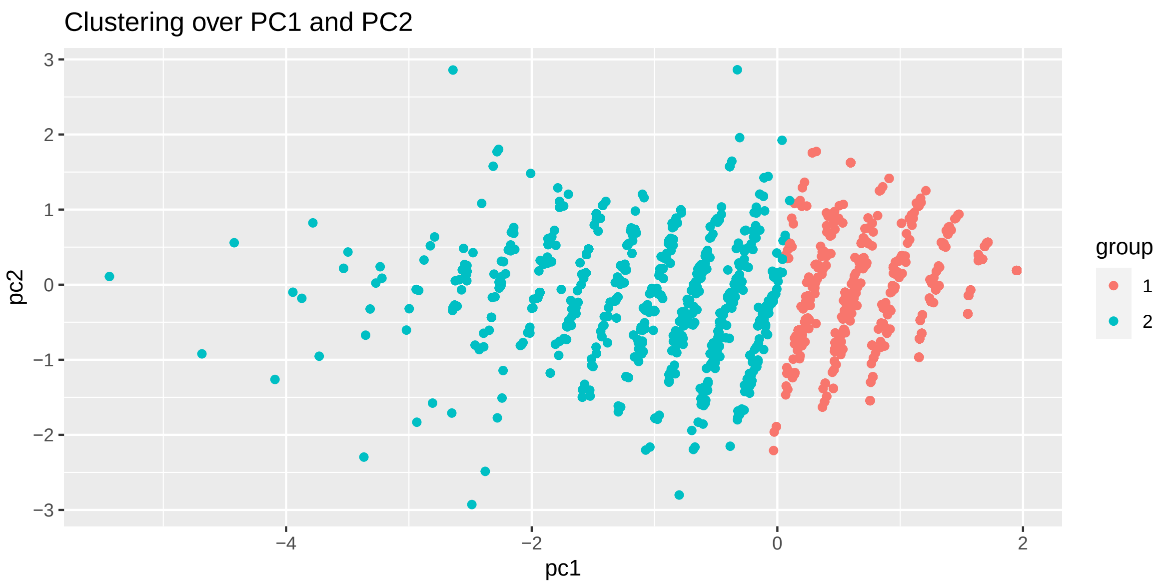
```
## 2348    4    4    3    4    1
## 2349    4    2    4    4    1
## 2350    3    3    3    3    2
## 2351    4    4    4    4    1
## 2352    3    3    3    4    1
## 2353    4    4    4    4    1
## 2354    4    4    4    4    1
## 2355    3    4    3    3    1
## 2356    3    2    3    3    2
## 2357    3    3    3    3    2
## 2358    4    4    4    4    1
## 2359    3    4    4    1    1
## 2360    4    3    4    4    1
## 2361    4    3    3    3    1
## 2362    4    2    3    4    2
## 2363    3    3    3    4    2
## 2364    3    2    4    3    2
## 2365    3    3    3    3    2
## 2366    3    3    3    3    2
## 2367    2    3    2    3    2
## 2368    4    3    4    4    1
## 2369    3    2    2    2    2
## 2370    4    4    4    4    1
## 2371    4    4    4    4    1
## 2372    3    3    3    4    2
## 2373    4    4    4    4    1
## 2374    2    4    4    4    1
## 2375    3    3    2    3    2
## 2376    3    3    3    2    2
## 2377    3    3    3    3    1
## 2378    3    3    3    3    2
## 2379    3    3    2    3    2
## 2380    4    3    3    3    2
## 2381    4    3    3    4    1
## 2382    3    3    3    3    2
## 2383    3    3    4    4    2
## 2384    3    2    3    3    2
## 2385    4    4    4    4    1
## 2386    3    1    4    4    1
## 2387    4    4    4    4    1
## 2388    4    4    4    4    1
## 2389    3    3    3    3    2
## 2390    3    4    4    4    1
## 2391    3    4    4    4    1
## 2392    4    4    2    4    1
## 2393    3    2    2    3    2
## 2394    3    4    3    4    1
## 2395    4    4    4    4    1
## 2396    4    3    3    3    1
## 2397    3    3    3    3    2
## 2398    3    4    3    2    2
## 2399    3    2    2    3    2
## 2400    3    2    2    3    2
## 2401    4    4    4    4    1
```

```
## 2402            3         3         2         2         2
## 2403            3         3         3         3         2
## 2404            3         3         3         3         2
## 2405            2         2         2         2         2
## 2406            3         3         2         3         2
## 2407            4         3         2         4         1
## 2408            3         3         2         2         2
## 2409            3         3         3         3         1
## 2410            4         2         3         3         1
## 2411            3         3         2         3         2
## 2412            3         3         3         3         2
## 2413            3         3         3         3         2
## 2414            4         3         3         3         1
## 2415            3         3         4         3         1
## 2416            3         4         2         4         2
## 2417            3         3         3         3         2
## 2418            3         3         4         4         1
## 2419            4         4         4         4         1
## 2420            4         4         4         4         1
## 2421            4         3         3         3         1
## 2422            3         2         3         4         2
## 2423            3         2         3         4         2
## 2424            4         2         4         4         1
## 2425            4         3         3         3         1
## 2426            4         4         2         4         1
## 2427            4         4         4         4         1
## 2428            3         2         2         2         2
## 2429            4         3         4         4         1
## 2430            4         4         4         4         1
## 2431            2         2         2         1         2
```

Group.1	Esteem87_E1	Esteem87_E2	Esteem87_E3	Esteem87_E4	Esteem87_E5	Esteem87_E6	Esteem87_E7	Esteem87_E8	Esteem87_E9	Esteem87_E10	cluster
1	3.89	3.89	3.90	3.82	3.90	3.78	3.63	3.53	3.49	3.80	1
2	3.37	3.33	3.28	3.20	3.18	3.06	2.96	2.69	2.67	2.96	2

c) Can you visualize the clusters with somewhat clear boundaries? You may try different pairs of variables and different PC pairs of the esteem scores.

Answer: When we cluster by PC1 and PC2, we see a very clear boundary given by PC1. Specifically, group 1 is almost entirely to the left of PC1 = 0, while group 2 is almost entirely to the right of PC2 = 0.



6. We now try to find out what factors are related to self-esteem? PC1 of all the Esteem scores is a good variable to summarize one's esteem scores. We take PC1 as our response variable.

   a) Prepare possible factors/variables:

- EDA the data set first.
- Personal information: gender, education (05), log(income) in 87, job type in 87. One way to summarize one's weight and height is via Body Mass Index which is defined as the body mass divided by the square of the body height, and is universally expressed in units of kg/m². Note, you need to create BMI first. Then may include it as one possible predictor.
- Household environment: Imagazine, Inewspaper, Ilibrary, MotherEd, FatherEd, FamilyIncome78. Do set indicators `Imagazine`, `Inewspaper` and `Ilibrary` as factors.
- You may use PC1 of ASVAB as level of intelligence

```
\textcolor{red}{\textbf{Answer:}} See .rmd file for code. I created a dataframe that contains all o
```

```
##     Gender      Education05    LogIncome87    Imagazine Inewspaper Ilibrary
##  female:1199   Min.   : 6.0   Min.   : 0.00   0: 686    0: 339     0: 559
##  male  :1232   1st Qu.:12.0   1st Qu.: 8.41   1:1745    1:2092     1:1872
##                Median :13.0   Median : 9.39
##                Mean   :13.9   Mean   : 8.13
##                3rd Qu.:16.0   3rd Qu.: 9.85
##                Max.   :20.0   Max.   :10.99
##     MotherEd       FatherEd     FamilyIncome78    PC1_Esteem     PC1_asvab
##  Min.   : 0.0   Min.   : 0.0   Min.   :    0   Min.   :3.95   Min.   :  0.0
##  1st Qu.:11.0   1st Qu.:10.0   1st Qu.:11167   1st Qu.:7.48   1st Qu.: 60.9
##  Median :12.0   Median :12.0   Median :20000   Median :7.98   Median : 89.1
##  Mean   :11.7   Mean   :11.8   Mean   :21252   Mean   :7.88   Mean   : 85.4
##  3rd Qu.:12.0   3rd Qu.:14.0   3rd Qu.:27500   3rd Qu.:8.39   3rd Qu.:112.2
##  Max.   :20.0   Max.   :20.0   Max.   :75001   Max.   :9.74   Max.   :144.2
```

```
b)   Run a few regression models between PC1 of all the esteem scores and suitable variables listed in a

  - How did you land this model? Run a model diagnosis to see if the linear model assumptions are reason
```

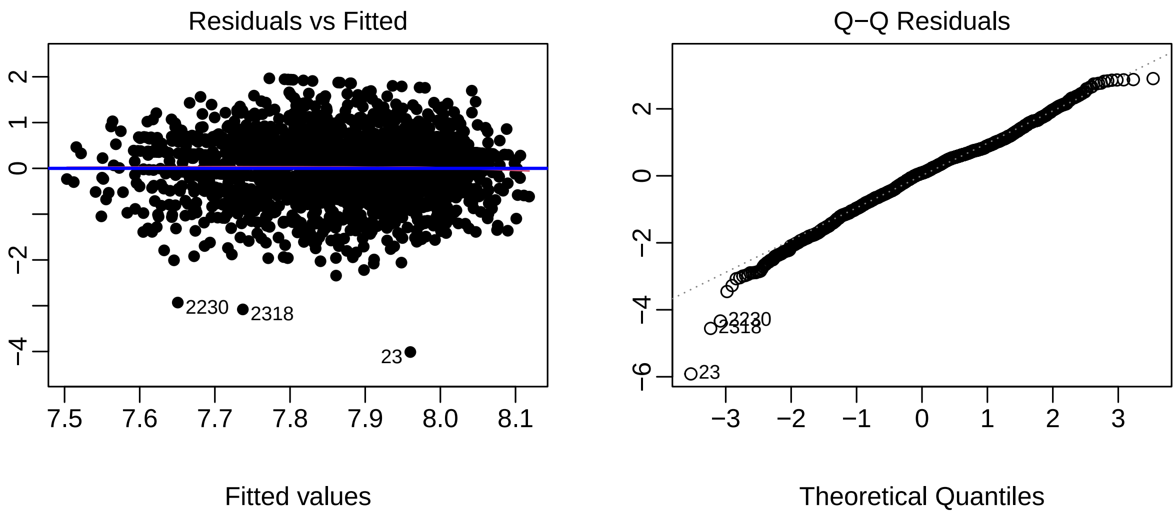
```
- Write a summary of your findings. In particular, explain what and how the variables in the model af
```

Answer:

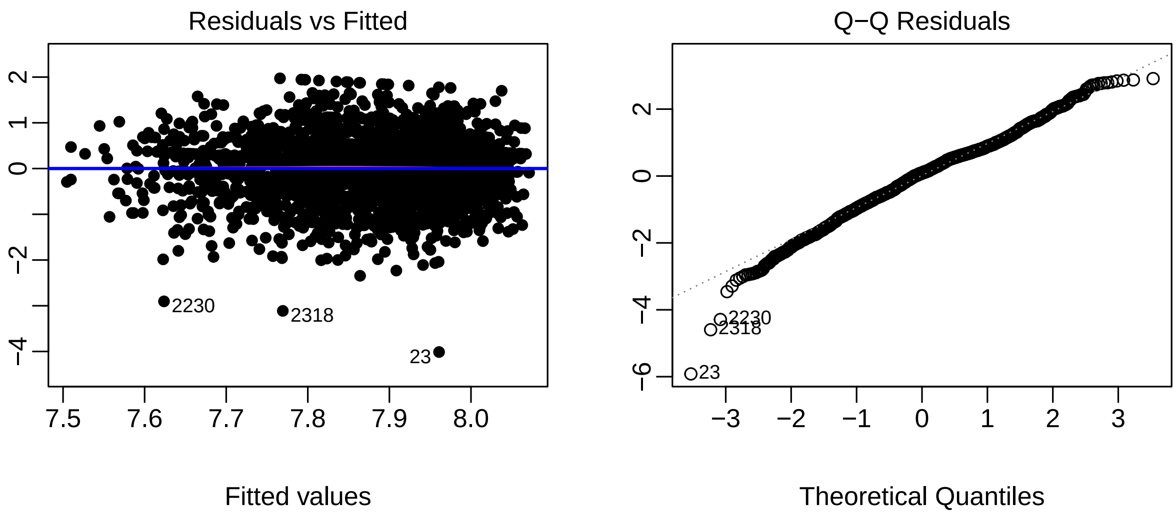
(i) model4 is my final best model. This model uses PC1 of the esteem scores as the dependent variables and the following as explanatory variables: gender, education level in 2005, log income in 1987, family income in 1978, and PC1 of ASVAB scores. I landed this model by running multiple regression models and looking into the residual and QQ plots. In all the models I ran, the plots provided evidence that the linearity and homoscedasity assumptions are met because the residuals follow a symmetric pattern around h=0 and are evenly distributed within a band. The QQ plot also provided evidence of the normality assumption being met due to the presence of a well fitted straight line. I decided not to use statistical significance as a criterion because the significance did not seem very informative – in the model that incorporated all variables, the intercept, IMagazine, and PC1 of the ASVAB scores were statistically significant. Intuitively, whether a family reads a magazine or not should not affect one's self-esteem. Reading a magazine could be correlated to income, and if this is the case, then we would not need to include this redudant variable. Additionally, Ward, Greenhill, & Bakke (2010) show that statistically significant models can actually have very low predictive power; thus, choosing variables based on statistical significance does not seem like a well-informed criterion.

(ii) When we use model4 as the final best model, we see that gender, education, income, family income, and intelligence all affect one's self-esteem. Specifically, being male and having more education, a higher income in 1987, a higher family income in 1978, and a higher score on the ASVAB as captured by PC1 is associated with having a higher self-esteem, as captured by PC1 of the 1987 esteem scores.

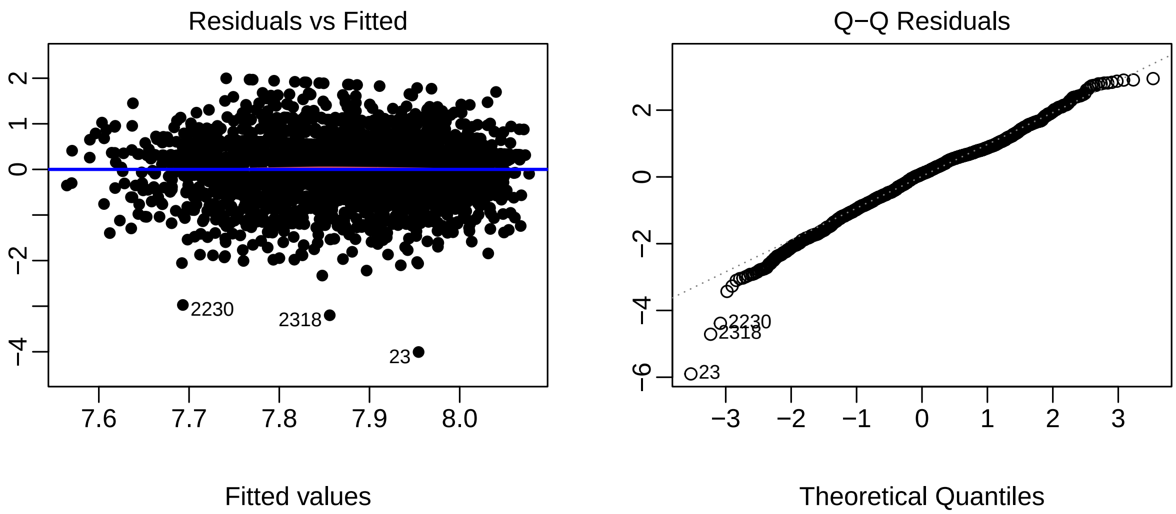
```
##
## Call:
## lm(formula = PC1_Esteem ~ Gender + Education05 + LogIncome87 +
##     Imagazine + Inewspaper + Ilibrary + MotherEd + FatherEd +
##     FamilyIncome78 + PC1_asvab, data = data87)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -4.011 -0.434  0.056  0.446  1.966
##
## Coefficients:
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)     7.45e+00   9.34e-02   79.73  < 2e-16 ***
## Gendermale      1.25e-02   2.80e-02    0.45  0.65468
## Education05     2.59e-03   7.09e-03    0.37  0.71431
## LogIncome87     5.46e-03   4.41e-03    1.24  0.21535
## Imagazine1      3.53e-02   3.41e-02    1.03  0.30078
## Inewspaper1     8.83e-02   4.37e-02    2.02  0.04330 *
## Ilibrary1      -2.56e-02   3.48e-02   -0.74  0.46123
## MotherEd        3.55e-03   7.08e-03    0.50  0.61623
## FatherEd        4.13e-04   5.27e-03    0.08  0.93756
## FamilyIncome78  1.22e-06   1.10e-06    1.11  0.26769
## PC1_asvab       2.16e-03   5.79e-04    3.74  0.00019 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.679 on 2420 degrees of freedom
## Multiple R-squared:  0.026,  Adjusted R-squared:  0.022
## F-statistic: 6.47 on 10 and 2420 DF,  p-value: 6.56e-10
```



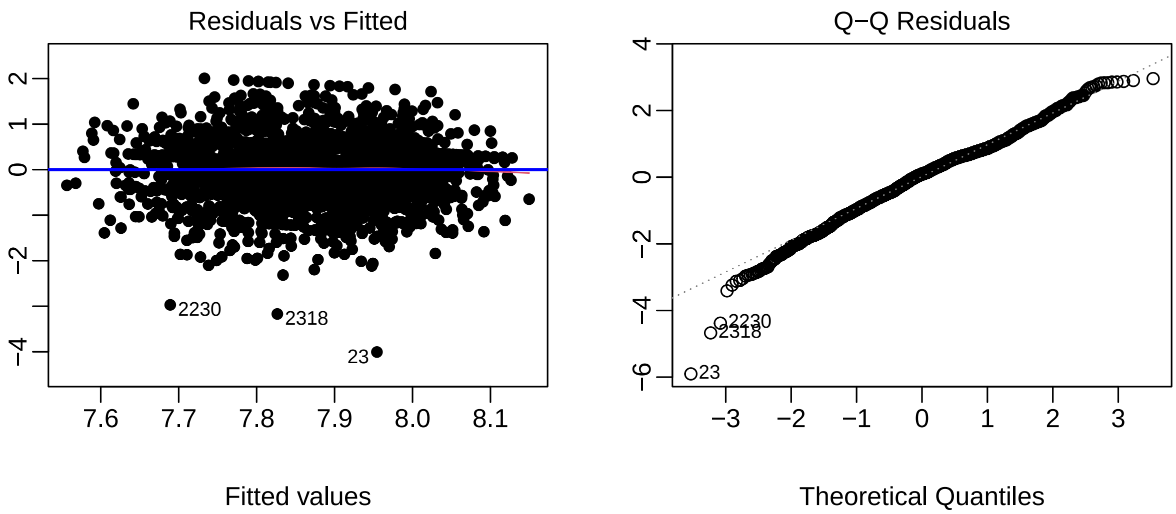

```
##
## Call:
## lm(formula = PC1_Esteem ~ Gender + Education05 + LogIncome87 +
##     Inewspaper + PC1_asvab, data = data87)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -4.012 -0.428  0.059  0.447  1.972
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 7.457714   0.087216   85.51  < 2e-16 ***
## Gendermale  0.016207   0.027854    0.58    0.561
## Education05 0.004496   0.006857    0.66    0.512
## LogIncome87 0.006116   0.004389    1.39    0.164
## Inewspaper1 0.103231   0.041417    2.49    0.013 *
## PC1_asvab   0.002438   0.000548    4.45  9.2e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.679 on 2425 degrees of freedom
## Multiple R-squared:  0.0245, Adjusted R-squared:  0.0225
## F-statistic: 12.2 on 5 and 2425 DF,  p-value: 1.1e-11
```




```
##
## Call:
## lm(formula = PC1_Esteem ~ Gender + Education05 + LogIncome87 +
##     PC1_asvab, data = data87)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -4.006 -0.424  0.063  0.450  1.997
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 7.510986   0.084647   88.73   <2e-16 ***
## Gendermale  0.016824   0.027882    0.60     0.55
## Education05 0.005190   0.006859    0.76     0.45
## LogIncome87 0.006401   0.004392    1.46     0.15
## PC1_asvab   0.002711   0.000538    5.04    5e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.679 on 2426 degrees of freedom
## Multiple R-squared:  0.022,  Adjusted R-squared:  0.0204
## F-statistic: 13.7 on 4 and 2426 DF,  p-value: 5.22e-11
```




```
##
## Call:
## lm(formula = PC1_Esteem ~ Gender + Education05 + LogIncome87 +
##     FamilyIncome78 + PC1_asvab, data = data87)
##
## Residuals:
##    Min     1Q Median     3Q    Max
## -4.005 -0.424  0.063  0.449  2.005
##
## Coefficients:
##                Estimate Std. Error t value Pr(>|t|)
## (Intercept)    7.51e+00   8.46e-02   88.77  < 2e-16 ***
## Gendermale     1.48e-02   2.79e-02    0.53     0.59
## Education05    3.87e-03   6.90e-03    0.56     0.58
## LogIncome87    5.81e-03   4.40e-03    1.32     0.19
## FamilyIncome78 1.79e-06   1.06e-06    1.70     0.09 .
## PC1_asvab      2.54e-03   5.47e-04    4.65  3.5e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.679 on 2425 degrees of freedom
## Multiple R-squared:  0.0232, Adjusted R-squared:  0.0212
## F-statistic: 11.5 on 5 and 2425 DF,  p-value: 5.34e-11
```



2 Case study 2: Breast cancer sub-type

The Cancer Genome Atlas (TCGA), a landmark cancer genomics program by National Cancer Institute (NCI), molecularly characterized over 20,000 primary cancer and matched normal samples spanning 33 cancer types. The genome data is open to public from the Genomic Data Commons Data Portal (GDC).

In this study, we focus on 4 sub-types of breast cancer (BRCA): basal-like (basal), Luminal A-like (lumA), Luminal B-like (lumB), HER2-enriched. The sub-type is based on PAM50, a clinical-grade luminal-basal classifier. (We had hoped to download the data for control groups for each type of the cancer. But failed to do so. Please let us know if you find the appropriate data.)

- Luminal A cancers are low-grade, tend to grow slowly and have the best prognosis.
- Luminal B cancers generally grow slightly faster than luminal A cancers and their prognosis is slightly worse.
- HER2-enriched cancers tend to grow faster than luminal cancers and can have a worse prognosis, but they are often successfully treated with targeted therapies aimed at the HER2 protein.
- Basal-like breast cancers or triple negative breast cancers do not have the three receptors that the other sub-types have so have fewer treatment options.

We will try to use mRNA expression data alone without the labels to classify 4 sub-types. Classification without labels or prediction without outcomes is called unsupervised learning. We will use K-means and spectrum clustering to cluster the mRNA data and see whether the sub-type can be separated through mRNA data.

We first read the data using `data.table::fread()` which is a faster way to read in big data than `read.csv()`.

```
## brca_subtype
## Basal  Her2  LumA  LumB
##   208    91   628   233
```

1. Summary and transformation

a) How many patients are there in each sub-type?

- Basal: 208
- Her2: 91
- LumA: 628
- LumB: 233

b) Randomly pick 5 genes and plot the histogram by each sub-type.

- See plot below

c) Clean and transform the mRNA sequences by first remove gene with zero count and no variability and then apply logarithmic transform.

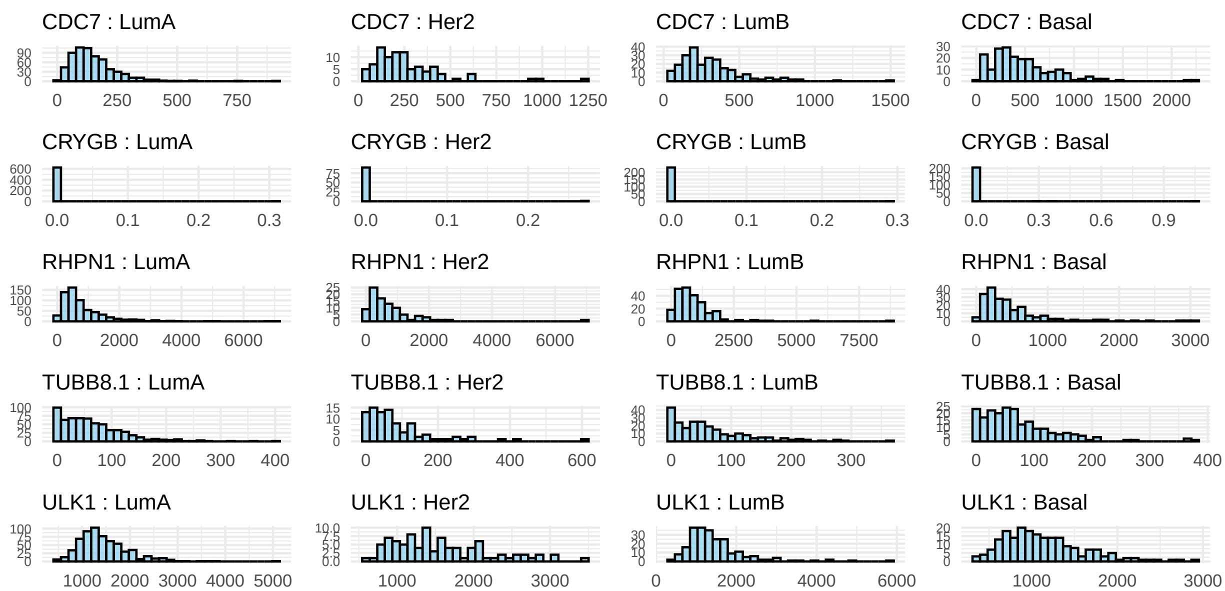
d) Apply PCA to the transformed data. How many PCs should we use and why?

- According to the scree plot, it would be best to use 2 PCs. The plot shows a clear elbow after the 2nd PC, and the proportion of variance explained looks significantly lower after the 2nd PC.

```
################
## Histograms ##
################

set.seed(124)
random_genes <- sample(colnames(brca)[-1], 5, replace = FALSE)

## Histogram function
plot_gene_histograms <- function(data, genes) {
  plots <- list()
  for (gene in genes) {
    for (subtype in unique(data$BRCA_Subtype_PAM50)) {
      subset_data <- data[data$BRCA_Subtype_PAM50 == subtype, ]
      p <- ggplot(subset_data, aes_string(x=gene)) +
        geom_histogram(bins=30, fill="skyblue", color="black", alpha=0.7) +
        labs(title=paste(gene, ":", subtype), x=NULL, y=NULL) + # Remove redundant axis titles
        theme_minimal() +
        theme(legend.position="none", # Hide legend
              plot.title=element_text(size=10), # Reduce title size
              axis.text.x=element_text(size=8), # Reduce axis text size
              axis.text.y=element_text(size=6)) # Reduce axis text size
      plots[[paste(gene, subtype)]] <- p
    }
  }
  return(plots)
}

# Generate and arrange plots
plots <- plot_gene_histograms(brca, random_genes)
```

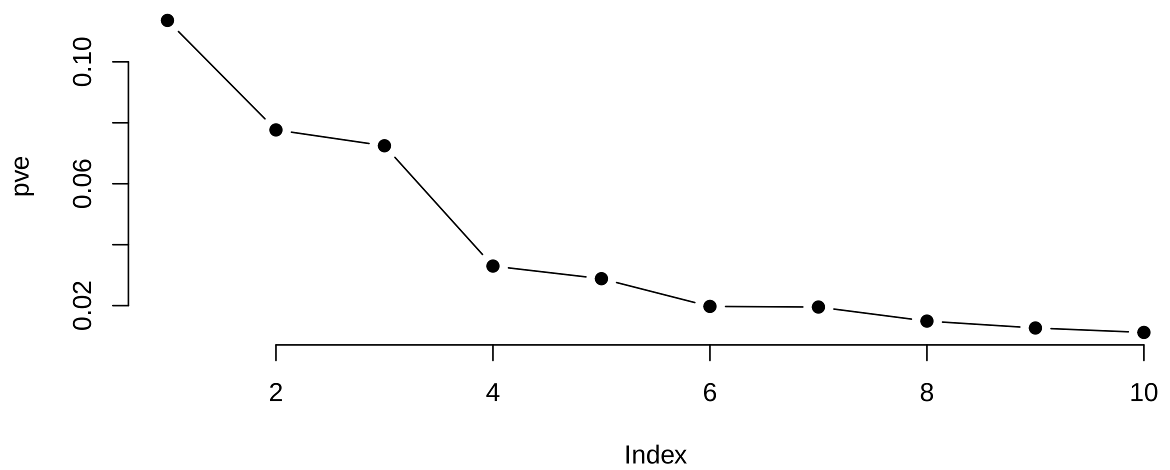
```
## Warning: `aes_string()` was deprecated in ggplot2 3.0.0.
## i Please use tidy evaluation idioms with `aes()`.
## i See also `vignette("ggplot2-in-packages")` for more information.
## This warning is displayed once every 8 hours.
## Call `lifecycle::last_lifecycle_warnings()` to see where this warning was
## generated.
```

```r
plot_grid <- do.call(patchwork::wrap_plots, c(plots, ncol = 4))

# Display the arranged plot grid
plot_grid
```




```r
################
### Cleaning ###
################

library(dplyr)

# Filter out genes with only zero counts and no variability
# genes_to_keep <- brca %>%
#   select(-BRCA_Subtype_PAM50) %>%
#   summarise(across(everything(), ~any(. != 0) & sd(.) != 0)) %>%
#   select_if(~ . == TRUE) %>%
#   names()
#
# brca_clean <- brca %>%
#   select(BRCA_Subtype_PAM50, all_of(genes_to_keep))
#
# # Apply logarithmic transformation
# brca_transformed <- brca_clean %>%
#   mutate(across(-BRCA_Subtype_PAM50, log1p))


brca_transformed <- readRDS("data/brca_transformed.rds")

################
##### PCA ######
################

# brca_pca <- prcomp(brca_transformed %>% select(-BRCA_Subtype_PAM50), scale. = T, center=TRUE)
```

```r
#
# brca_pca$rotation <- brca_pca$rotation[, 1:20]
# brca_pca$x <- brca_pca$x[, 1:20]
# saveRDS(brca_pca, "data/brca_pca.rds")

brca_pca <- readRDS("data/brca_pca.rds")


# Plot the scree plot
pve <- summary(brca_pca)$importance[2, 1:10]
plot(pve, type="b", pch = 19, frame = FALSE)
```



2. Apply kmeans on the transformed dataset with 4 centers (4 clusters) and output the discrepancy table between the real sub-type `brca_subtype` and the cluster labels.

```
##
## brca_subtype   1   2   3   4
##        Basal   0 190  17   1
##        Her2   23  13   9  46
##        LumA  210   0  71 347
##        LumB  169   1  22  41
```

3. Spectrum clustering: to scale or not to scale?

   a) Apply PCA on the centered and scaled dataset. How many PCs should we use and why? You are encouraged to use `irlba::irlba()`. **In order to do so please review the section about SVD in PCA module.**

   b) Plot PC1 vs PC2 of the centered and scaled data and PC1 vs PC2 of the centered but unscaled data side by side. Should we scale or not scale for clustering process? Why? (Hint: to put plots side by side, use `gridExtra::grid.arrange()` or `ggpubr::ggrrange()` or `egg::ggrrange()` for ggplots; use `fig.show="hold"` as chunk option for base plots)

4. Spectrum clustering: center but do not scale the data

   a) Use the first 4 PCs of the centered and unscaled data and apply kmeans. Find a reasonable number of clusters using within sum of squared with the elbow rule.
   b) Choose an optimal cluster number and apply kmeans. Compare the real sub-type and the clustering label as follows: Plot scatter plot of PC1 vs PC2. Use point color to indicate the true cancer type and point shape to indicate the clustering label. Plot the kmeans centroids with black dots. Summarize how good is clustering results compared to the real sub-type.
   c) Compare the clustering result from applying kmeans to the original data and the clustering result from applying kmeans to 4 PCs. Does PCA help in kmeans clustering? What might be the reasons if PCA helps?
   d) Now we have an x patient with breast cancer but with unknown sub-type. We have this patient's mRNA sequencing data. Project this x patient to the space of PC1 and PC2. (Hint: remember we remove some gene with no counts or no variablity, take log and centered, then find its PC1 to PC4 scores) Plot this patient in the plot in b) with a black dot as well. Calculate the Euclidean distance between this patient and each of the centroid of the cluster. (Don't forget the clusters are obtained by using 4 PC's) Can you tell which sub-type this patient might have?

3 Case Study: Fuel Efficiency in Automobiles

Linda will refine this case study by the following Monday, Feb 12th)

What determines how fuel efficient a car is? Are Japanese cars more fuel efficient? To answer thes questions we will build various linear models using the `Auto` dataset from the book `ISLR`. The original dataset contains information for about 400 different cars built in various years. To get the data, first install the package ISLR which has been done in the first R-chunk. The `Auto` dataset should be loaded automatically. Original data source is here: https://archive.ics.uci.edu/ml/datasets/auto+mpg

Get familiar with this dataset first. Tip: you can use the command `?ISLR::Auto` to view a description of the dataset. Our response variable will me `MPG`: miles per gallon.

3.1 EDA

a) Explore the data, list the variables with clear definitions. Set each variable with its appropriate class. For example `origin` should be set as a factor.

b) How many cars are included in this data set?

c) EDA, focus on pairwise plots and summary statistics. Briefly summarize your findings and any peculiarities in the data.

3.2 What effect does `time` have on `MPG`?

a) Start with a simple regression of `mpg` vs. `year` and report R's `summary` output. Is `year` a significant variable at the .05 level? State what effect `year` has on `mpg`, if any, according to this model.

b) Add `horsepower` on top of the variable `year` to your linear model. Is `year` still a significant variable at the .05 level? Give a precise interpretation of the `year`'s effect found here.

c) The two 95% CI's for the coefficient of year differ among (a) and (b). How would you explain the difference to a non-statistician?

d) Create a model with interaction by fitting `lm(mpg ~ year * horsepower)`. Is the interaction effect significant at .05 level? Explain the year effect (if any).

3.3 Categorical predictors

Remember that the same variable can play different roles! Take a quick look at the variable `cylinders`, and try to use this variable in the following analyses wisely. We all agree that a larger number of cylinders will lower mpg. However, we can interpret `cylinders` as either a continuous (numeric) variable or a categorical variable.

a) Fit a model that treats `cylinders` as a continuous/numeric variable. Is `cylinders` significant at the 0.01 level? What effect does `cylinders` play in this model?

b) Fit a model that treats `cylinders` as a categorical/factor. Is `cylinders` significant at the .01 level? What is the effect of `cylinders` in this model? Describe the `cylinders` effect over `mpg`.

c) What are the fundamental differences between treating `cylinders` as a continuous and categorical variable in your models?

d) Can you test the null hypothesis: fit0: `mpg` is linear in `cylinders` vs. fit1: `mpg` relates to `cylinders` as a categorical variable at .01 level?

3.4 Results

Final modeling question: we want to explore the effects of each feature as best as possible. You may explore interactions, feature transformations, higher order terms, or other strategies within reason. The model(s) should be as parsimonious (simple) as possible unless the gain in accuracy is significant from your point of view.

a) Describe the final model. Include diagnostic plots with particular focus on the model residuals and diagnoses.

b) Summarize the effects found.

c) Predict the `mpg` of the following car: A red car built in the US in 1983 that is 180 inches long, has eight cylinders, displaces 350 cu. inches, weighs 4000 pounds, and has a horsepower of 260. Also give a 95% CI for your prediction.

4 Simple Regression through simulations (Optional)

4.1 Linear model through simulations

This exercise is designed to help you understand the linear model using simulations. In this exercise, we will generate (x_i, y_i) pairs so that all linear model assumptions are met.

Presume that $\mathbf{x}$ and $\mathbf{y}$ are linearly related with a normal error $\boldsymbol{\varepsilon}$, such that $\mathbf{y} = 1 + 1.2\mathbf{x} + \boldsymbol{\varepsilon}$. The standard deviation of the error ε_i is $\sigma = 2$.

We can create a sample input vector ($n = 40$) for $\mathbf{x}$ with the following code:

```r
# Generates a vector of size 40 with equally spaced values between 0 and 1, inclusive
x <- seq(0, 1, length = 40)
```

4.1.1 Generate data

Create a corresponding output vector for $\mathbf{y}$ according to the equation given above. Use `set.seed(1)`. Then, create a scatterplot with (x_i, y_i) pairs. Base R plotting is acceptable, but if you can, please attempt to use `ggplot2` to create the plot. Make sure to have clear labels and sensible titles on your plots.

4.1.2 Understand the model

i. Find the LS estimates of β_0 and β_1, using the `lm()` function. What are the true values of β_0 and β_1? Do the estimates look to be good?

ii. What is your RSE for this linear model fit? Is it close to $\sigma = 2$?

iii. What is the 95% confidence interval for β_1? Does this confidence interval capture the true β_1?

iv. Overlay the LS estimates and the true lines of the mean function onto a copy of the scatterplot you made above.

4.1.3 diagnoses

i. Provide residual plot where fitted $\mathbf{y}$-values are on the x-axis and residuals are on the y-axis.

ii. Provide a normal QQ plot of the residuals.

iii. Comment on how well the model assumptions are met for the sample you used.

4.2 Understand sampling distribution and confidence intervals

This part aims to help you understand the notion of sampling statistics and confidence intervals. Let's concentrate on estimating the slope only.

Generate 100 samples of size $n = 40$, and estimate the slope coefficient from each sample. We include some sample code below, which should guide you in setting up the simulation. Note: this code is easier to follow but suboptimal; see the appendix for a more optimal R-like way to run this simulation.

```
# Inializing variables. Note b_1, upper_ci, lower_ci are vectors
x <- seq(0, 1, length = 40)
n_sim <- 100              # number of simulations
b1 <- 0                   # n_sim many LS estimates of beta_1 (=1.2). Initialize to 0 for now
upper_ci <- 0             # upper bound for beta_1. Initialize to 0 for now.
lower_ci <- 0             # lower bound for beta_1. Initialize to 0 for now.
t_star <- qt(0.975, 38)   # Food for thought: why 38 instead of 40? What is t_star?

# Perform the simulation
for (i in 1:n_sim){I l
  y <- 1 + 1.2 * x + rnorm(40, sd = 2)
  lse <- lm(y ~ x)
  lse_output <- summary(lse)$coefficients
  se <- lse_output[2, 2]
  b1[i] <- lse_output[2, 1]
  upper_ci[i] <- b1[i] + t_star * se
  lower_ci[i] <- b1[i] - t_star * se
}
results <- as.data.frame(cbind(se, b1, upper_ci, lower_ci))

# remove unecessary variables from our workspace
rm(se, b1, upper_ci, lower_ci, x, n_sim, b1, t_star, lse, lse_out)
```

i. Summarize the LS estimates of β_1 (stored in `results$b1`). Does the sampling distribution agree with theory?

ii. How many of your 95% confidence intervals capture the true $\boldsymbol{\beta}_1$? Display your confidence intervals graphically.