Homework 3

Applied Mutlivariate Analysis

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1 Workspace

1.1 Packages

```
library(car)
library(knitr)
library(psych)
library(lavaan)
library(semPlot)
library(kableExtra)
library(multcomp)
library(lme4)
library(plyr)
library(tidyverse)
library(MVN)
```

1.2 data

The file, Set_5.csv, contains data from a study in which college students completed the NEO-PI Personality Inventory. This 240-item scale purportedly measures the Big Five personality dimensions, assumed to be fairly independent. The inventory is scored on 6 subscales per dimension, listed below. The file contains the subscale scores, rather than the individual items, which should help reduce the impact of the small sample size.

Neuroticism: Anxiety
Neuroticism: Angry_Hostility
Neuroticism: Depression
Neuroticism: Self_Consciousness
Neuroticism: Impulsiveness
Neuroticism: Vulnerability
Extraversion: Warmth
Extraversion: Gregariousness
Extraversion: Assertiveness
Extraversion: Activity
Extraversion: Excitement_Seeking
Extraversion: Positive_Emotions
Openness: Fantasy
Openness: Aesthetics
Openness: Feelings
Openness: Actions

Openness: Ideas
Openness: Values
Agreeableness: Trust
Agreeableness: Straightforwardness
Agreeableness: Altruism
Agreeableness: Compliance
Agreeableness: Modesty
Agreeableness: Tender_Mindedness
Conscientiousness: Competence
Conscientiousness: Order
Conscientiousness: Dutifulness
Conscientiousness: Achievement_Striving
Conscientiousness: Self_Discipline
Conscientiousness: Deliberation

```
wd <- "https://github.com/emoriebeck/homeworks/raw/master/multivariate/homeworks/homework6"

dat <- sprintf("%s/Set_5(1).csv", wd) %>%
  read.csv(., stringsAsFactors = F)

head(dat)
```

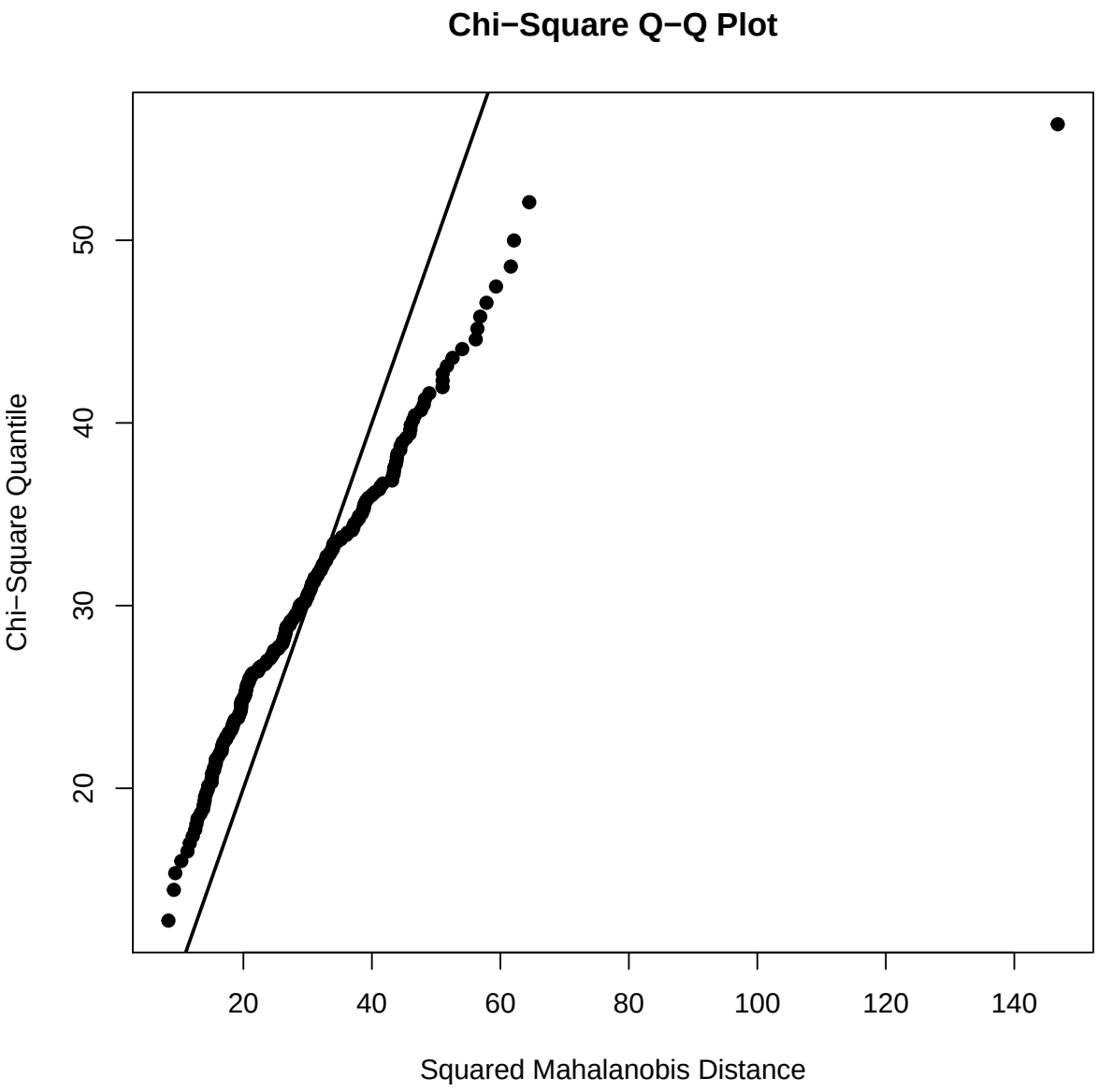
```
##   ID Anxiety Angry_Hostility Depression Self_Consciousness Impulsiveness
## 1  2   2.625           2.000      1.750           2.250000         2.625
## 2  3   3.625           2.875      3.000           3.500000         4.250
## 3  4   3.000           2.750      2.625           2.875000         3.000
## 4  5   4.375           3.125      4.500           4.000000         3.875
## 5  6   3.500           2.875      3.000           2.571429         3.625
## 6  7   4.000           4.125      2.875           2.375000         4.000
##   Vulnerability   Warmth Gregariousness Assertiveness Activity
## 1      2.166667 4.666667          4.000      3.000000 4.833333
## 2      2.125000 4.500000          2.750      2.625000 3.000000
## 3      2.875000 3.750000          3.125      2.375000 3.250000
## 4      3.750000 3.250000          2.250      2.500000 1.875000
## 5      2.750000 3.750000          3.125      3.285714 3.500000
## 6      3.125000 3.500000          2.625      3.375000 3.125000
##   Excitement_Seeking Positive_Emotions  Fantasy Aesthetics Feelings
## 1              3.500             4.750 3.857143   3.571429 4.666667
## 2              2.875             3.500 3.500000   4.125000 3.625000
## 3              3.875             3.375 3.375000   3.500000 3.250000
## 4              2.750             2.625 3.000000   3.750000 4.250000
## 5              3.750             3.625 3.125000   1.625000 3.125000
## 6              2.000             3.375 3.500000   2.000000 3.250000
##    Actions Ideas Values Trust Straightforwardness Altruism Compliance
## 1 2.571429 4.400  4.600 5.000            2.166667 4.833333      2.750
## 2 3.000000 3.875  3.125 3.250            3.750000 3.625000      3.125
## 3 2.375000 4.125  3.500 3.250            3.125000 4.000000      3.750
## 4 3.375000 2.750  4.125 3.000            3.428571 3.875000      4.000
## 5 2.750000 2.500  3.625 3.375            3.250000 4.125000      3.625
## 6 2.625000 1.125  3.625 2.500            2.875000 3.000000      2.250
##   Modesty Tender_Mindedness Competence Order Dutifulness
## 1   4.000          3.833333       4.50 3.625    3.285714
## 2   2.625          3.250000       3.00 2.250    3.875000
```

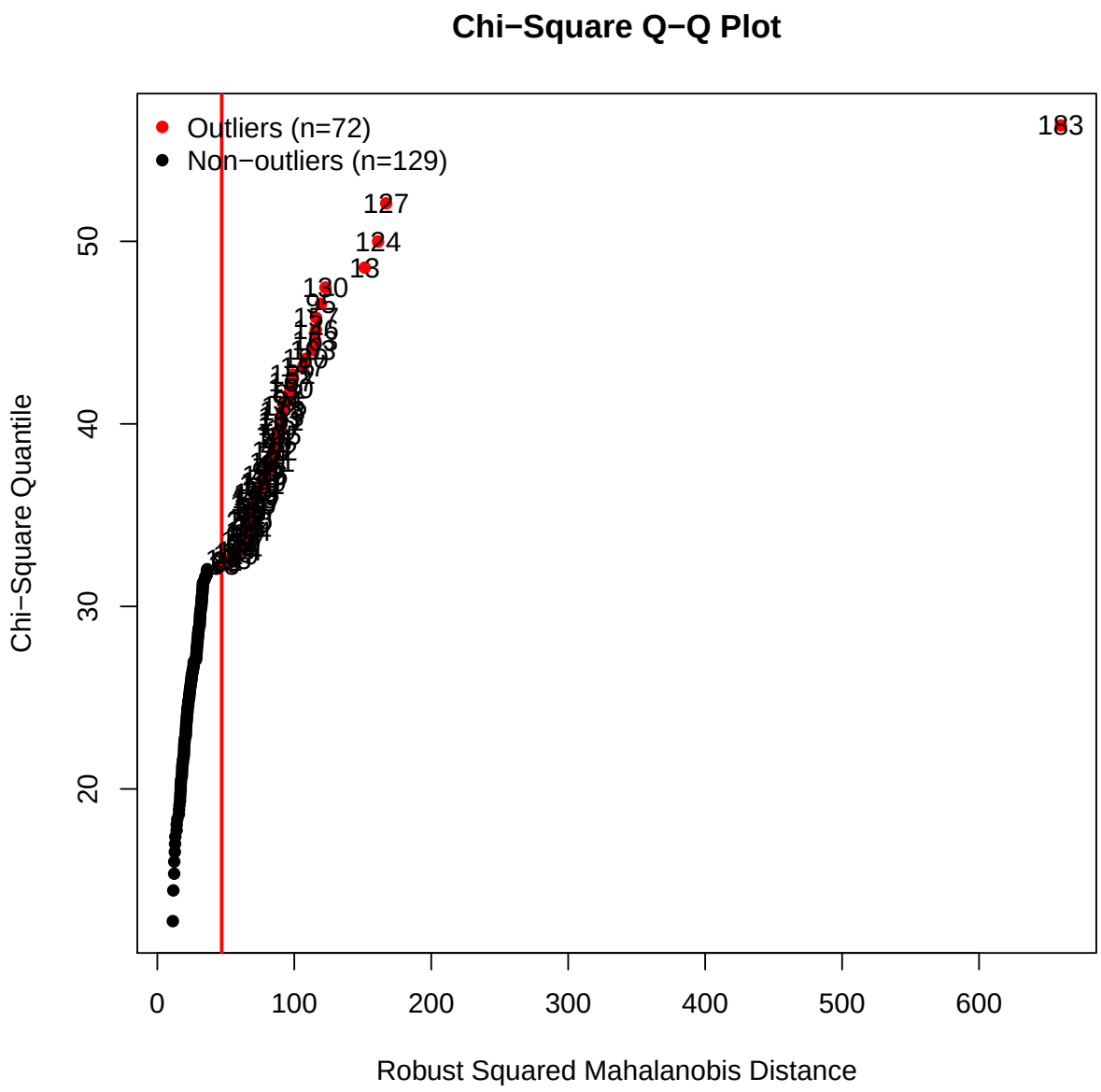
```
## 3   2.750          3.250000       3.75 3.250    3.750000
## 4   4.125          3.750000       2.75 3.000    2.875000
## 5   3.375          3.375000       3.75 4.000    3.750000
## 6   2.625          3.375000       3.00 3.625    2.625000
##   Achievement_Striving Self_Discipline Deliberation
## 1             4.333333           4.250        2.875
## 2             2.750000           3.750        3.500
## 3             3.375000           3.375        3.125
## 4             2.875000           2.625        3.250
## 5             3.375000           2.875        3.375
## 6             3.000000           2.625        2.625
```

```
source <- tribble(
~Factor, ~Facet,
"Neuroticism", "Anxiety",
"Neuroticism", "Angry_Hostility",
"Neuroticism", "Depression",
"Neuroticism", "Self_Consciousness",
"Neuroticism", "Impulsiveness",
"Neuroticism", "Vulnerability",
"Extraversion", "Warmth",
"Extraversion", "Gregariousness",
"Extraversion", "Assertiveness",
"Extraversion", "Activity",
"Extraversion", "Excitement_Seeking",
"Extraversion", "Positive_Emotions",
"Openness", "Fantasy",
"Openness", "Aesthetics",
"Openness", "Feelings",
"Openness", "Actions",
"Openness", "Ideas",
"Openness", "Values",
"Agreeableness", "Trust",
"Agreeableness", "Straightforwardness" ,
"Agreeableness", "Altruism",
"Agreeableness", "Compliance",
"Agreeableness", "Modesty",
"Agreeableness", "Tender_Mindedness",
"Conscientiousness", "Competence",
"Conscientiousness", "Order",
"Conscientiousness", "Dutifulness",
"Conscientiousness", "Achievement_Striving",
"Conscientiousness", "Self_Discipline",
"Conscientiousness", "Deliberation"
)

dat <- dat %>% select(ID, source$Facet)
```

1.3 Check for Outliers

```r
dat2 <- dat %>% select(-ID, ) %>% data.frame
rownames(dat2) <- dat$ID #1:nrow(dat2)
(mv <- mvn(dat2,mvnTest="mardia", multivariatePlot="qq",multivariateOutlierMethod="quan",showOutliers=T
```






```
## $multivariateNormality
##              Test        Statistic               p value Result
## 1 Mardia Skewness  8953.5001026237 9.27843696584267e-234     NO
## 2 Mardia Kurtosis 25.6787714020441                     0     NO
## 3             MVN             <NA>                  <NA>     NO
##
## $univariateNormality
##            Test             Variable Statistic   p value Normality
## 1  Shapiro-Wilk       Anxiety           0.9688   2e-04      NO
## 2  Shapiro-Wilk   Angry_Hostility       0.9826  0.0138      NO
## 3  Shapiro-Wilk      Depression         0.9869  0.0595      YES
## 4  Shapiro-Wilk  Self_Consciousness     0.9777  0.0028      NO
## 5  Shapiro-Wilk    Impulsiveness        0.9472  <0.001      NO
## 6  Shapiro-Wilk    Vulnerability        0.9857  0.0391      NO
```

```
## 7  Shapiro-Wilk        Warmth           0.9344  <0.001      NO
## 8  Shapiro-Wilk    Gregariousness       0.9785  0.0036      NO
## 9  Shapiro-Wilk    Assertiveness        0.9839  0.0211      NO
## 10 Shapiro-Wilk       Activity          0.9547  <0.001      NO
## 11 Shapiro-Wilk  Excitement_Seeking     0.9499  <0.001      NO
## 12 Shapiro-Wilk  Positive_Emotions      0.9491  <0.001      NO
## 13 Shapiro-Wilk       Fantasy           0.9523  <0.001      NO
## 14 Shapiro-Wilk      Aesthetics         0.9735   7e-04      NO
## 15 Shapiro-Wilk       Feelings          0.9154  <0.001      NO
## 16 Shapiro-Wilk       Actions           0.9627  <0.001      NO
## 17 Shapiro-Wilk        Ideas            0.9696   2e-04      NO
## 18 Shapiro-Wilk        Values           0.9087  <0.001      NO
## 19 Shapiro-Wilk        Trust            0.9527  <0.001      NO
## 20 Shapiro-Wilk Straightforwardness     0.9687   2e-04      NO
## 21 Shapiro-Wilk       Altruism          0.9090  <0.001      NO
## 22 Shapiro-Wilk      Compliance         0.9673   1e-04      NO
## 23 Shapiro-Wilk       Modesty           0.9718   5e-04      NO
## 24 Shapiro-Wilk  Tender_Mindedness      0.9164  <0.001      NO
## 25 Shapiro-Wilk      Competence         0.9493  <0.001      NO
## 26 Shapiro-Wilk        Order            0.9827  0.0143      NO
## 27 Shapiro-Wilk     Dutifulness         0.9525  <0.001      NO
## 28 Shapiro-Wilk Achievement_Striving    0.9609  <0.001      NO
## 29 Shapiro-Wilk   Self_Discipline       0.9774  0.0025      NO
## 30 Shapiro-Wilk     Deliberation        0.9615  <0.001      NO
##
## $Descriptives
##                        n     Mean   Std.Dev Median Min      Max     25th
## Anxiety              201 3.384453 0.7779526  3.500   0 4.875000 2.875000
## Angry_Hostility      201 2.821660 0.6890159  2.750   0 4.500000 2.375000
## Depression           201 2.949893 0.8391123  3.000   0 5.000000 2.375000
## Self_Consciousness   201 3.110519 0.6671846  3.125   0 4.750000 2.714286
## Impulsiveness        201 3.249556 0.5953863  3.375   0 4.625000 2.875000
## Vulnerability        201 2.609660 0.6780842  2.625   0 4.625000 2.125000
## Warmth               201 3.779561 0.6598163  3.875   0 5.000000 3.500000
## Gregariousness       201 3.158333 0.7554524  3.250   0 4.875000 2.750000
## Assertiveness        201 2.941927 0.7141767  3.000   0 4.875000 2.500000
## Activity             201 3.229004 0.5767897  3.250   0 4.833333 2.875000
## Excitement_Seeking   201 3.584577 0.6270903  3.625   0 5.000000 3.250000
## Positive_Emotions    201 3.684287 0.7378122  3.750   0 5.000000 3.125000
## Fantasy              201 3.659737 0.7265031  3.750   0 4.875000 3.250000
## Aesthetics           201 3.363539 0.8571747  3.375   0 5.000000 2.875000
## Feelings             201 3.887379 0.6477835  4.000   0 5.000000 3.500000
## Actions              201 2.971251 0.5849788  3.000   0 4.625000 2.625000
## Ideas                201 3.513599 0.7696339  3.625   0 5.000000 3.000000
## Values               201 3.783807 0.5664002  3.750   0 4.875000 3.500000
## Trust                201 3.343106 0.6984903  3.500   0 5.000000 3.000000
## Straightforwardness  201 3.247631 0.6981927  3.250   0 4.714286 2.750000
## Altruism             201 3.897092 0.5879144  3.875   0 5.000000 3.625000
## Compliance           201 3.114641 0.6383796  3.125   0 4.625000 2.750000
## Modesty              201 3.160537 0.6504879  3.250   0 5.000000 2.750000
## Tender_Mindedness    201 3.511058 0.5400171  3.500   0 4.800000 3.250000
## Competence           201 3.486407 0.6072013  3.500   0 5.000000 3.125000
## Order                201 3.165689 0.7473491  3.250   0 5.000000 2.625000
```

```
## Dutifulness          201 3.630360 0.6517670  3.625   0 5.000000 3.250000
## Achievement_Striving 201 3.371150 0.6828271  3.375   0 4.750000 3.000000
## Self_Discipline      201 3.261443 0.7019657  3.250   0 5.000000 2.875000
## Deliberation         201 3.106965 0.6145893  3.125   0 4.875000 2.750000
##                       75th        Skew   Kurtosis
## Anxiety              3.875 -0.65520717  0.8494755
## Angry_Hostility      3.250 -0.11418960  0.5226148
## Depression           3.500 -0.02546588 -0.1581829
## Self_Consciousness   3.500 -0.39666446  1.4360305
## Impulsiveness        3.625 -1.00765416  3.8124686
## Vulnerability        3.000  0.02402429  0.8095776
## Warmth               4.250 -1.16223708  4.2653957
## Gregariousness       3.625 -0.48949185  0.9682252
## Assertiveness        3.500 -0.37114794  0.5705680
## Activity             3.625 -0.80844019  3.8700815
## Excitement_Seeking   4.000 -0.95293496  4.2442910
## Positive_Emotions    4.125 -0.90030645  2.2648330
## Fantasy              4.250 -0.88404796  2.1427595
## Aesthetics           4.000 -0.63342270  0.5954302
## Feelings             4.375 -1.42084843  5.8519983
## Actions              3.375 -0.27038758  2.5855684
## Ideas                4.000 -0.61785669  1.3204615
## Values               4.125 -1.52503915  8.6067997
## Trust                3.750 -0.91355637  2.0762294
## Straightforwardness  3.750 -0.64260256  1.7225889
## Altruism             4.250 -1.54955211  8.2271156
## Compliance           3.625 -0.73499044  1.9911054
## Modesty              3.500 -0.58692618  2.2146126
## Tender_Mindedness    3.875 -1.49527616  7.7506175
## Competence           3.875 -0.87987169  4.3566406
## Order                3.625 -0.42211638  0.7859926
## Dutifulness          4.000 -0.86187907  3.7620876
## Achievement_Striving 3.750 -0.74643750  2.2765782
## Self_Discipline      3.750 -0.52501450  1.4461432
## Deliberation         3.500 -0.77452947  2.7793545
##
## $multivariateOutliers
##     Observation Mahalanobis Distance Outlier
## 183         183              659.678    TRUE
## 127         127              167.071    TRUE
## 124         124              161.143    TRUE
## 13           13              151.489    TRUE
## 130         130              122.773    TRUE
## 95           95              119.521    TRUE
## 157         157              115.901    TRUE
## 146         146              115.801    TRUE
## 163         163              115.350    TRUE
## 103         103              113.642    TRUE
## 180         180              108.203    TRUE
## 147         147              106.359    TRUE
## 132         132               98.741    TRUE
## 167         167               98.056    TRUE
## 150         150               97.320    TRUE
```

```
## 62           62              96.021    TRUE
## 94           94              95.148    TRUE
## 185         185              92.874    TRUE
## 118         118              91.402    TRUE
## 113         113              90.491    TRUE
## 101         101              90.325    TRUE
## 177         177              90.167    TRUE
## 60           60              90.032    TRUE
## 105         105              88.414    TRUE
## 84           84              87.534    TRUE
## 40           40              87.376    TRUE
## 44           44              86.625    TRUE
## 182         182              85.756    TRUE
## 24           24              84.211    TRUE
## 2             2              84.114    TRUE
## 151         151              83.943    TRUE
## 46           46              82.738    TRUE
## 45           45              82.185    TRUE
## 90           90              80.278    TRUE
## 176         176              78.757    TRUE
## 42           42              78.028    TRUE
## 179         179              77.561    TRUE
## 121         121              76.356    TRUE
## 51           51              76.188    TRUE
## 25           25              73.157    TRUE
## 143         143              72.663    TRUE
## 190         190              72.155    TRUE
## 119         119              71.332    TRUE
## 120         120              70.421    TRUE
## 145         145              69.898    TRUE
## 93           93              68.914    TRUE
## 83           83              68.726    TRUE
## 18           18              68.433    TRUE
## 41           41              68.072    TRUE
## 7             7              67.741    TRUE
## 168         168              67.683    TRUE
## 200         200              67.166    TRUE
## 17           17              67.056    TRUE
## 11           11              67.013    TRUE
## 70           70              66.905    TRUE
## 144         144              66.595    TRUE
## 27           27              66.336    TRUE
## 43           43              64.412    TRUE
## 55           55              63.449    TRUE
## 117         117              63.067    TRUE
## 31           31              62.729    TRUE
## 74           74              61.775    TRUE
## 92           92              61.518    TRUE
## 64           64              61.073    TRUE
## 134         134              60.150    TRUE
## 30           30              58.706    TRUE
## 129         129              57.333    TRUE
## 3             3              56.163    TRUE
```

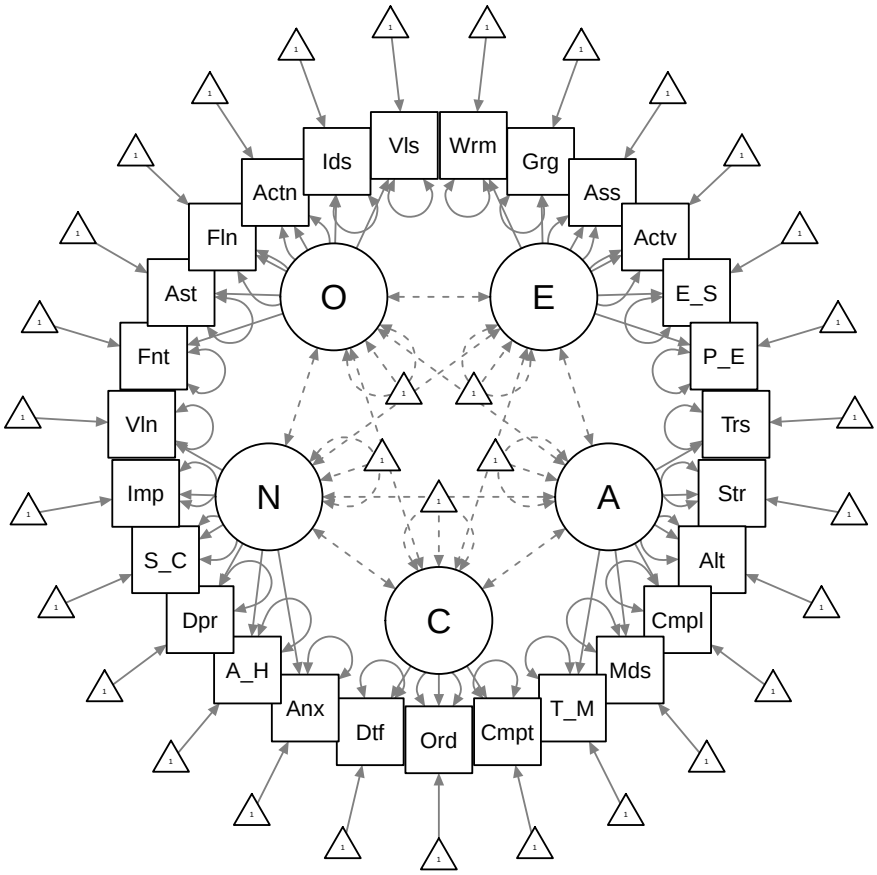
```
## 165         165               52.006    TRUE
## 82           82               51.205    TRUE
## 69           69               50.503    TRUE
## 38           38               48.784    TRUE

remove <- as.numeric(as.character(mv$multivariateOutliers$Observation[1]))
dat2 <- dat %>% filter(!(ID %in% remove))
```

Use confirmatory factor analysis to answer the following questions.

2 Question 1

First, test the hypothesis that the structure of personality is best described by five independent factors. How well does this model fit the data? Base your decision on the χ^2 goodness of fit test along with the goodness-of-fit index of your choice.

```
b5.base <- '
# define the measurement model
E =~ Warmth + Gregariousness + Assertiveness + Activity + Excitement_Seeking + Positive_Emotions
A =~ Trust + Straightforwardness + Altruism + Compliance + Modesty + Tender_Mindedness
C =~ Competence + Order + Dutifulness + Competence + Order + Dutifulness
N =~ Anxiety + Angry_Hostility + Depression + Self_Consciousness + Impulsiveness + Vulnerability
O =~ Fantasy + Aesthetics + Feelings + Actions + Ideas + Values
'
b5.uncorr <-
'
# uncorrelated factors
E ~~ 0*A
E ~~ 0*C
E ~~ 0*N
E ~~ 0*O

A ~~ 0*C
A ~~ 0*N
A ~~ 0*O

C ~~ 0*N
C ~~ 0*O
'

b5.mod <- paste(b5.base, '\n\n', b5.uncorr, sep = '', collapse = '')

fit1 <- cfa(b5.mod, dat2, orthogonal = T, missing = 'ML', std.lv = T)

semPaths(fit1, layout = "circle2")
```




```
summary(fit1)

## lavaan 0.6-3 ended normally after 54 iterations
##
##   Optimization method                           NLMINB
##   Number of free parameters                         81
##
##   Number of observations                           200
##   Number of missing patterns                         1
##
##   Estimator                                         ML
##   Model Fit Test Statistic                    1412.317
##   Degrees of freedom                               324
##   P-value (Chi-square)                           0.000
```

```
##
## Parameter Estimates:
##
##   Information                                 Observed
##   Observed information based on                Hessian
##   Standard Errors                             Standard
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   E =~
##     Warmth            0.464    0.040   11.706    0.000
##     Gregariousness    0.518    0.049   10.614    0.000
##     Assertiveness     0.364    0.049    7.402    0.000
##     Activity          0.293    0.038    7.723    0.000
##     Excitemnt_Sknng   0.248    0.043    5.783    0.000
##     Positive_Emtns    0.522    0.046   11.449    0.000
##   A =~
##     Trust             0.403    0.050    8.138    0.000
##     Strghtfrwrdnss    0.359    0.051    7.058    0.000
##     Altruism          0.348    0.039    8.978    0.000
##     Compliance        0.358    0.045    7.887    0.000
##     Modesty           0.255    0.049    5.240    0.000
##     Tender_Mnddnss    0.244    0.037    6.594    0.000
##   C =~
##     Competence        0.394    0.042    9.363    0.000
##     Order             0.449    0.053    8.424    0.000
##     Dutifulness       0.464    0.046   10.091    0.000
##   N =~
##     Anxiety           0.614    0.045   13.703    0.000
##     Angry_Hostilty    0.323    0.046    6.995    0.000
##     Depression        0.695    0.048   14.390    0.000
##     Self_Conscsnss    0.471    0.040   11.863    0.000
##     Impulsiveness     0.213    0.040    5.392    0.000
##     Vulnerability     0.516    0.040   12.895    0.000
##   O =~
##     Fantasy           0.444    0.051    8.675    0.000
##     Aesthetics        0.528    0.063    8.432    0.000
##     Feelings          0.282    0.046    6.173    0.000
##     Actions           0.303    0.042    7.209    0.000
##     Ideas             0.350    0.057    6.123    0.000
##     Values            0.287    0.038    7.603    0.000
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   E ~~
##     A                 0.000
##     C                 0.000
##     N                 0.000
##     O                 0.000
##   A ~~
##     C                 0.000
##     N                 0.000
##     O                 0.000
```

```
##   C ~~
##     N                 0.000
##     O                 0.000
##   N ~~
##     O                 0.000
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .Warmth            3.798    0.043   89.089    0.000
##    .Gregariousness    3.174    0.051   62.215    0.000
##    .Assertiveness     2.957    0.048   61.215    0.000
##    .Activity          3.245    0.037   86.685    0.000
##    .Excitemnt_Skng    3.603    0.041   88.866    0.000
##    .Positive_Emtns    3.703    0.049   75.886    0.000
##    .Trust             3.360    0.046   72.315    0.000
##    .Strghtfrwrdnss    3.264    0.047   70.027    0.000
##    .Altruism          3.917    0.037  106.729    0.000
##    .Compliance        3.130    0.042   73.905    0.000
##    .Modesty           3.176    0.043   73.557    0.000
##    .Tender_Mnddnss    3.529    0.034  104.127    0.000
##    .Competence        3.504    0.039   89.342    0.000
##    .Order             3.182    0.050   63.117    0.000
##    .Dutifulness       3.649    0.042   86.167    0.000
##    .Anxiety           3.401    0.052   65.001    0.000
##    .Angry_Hostilty    2.836    0.047   60.824    0.000
##    .Depression        2.965    0.057   51.593    0.000
##    .Self_Conscsnss    3.126    0.045   70.207    0.000
##    .Impulsiveness     3.266    0.039   84.123    0.000
##    .Vulnerability     2.623    0.046   56.856    0.000
##    .Fantasy           3.678    0.048   76.650    0.000
##    .Aesthetics        3.380    0.058   58.062    0.000
##    .Feelings          3.907    0.041   94.244    0.000
##    .Actions           2.986    0.039   77.380    0.000
##    .Ideas             3.531    0.051   68.576    0.000
##    .Values            3.803    0.035  107.802    0.000
##     E                 0.000
##     A                 0.000
##     C                 0.000
##     N                 0.000
##     O                 0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .Warmth            0.149    0.022    6.862    0.000
##    .Gregariousness    0.252    0.033    7.556    0.000
##    .Assertiveness     0.334    0.037    9.149    0.000
##    .Activity          0.194    0.022    9.006    0.000
##    .Excitemnt_Skng    0.267    0.028    9.457    0.000
##    .Positive_Emtns    0.203    0.029    7.043    0.000
##    .Trust             0.269    0.034    7.848    0.000
##    .Strghtfrwrdnss    0.305    0.036    8.425    0.000
##    .Altruism          0.148    0.021    7.031    0.000
##    .Compliance        0.231    0.029    8.001    0.000
```

```
##    .Modesty           0.308    0.033    9.199    0.000
##    .Tender_Mnddnss    0.170    0.019    8.771    0.000
##    .Competence        0.153    0.025    6.160    0.000
##    .Order             0.307    0.040    7.702    0.000
##    .Dutifulness       0.144    0.031    4.686    0.000
##    .Anxiety           0.171    0.025    6.946    0.000
##    .Angry_Hostilty    0.330    0.034    9.603    0.000
##    .Depression        0.177    0.028    6.383    0.000
##    .Self_Conscsnss    0.174    0.021    8.334    0.000
##    .Impulsiveness     0.256    0.026    9.773    0.000
##    .Vulnerability     0.159    0.020    7.908    0.000
##    .Fantasy           0.263    0.037    7.202    0.000
##    .Aesthetics        0.399    0.054    7.340    0.000
##    .Feelings          0.264    0.030    8.924    0.000
##    .Actions           0.206    0.025    8.355    0.000
##    .Ideas             0.408    0.046    8.857    0.000
##    .Values            0.166    0.020    8.255    0.000
##     E                 1.000
##     A                 1.000
##     C                 1.000
##     N                 1.000
##     O                 1.000

fm <- fitmeasures(fit1)
```

The χ^2 test indicates poor model fit, $\chi^2(324) = 1412.32, p = 0$.

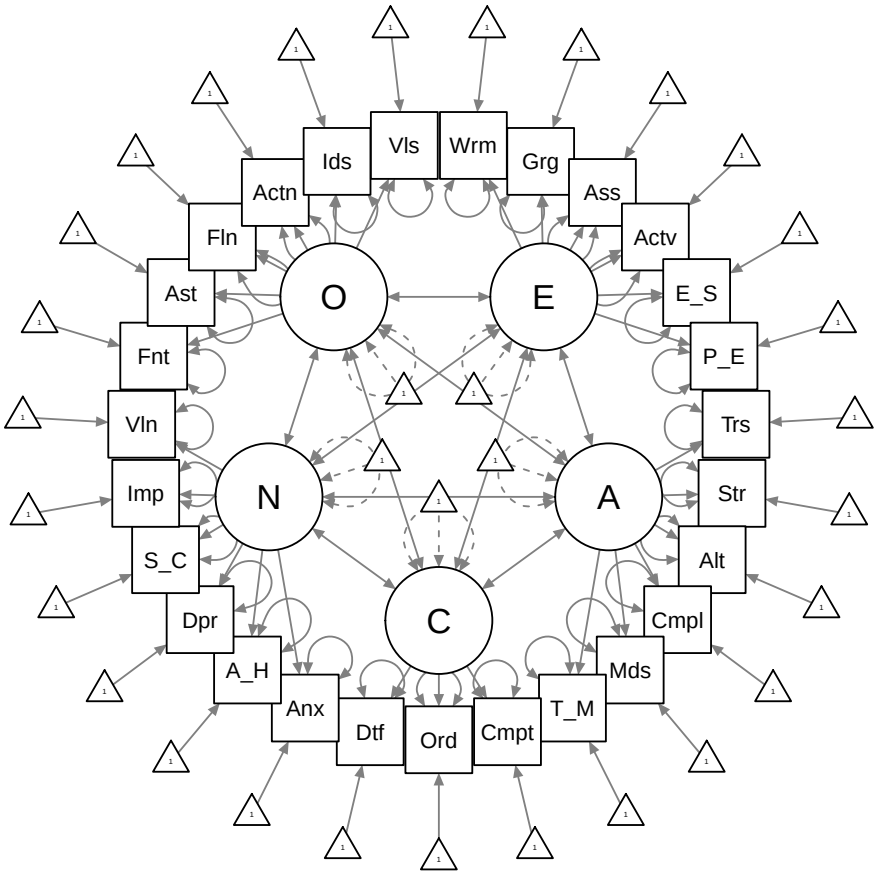
3 Question 2

Now allow the factors to correlate.

3.1 Part A

Does this model fit the data significantly better? Use a χ^2 difference test to answer the question.

```
fit2 <- cfa(b5.base, dat2, missing = 'ML', std.lv = T)
semPaths(fit2, layout = "circle2")
```




```
(c1 <- anova(fit1, fit2))

## Chi Square Difference Test
##
##       Df    AIC    BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## fit2 314 8964.5 9264.6 1261.2
## fit1 324 9095.6 9362.8 1412.3     151.14      10  < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The correlated factor model fits the data better, $\chi^2_{diff}(10) = 151.14$.

Table 1: Question 2B

lhs	E	A	C	N	O
E		**0.60 [0.46, 0.74]**	**0.34 [0.17, 0.51]**	**-0.41 [-0.55, -0.28]**	**0.46 [0.30, 0.62]**
A			**0.32 [0.15, 0.49]**	0.01 [-0.17, 0.18]	**0.31 [0.14, 0.48]**
C				**-0.32 [-0.53, -0.12]**	**-0.26 [-0.45, -0.07]**
N					-0.03 [-0.21, 0.14]
O					

3.2 Part B

Which of the factor correlations are statistically significant?

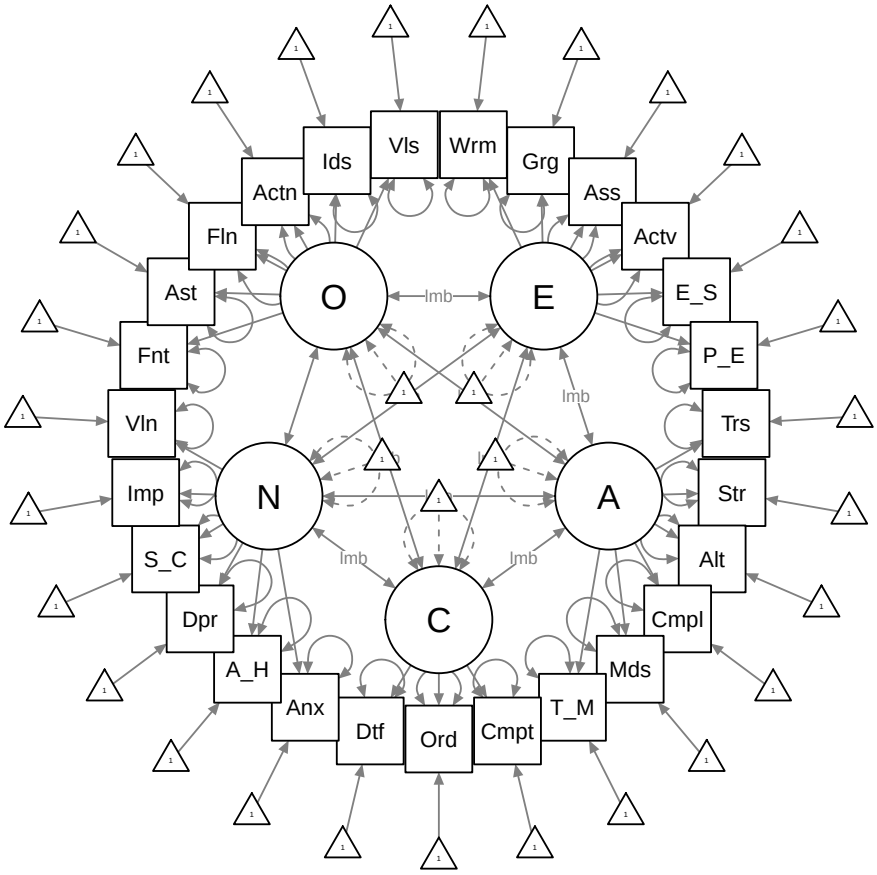
```
res2 <- parameterestimates(fit2, standardized = T)

res2 %>% tbl_df %>%
  filter(op == "~~" & lhs %in% c("E", "A", "C", "N", "O")) %>%
  full_join(crossing(lhs = c("E", "A", "C", "N", "O"), rhs = c("E", "A", "C", "N", "O"))) %>%
  mutate(sig = ifelse(pvalue < .05, "sig", "ns")) %>%
  select(lhs, rhs, est, ci.lower, ci.upper, sig) %>%
  mutate_at(vars(est:ci.upper), funs(sprintf("%.2f", .))) %>%
  mutate_at(vars(lhs, rhs), funs(factor(., levels = c("E", "A", "C", "N", "O")))) %>%
  mutate(value = sprintf("%s [%s, %s]", est, ci.lower, ci.upper),
         value = ifelse(sig == "sig", sprintf("\\textbf{%s}", value), value),
         value = ifelse(is.na(value), "", value)) %>%
  select(lhs, rhs, value) %>%
  spread(key = rhs, value = value) %>%
  kable(., "latex", booktabs = T, escape = F,
        caption = "Question 2B") %>%
  kable_styling(full_width = F)
```

4 Question 3

Test a model that constrains all factor correlations to be equal.

```
b5.corr <- '
# equally correlated factors
E ~~ lambda*A
E ~~ lambda*C
E ~~ lambda*N
E ~~ lambda*O

A ~~ lambda*C
A ~~ lambda*N
A ~~ lambda*O

C ~~ lambda*N
C ~~ lambda*O
'

b5.mod <- paste(b5.base, '\n\n', b5.corr, sep = '', collapse = '')
```

```
fit3 <- cfa(b5.mod, dat2, missing = 'ML', std.lv = T)
semPaths(fit3, layout = "circle2")
```



4.1 Part A

Is this constraint acceptable (i.e., is it statistically different from the model tested in Question 2)?

```
(c3 <- anova(fit3, fit2))

## Chi Square Difference Test
##
##       Df    AIC    BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## fit2 314 8964.5 9264.6 1261.2
## fit3 322 9092.4 9366.2 1405.1     143.97       8  < 2.2e-16 ***
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Constraining the factor correlations to be equal does not appear to be justified, $\chi^2_{diff}(8) = 143.97$.

4.2 Part B

Is the estimated latent variable correlation significant?

```
res3 <- parameterestimates(fit3, standardized = T)

res3 %>% tbl_df %>% filter(label == "lambda") %>%
  select(label, est, ci.lower, ci.upper) %>%
  filter(row_number() == 1)

## # A tibble: 1 x 4
##   label     est ci.lower ci.upper
##   <chr>   <dbl>    <dbl>    <dbl>
## 1 lambda 0.0834   0.0165    0.150
```

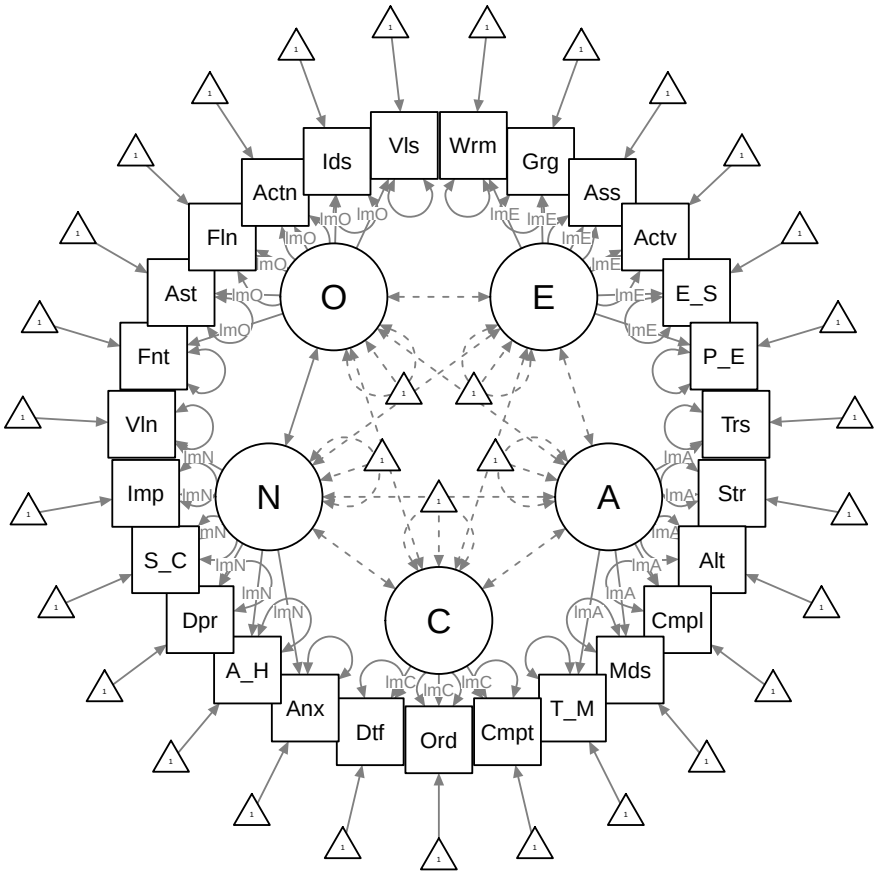
Yes, the estimated latent variable correlation is significant.

5 Question 4

Use the most parsimonious model from the first three steps. Constrain the loadings within each dimension to be equal. Is this simplification acceptable?

Fit 1 is the most parsimonious model because it estimates the fewest parameters.

```
b5.lc <- '
# define the measurement model
E =~ lambdaE*Warmth + lambdaE*Gregariousness + lambdaE*Assertiveness + lambdaE*Activity + lambdaE*Excit
A =~ lambdaA*Trust + lambdaA*Straightforwardness + lambdaA*Altruism + lambdaA*Compliance + lambdaA*Mode
C =~ lambdaC*Competence + lambdaC*Order + lambdaC*Dutifulness + lambdaC*Competence + lambdaC*Order + la
N =~ lambdaN*Anxiety + lambdaN*Angry_Hostility + lambdaN*Depression + lambdaN*Self_Consciousness + lamb
O =~ lambdaO*Fantasy + lambdaO*Aesthetics + lambdaO*Feelings + lambdaO*Actions + lambdaO*Ideas + lambda
'

b5.mod <- paste(b5.lc, '\n\n', b5.uncorr, sep = '', collapse = '')
fit4 <- cfa(b5.mod, dat2, missing = 'ML', std.lv = T)
semPaths(fit4, layout = "circle2")
```




```
summary(fit4)

## lavaan 0.6-3 ended normally after 63 iterations
##
##   Optimization method                           NLMINB
##   Number of free parameters                         82
##   Number of equality constraints                    22
##
##   Number of observations                           200
##   Number of missing patterns                         1
##
##   Estimator                                         ML
##   Model Fit Test Statistic                    1597.946
##   Degrees of freedom                               345
```

```
##   P-value (Chi-square)                          0.000
##
## Parameter Estimates:
##
##   Information                                 Observed
##   Observed information based on                Hessian
##   Standard Errors                             Standard
##
## Latent Variables:
##                   Estimate  Std.Err  z-value  P(>|z|)
##   E =~
##     Warmth  (lmbE)    0.396    0.025   15.638    0.000
##     Grgrsns (lmbE)    0.396    0.025   15.638    0.000
##     Assrtvn (lmbE)    0.396    0.025   15.638    0.000
##     Activty (lmbE)    0.396    0.025   15.638    0.000
##     Exctm_S (lmbE)    0.396    0.025   15.638    0.000
##     Pstv_Em (lmbE)    0.396    0.025   15.638    0.000
##   A =~
##     Trust   (lmbA)    0.321    0.022   14.507    0.000
##     Strghtf (lmbA)    0.321    0.022   14.507    0.000
##     Altrusm (lmbA)    0.321    0.022   14.507    0.000
##     Complnc (lmbA)    0.321    0.022   14.507    0.000
##     Modesty (lmbA)    0.321    0.022   14.507    0.000
##     Tndr_Mn (lmbA)    0.321    0.022   14.507    0.000
##   C =~
##     Comptnc (lmbC)    0.431    0.029   14.871    0.000
##     Order   (lmbC)    0.431    0.029   14.871    0.000
##     Dtflnss (lmbC)    0.431    0.029   14.871    0.000
##   N =~
##     Anxiety (lmbN)    0.486    0.029   16.641    0.000
##     Angry_H (lmbN)    0.486    0.029   16.641    0.000
##     Deprssn (lmbN)    0.486    0.029   16.641    0.000
##     Slf_Cns (lmbN)    0.486    0.029   16.641    0.000
##     Implsvn (lmbN)    0.486    0.029   16.641    0.000
##     Vlnrblt (lmbN)    0.486    0.029   16.641    0.000
##   O =~
##     Fantasy (lmbO)    0.341    0.024   14.425    0.000
##     Asthtcs (lmbO)    0.341    0.024   14.425    0.000
##     Feelngs (lmbO)    0.341    0.024   14.425    0.000
##     Actions (lmbO)    0.341    0.024   14.425    0.000
##     Ideas   (lmbO)    0.341    0.024   14.425    0.000
##     Values  (lmbO)    0.341    0.024   14.425    0.000
##
## Covariances:
##                   Estimate  Std.Err  z-value  P(>|z|)
##   E ~~
##     A                 0.000
##     C                 0.000
##     N                 0.000
##     O                 0.000
##   A ~~
##     C                 0.000
##     N                 0.000
```

```
##     O                 0.000
##   C ~~
##     N                 0.000
##     O                 0.000
##   N ~~
##     O                -0.050    0.090   -0.558    0.577
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .Warmth            3.798    0.041   92.146    0.000
##    .Gregariousness    3.174    0.047   67.696    0.000
##    .Assertiveness     2.957    0.049   60.478    0.000
##    .Activity          3.245    0.041   79.492    0.000
##    .Excitemnt_Skng    3.603    0.046   78.369    0.000
##    .Positive_Emtns    3.703    0.045   82.033    0.000
##    .Trust             3.360    0.045   74.882    0.000
##    .Strghtfrwrdnss    3.264    0.046   71.336    0.000
##    .Altruism          3.917    0.036  108.755    0.000
##    .Compliance        3.130    0.041   75.548    0.000
##    .Modesty           3.176    0.045   71.290    0.000
##    .Tender_Mnddnss    3.529    0.036   97.873    0.000
##    .Competence        3.504    0.040   87.573    0.000
##    .Order             3.182    0.050   63.712    0.000
##    .Dutifulness       3.649    0.042   87.427    0.000
##    .Anxiety           3.401    0.047   72.135    0.000
##    .Angry_Hostilty    2.836    0.053   53.347    0.000
##    .Depression        2.965    0.050   59.592    0.000
##    .Self_Conscsnss    3.126    0.046   68.506    0.000
##    .Impulsiveness     3.266    0.052   63.034    0.000
##    .Vulnerability     2.623    0.045   58.658    0.000
##    .Fantasy           3.678    0.045   81.125    0.000
##    .Aesthetics        3.380    0.055   61.924    0.000
##    .Feelings          3.907    0.044   89.404    0.000
##    .Actions           2.986    0.039   75.610    0.000
##    .Ideas             3.531    0.052   68.543    0.000
##    .Values            3.803    0.037  104.043    0.000
##     E                 0.000
##     A                 0.000
##     C                 0.000
##     N                 0.000
##     O                 0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .Warmth            0.183    0.023    8.088    0.000
##    .Gregariousness    0.283    0.032    8.812    0.000
##    .Assertiveness     0.321    0.036    9.002    0.000
##    .Activity          0.176    0.022    8.111    0.000
##    .Excitemnt_Skng    0.265    0.030    8.725    0.000
##    .Positive_Emtns    0.250    0.029    8.608    0.000
##    .Trust             0.299    0.033    9.031    0.000
##    .Strghtfrwrdnss    0.316    0.035    9.092    0.000
##    .Altruism          0.156    0.019    8.174    0.000
```

```
##    .Compliance        0.240    0.027    8.824    0.000
##    .Modesty           0.294    0.032    9.045    0.000
##    .Tender_Mnddnss    0.157    0.019    8.213    0.000
##    .Competence        0.135    0.021    6.443    0.000
##    .Order             0.313    0.037    8.493    0.000
##    .Dutifulness       0.163    0.023    7.009    0.000
##    .Anxiety           0.209    0.025    8.262    0.000
##    .Angry_Hostilty    0.329    0.037    8.891    0.000
##    .Depression        0.259    0.030    8.593    0.000
##    .Self_Conscsnss    0.180    0.022    8.080    0.000
##    .Impulsiveness     0.301    0.035    8.678    0.000
##    .Vulnerability     0.164    0.021    7.924    0.000
##    .Fantasy           0.295    0.033    8.866    0.000
##    .Aesthetics        0.480    0.052    9.282    0.000
##    .Feelings          0.266    0.030    8.742    0.000
##    .Actions           0.196    0.024    8.314    0.000
##    .Ideas             0.415    0.045    9.211    0.000
##    .Values            0.151    0.019    7.880    0.000
##     E                 1.000
##     A                 1.000
##     C                 1.000
##     N                 1.000
##     O                 1.000

(c4 <- anova(fit1, fit4))

## Chi Square Difference Test
##
##       Df    AIC    BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## fit1 324 9095.6 9362.8 1412.3
## fit4 345 9239.2 9437.1 1597.9     185.63      21  < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

A likelihood ratio test suggests that constraining the loadings is not justified. $\chi^2_{diff}(21) = 185.63$

6 Question 5

Use the modification indices to diagnose the major problem with the model in Question 2. What change to that model would produce the biggest improvement in model fit?

```
mi2 <- modificationindices(fit2) %>% arrange(desc(mi))
```

The biggest problem in the model from Question 2 was the *covariation* between $Compliance Angry_H ostility$.