

Homework 3

Applied Multivariate 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
```

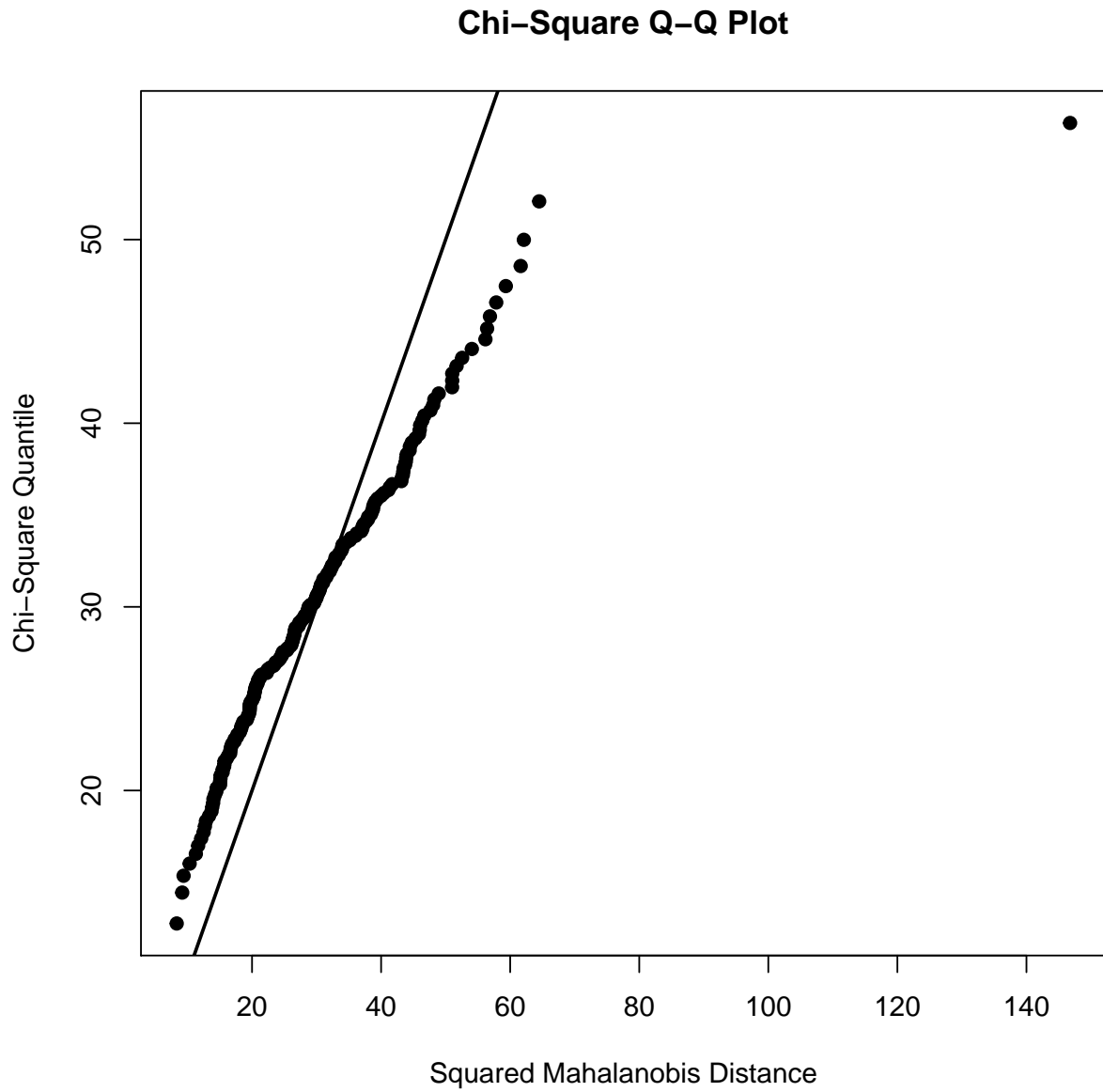
```
## 3 2.750 3.250000 3.75 3.250 3.750000
## 4 4.125 3.750000 2.75 3.000 2.875000
## 5 3.375 3.375000 3.75 4.000 3.750000
## 6 2.625 3.375000 3.00 3.625 2.625000
## Achievement_Striving Self_Discipline Deliberation
## 1 4.333333 4.250 2.875
## 2 2.750000 3.750 3.500
## 3 3.375000 3.375 3.125
## 4 2.875000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

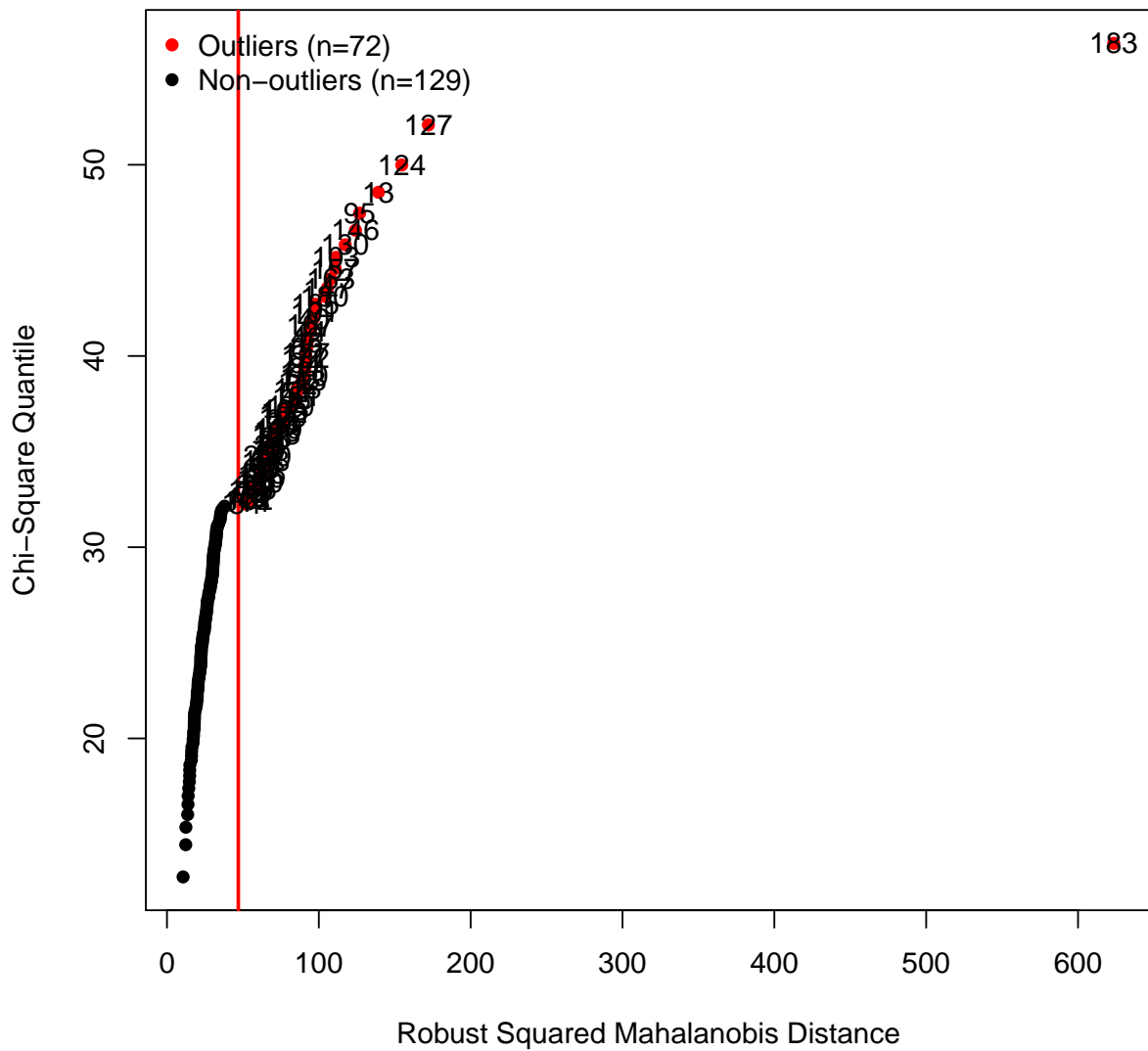
dat <- dat %>% select(ID, source$Facet)
```

1.3 Check for Outliers

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



Chi-Square Q-Q Plot



```
## $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           623.491    TRUE
## 127           127           172.166    TRUE
## 124           124           154.628    TRUE
## 13             13           139.238    TRUE
## 95             95           126.835    TRUE
## 146           146           124.144    TRUE
## 130           130           117.366    TRUE
## 103           103           111.272    TRUE
## 157           157           110.786    TRUE
## 163           163           107.951    TRUE
## 147           147           105.678    TRUE
## 180           180           103.844    TRUE
## 185           185            97.818    TRUE
## 101           101            97.392    TRUE
## 40             40            96.517    TRUE

```

## 167	167	94.475	TRUE
## 44	44	94.366	TRUE
## 42	42	92.315	TRUE
## 45	45	92.244	TRUE
## 60	60	92.046	TRUE
## 177	177	91.396	TRUE
## 132	132	91.307	TRUE
## 94	94	91.236	TRUE
## 84	84	90.888	TRUE
## 121	121	90.535	TRUE
## 150	150	90.463	TRUE
## 113	113	89.211	TRUE
## 62	62	88.750	TRUE
## 118	118	85.862	TRUE
## 51	51	85.282	TRUE
## 151	151	85.222	TRUE
## 46	46	84.425	TRUE
## 2	2	84.284	TRUE
## 179	179	81.487	TRUE
## 105	105	77.799	TRUE
## 182	182	76.639	TRUE
## 120	120	76.505	TRUE
## 27	27	76.106	TRUE
## 90	90	75.979	TRUE
## 70	70	74.443	TRUE
## 119	119	73.535	TRUE
## 190	190	72.079	TRUE
## 143	143	71.999	TRUE
## 83	83	71.961	TRUE
## 55	55	70.381	TRUE
## 41	41	69.901	TRUE
## 25	25	68.066	TRUE
## 18	18	67.094	TRUE
## 78	78	66.841	TRUE
## 17	17	66.592	TRUE
## 200	200	66.201	TRUE
## 64	64	65.969	TRUE
## 168	168	65.094	TRUE
## 3	3	64.094	TRUE
## 43	43	63.707	TRUE
## 53	53	63.356	TRUE
## 7	7	63.222	TRUE
## 176	176	62.555	TRUE
## 11	11	62.246	TRUE
## 145	145	62.044	TRUE
## 93	93	61.180	TRUE
## 140	140	60.793	TRUE
## 24	24	60.725	TRUE
## 30	30	59.972	TRUE
## 155	155	56.381	TRUE
## 76	76	55.695	TRUE
## 92	92	55.597	TRUE
## 74	74	55.339	TRUE


```
## 131      131      54.678    TRUE
## 102      102      54.193    TRUE
## 114      114      52.003    TRUE
## 54       54       51.632    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 ~~ O*A
E ~~ O*C
E ~~ O*N
E ~~ O*O

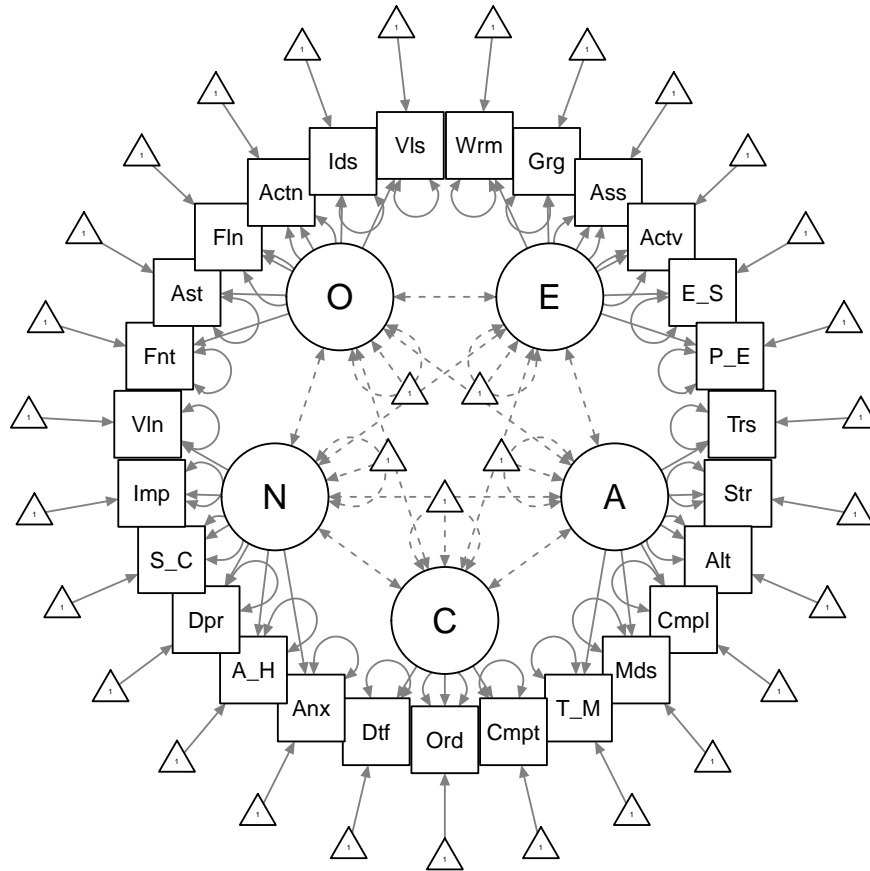
A ~~ O*C
A ~~ O*N
A ~~ O*O

C ~~ O*N
C ~~ O*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_Skng 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
## Strghtfrwrdsnss 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
## .Strghtfrwrdsnss 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
## .Strghtfrwrdsnss 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, $\chi^2(324) = 1412.32, p = 0$.

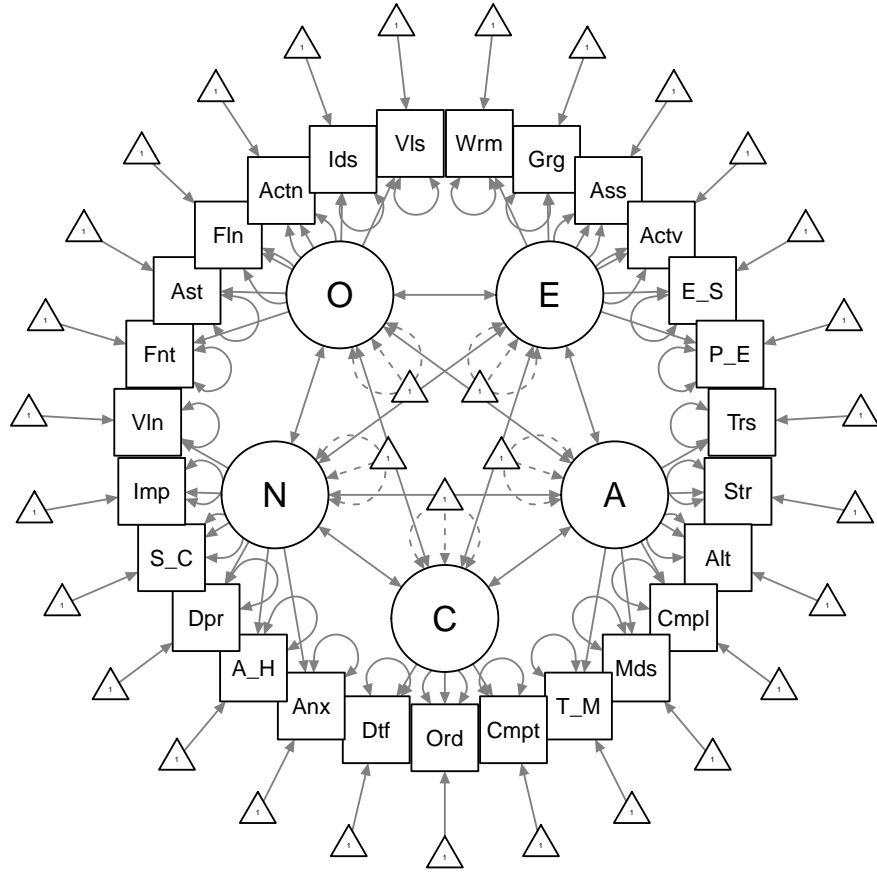
3 Question 2

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.

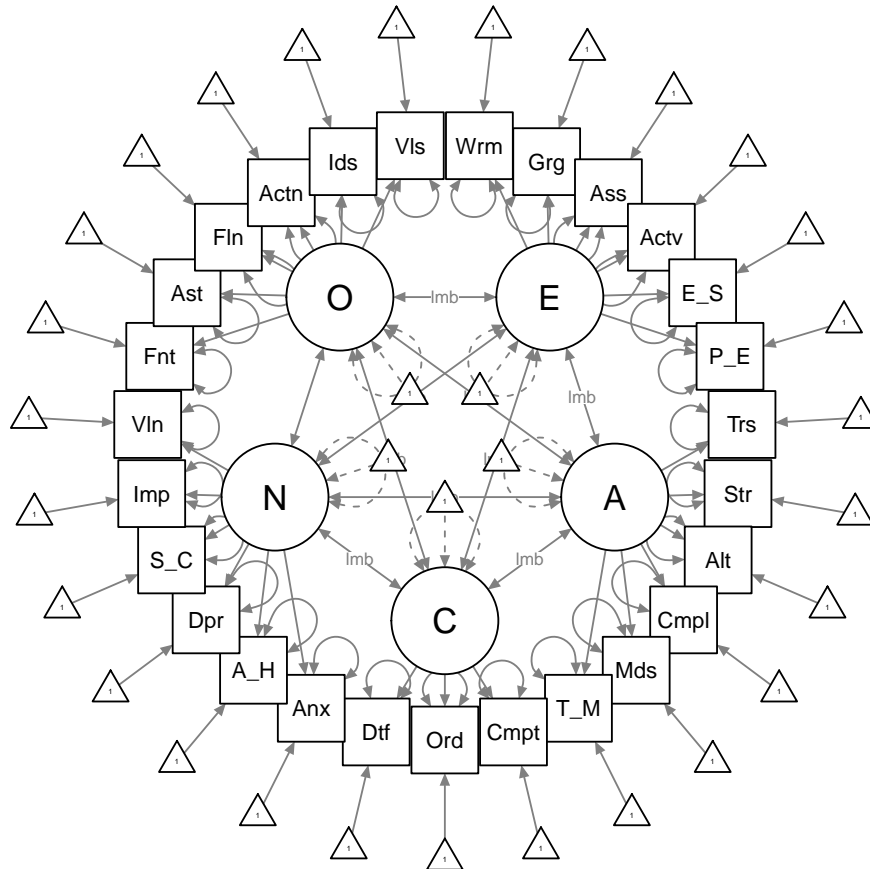
```
b5.corr <- '
# equally correlated factors
E ~~ lambda*A
E ~~ lambda*C
E ~~ lambda*N
E ~~ lambda*O

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.

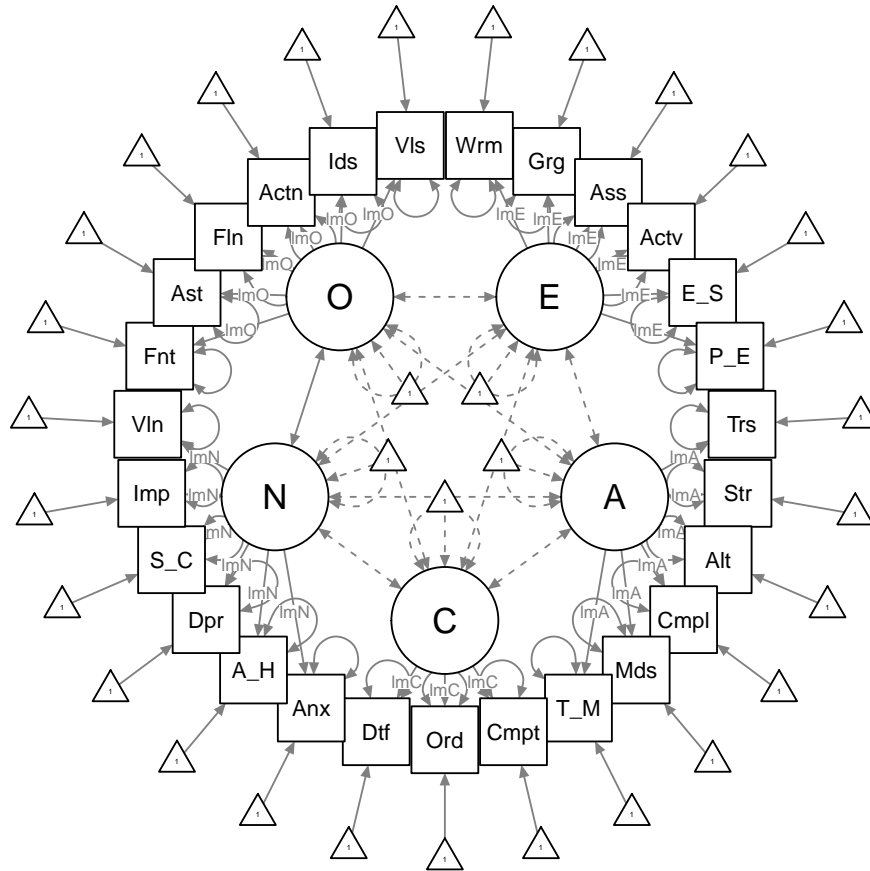
5 Question 4

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*Excitement
A =~ lambdaA*Trust + lambdaA*Straightforwardness + lambdaA*Altruism + lambdaA*Compliance + lambdaA*Mode
C =~ lambdaC*Competence + lambdaC*Order + lambdaC*Dutifulness + lambdaC*Competence + lambdaC*Order + lambdaC*
N =~ lambdaN*Anxiety + lambdaN*Angry_Hostility + lambdaN*Depression + lambdaN*Self_Consciousness + lambdaN*
O =~ lambdaO*Fantasy + lambdaO*Aesthetics + lambdaO*Feelings + lambdaO*Actions + lambdaO*Ideas + lambdaO*
'

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

```

```

##      0      0.000
##      C  ~~
##      N      0.000
##      0      0.000
##      N  ~~
##      0      -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
##      .Strghtfrwrdsnss      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
##      0      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
##      .Strghtfrwrdsnss      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_Hostility  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* and *Angry_Hostility*.