

# Homework 3

## Applied Multivariate Analysis

Emorie Beck

September 22, 2018

## 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)
```

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  $\chi^2$  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

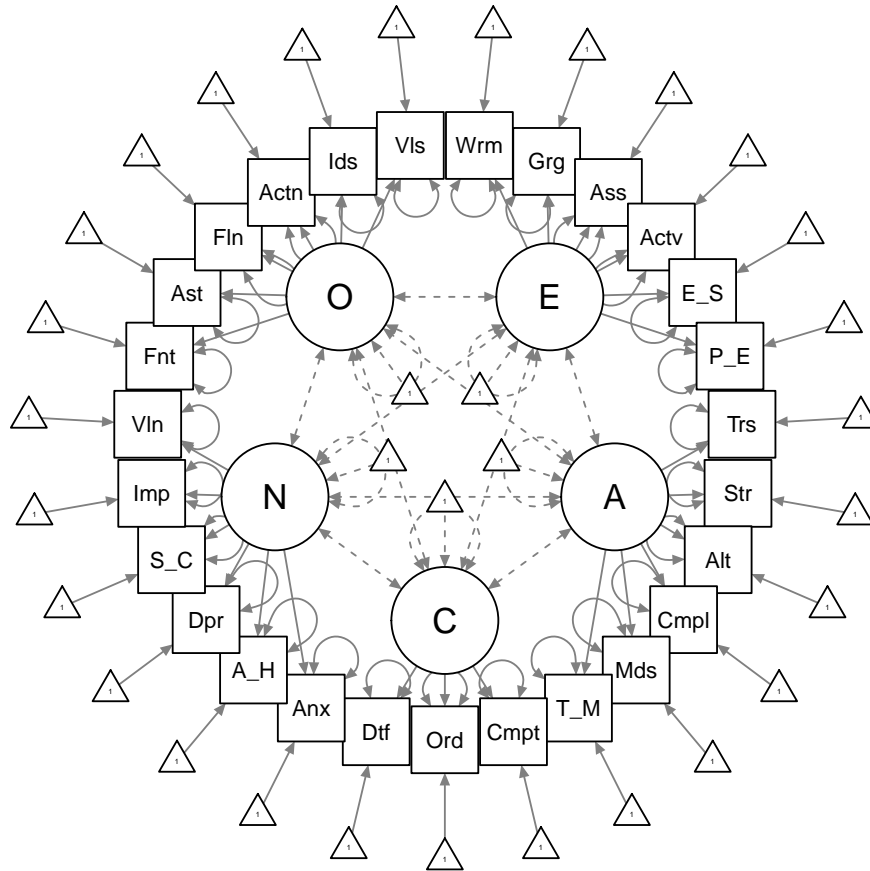
A ~~ 0*C
A ~~ 0*N
A ~~ 0*O

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

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

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

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



```
summary(fit1)
```

```
## lavaan 0.6-3 ended normally after 36 iterations
```

```
##
```

```
## Optimization method NLMINB
```

```
## Number of free parameters 81
```

```
##
```

```
## Number of observations 201
```

```
## Number of missing patterns 1
```

```
##
```

```
## Estimator ML
```

```
## Model Fit Test Statistic 1467.470
```

```
## 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 0.532 0.041 13.008 0.000
## Gregariousness 0.561 0.049 11.552 0.000
## Assertiveness 0.419 0.049 8.561 0.000
## Activity 0.367 0.039 9.437 0.000
## Excitemnt_Skng 0.338 0.044 7.675 0.000
## Positive_Emtns 0.583 0.046 12.636 0.000
## A =~
## Trust 0.461 0.048 9.600 0.000
## Strghtfrwrdsnss 0.423 0.049 8.579 0.000
## Altruism 0.444 0.039 11.363 0.000
## Compliance 0.417 0.044 9.443 0.000
## Modesty 0.339 0.047 7.182 0.000
## Tender_Mnddnss 0.343 0.038 9.149 0.000
## C =~
## Competence 0.462 0.042 10.929 0.000
## Order 0.499 0.052 9.571 0.000
## Dutifulness 0.529 0.045 11.676 0.000
## N =~
## Anxiety 0.659 0.046 14.414 0.000
## Angry_Hostilty 0.373 0.047 7.951 0.000
## Depression 0.719 0.049 14.696 0.000
## Self_Conscsnss 0.518 0.041 12.666 0.000
## Impulsiveness 0.280 0.041 6.749 0.000
## Vulnerability 0.547 0.041 13.426 0.000
## O =~
## Fantasy 0.515 0.050 10.399 0.000
## Aesthetics 0.565 0.060 9.456 0.000
## Feelings 0.384 0.046 8.337 0.000
## Actions 0.370 0.041 9.014 0.000
## Ideas 0.425 0.056 7.633 0.000
## Values 0.387 0.039 9.964 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 3.780 0.046 81.414 0.000
## .Gregariousness 3.158 0.053 59.420 0.000
## .Assertiveness 2.942 0.050 58.547 0.000
## .Activity 3.229 0.041 79.567 0.000
## .Excitemnt_Skng 3.585 0.044 81.244 0.000
## .Positive_Emtns 3.684 0.052 70.972 0.000
## .Trust 3.343 0.049 68.025 0.000
## .Strghtfrwrdsnss 3.248 0.049 66.111 0.000
## .Altruism 3.897 0.041 94.212 0.000
## .Compliance 3.115 0.045 69.344 0.000
## .Modesty 3.161 0.046 69.056 0.000
## .Tender_Mnddnss 3.511 0.038 92.408 0.000
## .Competence 3.486 0.043 81.607 0.000
## .Order 3.166 0.053 60.204 0.000
## .Dutifulness 3.630 0.046 79.166 0.000
## .Anxiety 3.384 0.055 61.832 0.000
## .Angry_Hostilty 2.822 0.048 58.204 0.000
## .Depression 2.950 0.059 49.965 0.000
## .Self_Conscsnss 3.111 0.047 66.263 0.000
## .Impulsiveness 3.250 0.042 77.572 0.000
## .Vulnerability 2.610 0.048 54.699 0.000
## .Fantasy 3.660 0.051 71.597 0.000
## .Aesthetics 3.364 0.060 55.771 0.000
## .Feelings 3.887 0.046 85.292 0.000
## .Actions 2.971 0.041 72.190 0.000
## .Ideas 3.514 0.054 64.885 0.000
## .Values 3.784 0.040 94.948 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 0.151 0.022 6.925 0.000
## .Gregariousness 0.254 0.032 7.901 0.000
## .Assertiveness 0.332 0.036 9.153 0.000
## .Activity 0.196 0.022 8.847 0.000
## .Excitemnt_Skng 0.277 0.030 9.304 0.000
## .Positive_Emtns 0.202 0.028 7.235 0.000
## .Trust 0.273 0.033 8.214 0.000
## .Strghtfrwrdsnss 0.306 0.036 8.608 0.000
## .Altruism 0.147 0.021 6.881 0.000
## .Compliance 0.232 0.028 8.258 0.000

```

```
##      .Modesty      0.306    0.034    9.112    0.000
##      .Tender_Mnddnss 0.172    0.020    8.450    0.000
##      .Competence    0.153    0.026    5.971    0.000
##      .Order         0.306    0.039    7.878    0.000
##      .Dutifulness    0.142    0.031    4.665    0.000
##      .Anxiety       0.168    0.024    6.937    0.000
##      .Angry_Hostilty 0.333    0.035    9.563    0.000
##      .Depression     0.183    0.027    6.750    0.000
##      .Self_Conscsnss 0.175    0.021    8.279    0.000
##      .Impulsiveness  0.274    0.028    9.709    0.000
##      .Vulnerability  0.159    0.020    7.950    0.000
##      .Fantasy       0.260    0.035    7.489    0.000
##      .Aesthetics     0.412    0.051    8.074    0.000
##      .Feelings      0.270    0.031    8.699    0.000
##      .Actions       0.204    0.024    8.372    0.000
##      .Ideas         0.409    0.046    8.914    0.000
##      .Values        0.169    0.021    7.873    0.000
##      E              1.000
##      A              1.000
##      C              1.000
##      N              1.000
##      O              1.000

fm <- fitmeasures(fit1)
```

The  $\chi^2$  test indicates poor model fit,  $\chi^2(324) = 1467.47, p = 0$ .

## 3 Question 2

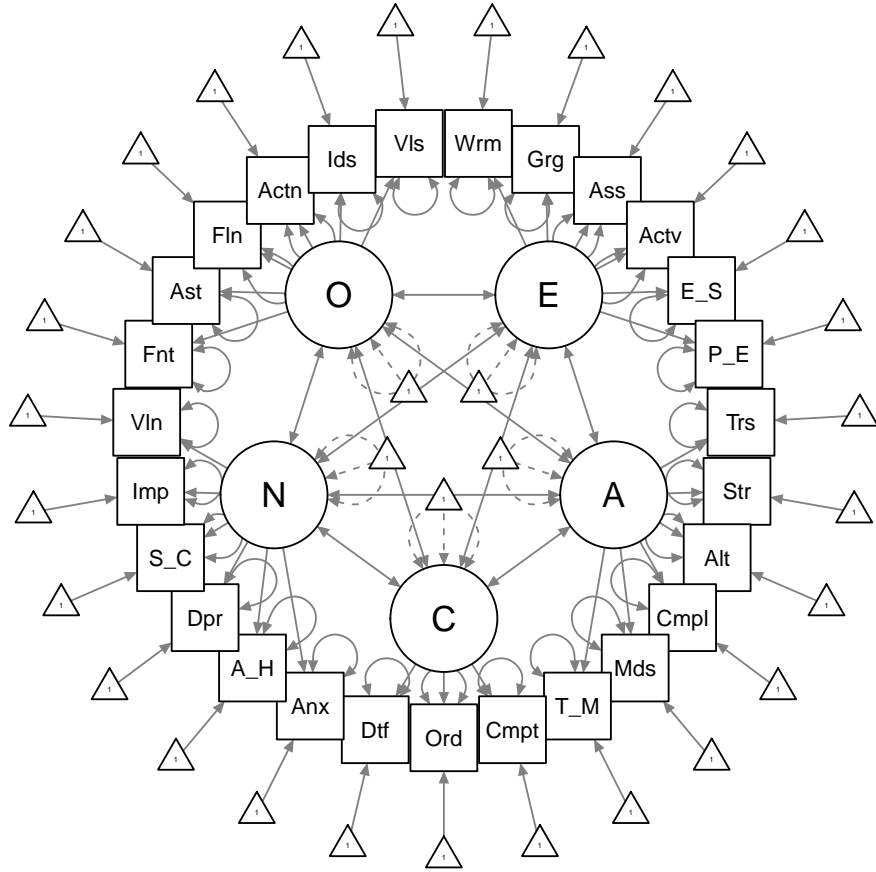
Now allow the factors to correlate.

### 3.1 Part A

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

```
fit2 <- cfa(b5.base, dat, 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 9196.4 9497.0 1224.6
## fit1 324 9419.2 9686.8 1467.5      242.88      10 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The correlated factor model fits the data better,  $\chi^2_{diff}(10) = 242.88$ .

Table 1: Question 2B

lhs	E	A	C	N	O
E		<b>0.68</b> [0.57, 0.79]	<b>0.49</b> [0.35, 0.62]	-0.15 [-0.30, 0.00]	<b>0.62</b> [0.50, 0.74]
A			<b>0.51</b> [0.38, 0.65]	<b>0.25</b> [0.09, 0.40]	<b>0.57</b> [0.44, 0.69]
C				-0.02 [-0.20, 0.16]	0.11 [-0.06, 0.29]
N					<b>0.21</b> [0.05, 0.36]
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.

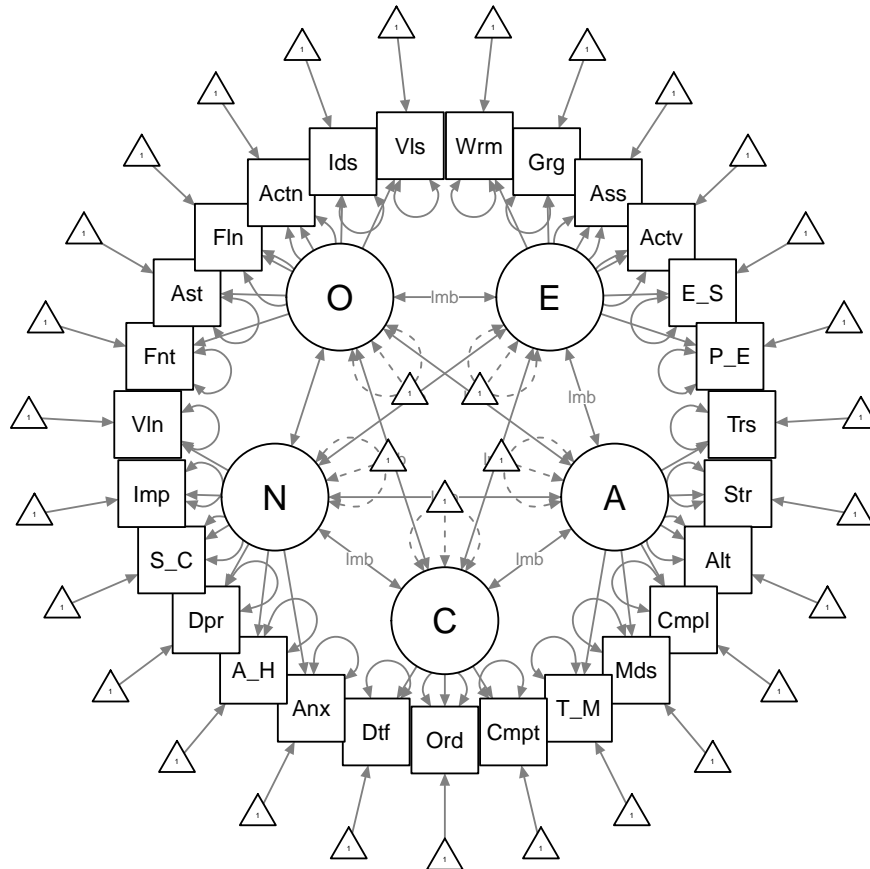
```
b5.corr <- '
# equally correlated factors
E ~~ lambda*A
E ~~ lambda*C
E ~~ lambda*N
E ~~ lambda*O

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, dat, 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 9196.4 9497.0 1224.6
## fit3 322 9323.4 9597.6 1367.6      143.04      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,  $\chi^2_{diff}(8) = 143.04$ .

## 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 0.317   0.240   0.393
```

Yes, the estimated latent variable correlation is significant.

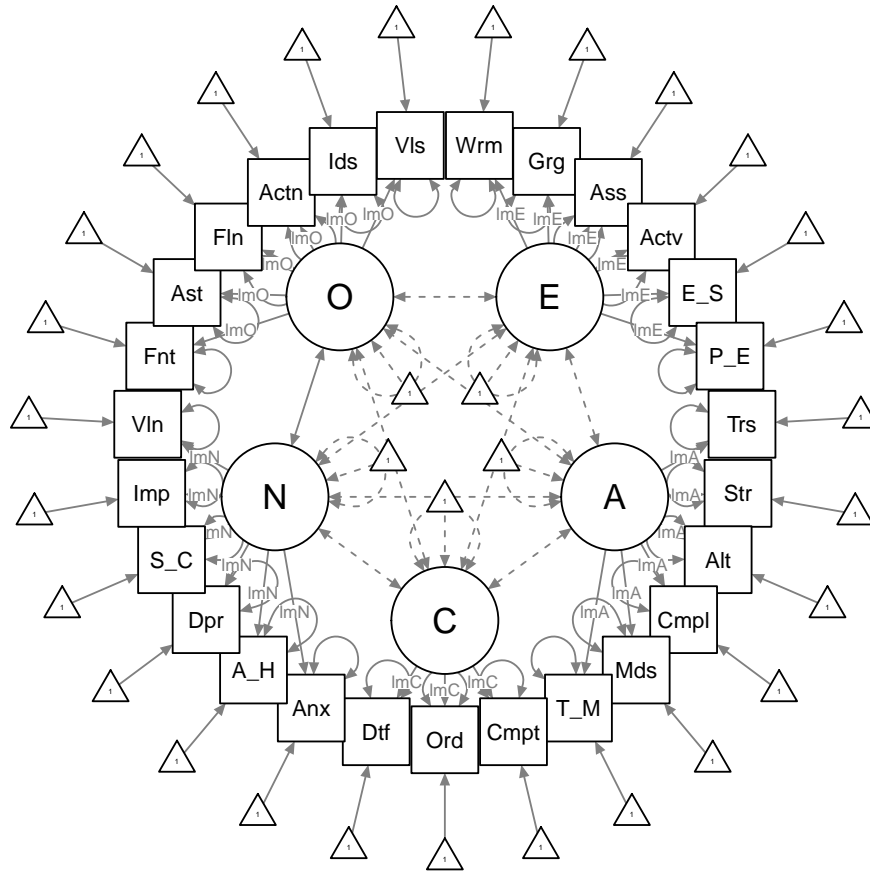
## 5 Question 4

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 + 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 = '\n', collapse = '')
fit4 <- cfa(b5.mod, dat, missing = 'ML', std.lv = T)
semPaths(fit4, layout = "circle2")
```



```
summary(fit4)
```

```
## lavaan 0.6-3 ended normally after 53 iterations
```

```
##
```

```
## Optimization method NLMINB
```

```
## Number of free parameters 82
```

```
## Number of equality constraints 22
```

```
##
```

```
## Number of observations 201
```

```
## Number of missing patterns 1
```

```
##
```

```
## Estimator ML
```

```
## Model Fit Test Statistic 1617.926
```

```
## 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)   0.465   0.028   16.710   0.000
##      Grgrsns   (lmbE)   0.465   0.028   16.710   0.000
##      Assrtvn   (lmbE)   0.465   0.028   16.710   0.000
##      Activty   (lmbE)   0.465   0.028   16.710   0.000
##      Exctm_S   (lmbE)   0.465   0.028   16.710   0.000
##      Pstv_Em   (lmbE)   0.465   0.028   16.710   0.000
##
##      A =~
##      Trust     (lmbA)   0.402   0.025   16.166   0.000
##      Strghtf   (lmbA)   0.402   0.025   16.166   0.000
##      Altrusm   (lmbA)   0.402   0.025   16.166   0.000
##      Complnc   (lmbA)   0.402   0.025   16.166   0.000
##      Modesty   (lmbA)   0.402   0.025   16.166   0.000
##      Tndr_Mn   (lmbA)   0.402   0.025   16.166   0.000
##
##      C =~
##      Comptnc   (lmbC)   0.495   0.031   15.921   0.000
##      Order     (lmbC)   0.495   0.031   15.921   0.000
##      Dtflnss   (lmbC)   0.495   0.031   15.921   0.000
##
##      N =~
##      Anxiety   (lmbN)   0.531   0.031   17.238   0.000
##      Angry_H   (lmbN)   0.531   0.031   17.238   0.000
##      Deprssn   (lmbN)   0.531   0.031   17.238   0.000
##      Slf_Cns   (lmbN)   0.531   0.031   17.238   0.000
##      Implsvn   (lmbN)   0.531   0.031   17.238   0.000
##      Vlnrblt   (lmbN)   0.531   0.031   17.238   0.000
##
##      O =~
##      Fantasy   (lmbO)   0.423   0.026   16.048   0.000
##      Asthtcs   (lmbO)   0.423   0.026   16.048   0.000
##      Feelngs   (lmbO)   0.423   0.026   16.048   0.000
##      Actions   (lmbO)   0.423   0.026   16.048   0.000
##      Ideas     (lmbO)   0.423   0.026   16.048   0.000
##      Values    (lmbO)   0.423   0.026   16.048   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                0.203    0.082    2.478    0.013
##
## Intercepts:
##              Estimate Std.Err z-value P(>|z|)
##      .Warmth          3.780   0.045  84.907  0.000
##      .Gregariousness  3.158   0.049  63.972  0.000
##      .Assertiveness   2.942   0.052  57.043  0.000
##      .Activity        3.229   0.044  72.811  0.000
##      .Excitemnt_Skng  3.585   0.049  72.695  0.000
##      .Positive_Emtns  3.684   0.048  76.864  0.000
##      .Trust           3.343   0.048  70.259  0.000
##      .Strghtfrwrdsnss 3.248   0.048  67.059  0.000
##      .Altruism        3.897   0.040  97.411  0.000
##      .Compliance      3.115   0.044  70.167  0.000
##      .Modesty         3.161   0.048  66.373  0.000
##      .Tender_Mnddnss  3.511   0.040  87.448  0.000
##      .Competence      3.486   0.044  80.074  0.000
##      .Order           3.166   0.052  60.365  0.000
##      .Dutifulness     3.630   0.045  80.644  0.000
##      .Anxiety         3.384   0.049  68.746  0.000
##      .Angry_Hostilty  2.822   0.055  51.059  0.000
##      .Depression      2.950   0.052  57.271  0.000
##      .Self_Conscsnss  3.111   0.048  64.762  0.000
##      .Impulsiveness   3.250   0.054  60.204  0.000
##      .Vulnerability    2.610   0.047  55.506  0.000
##      .Fantasy         3.660   0.048  75.811  0.000
##      .Aesthetics      3.364   0.056  59.660  0.000
##      .Feelings        3.887   0.047  82.656  0.000
##      .Actions         2.971   0.043  68.458  0.000
##      .Ideas           3.514   0.055  64.438  0.000
##      .Values          3.784   0.041  93.083  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          0.182   0.023   8.010  0.000
##      .Gregariousness  0.274   0.031   8.757  0.000
##      .Assertiveness   0.318   0.036   8.957  0.000
##      .Activity        0.179   0.022   8.047  0.000
##      .Excitemnt_Skng  0.272   0.031   8.728  0.000
##      .Positive_Emtns  0.245   0.029   8.544  0.000
##      .Trust           0.293   0.033   8.938  0.000
##      .Strghtfrwrdsnss 0.309   0.034   9.000  0.000
##      .Altruism        0.160   0.020   8.049  0.000

```

```
##      .Compliance      0.234      0.027      8.695      0.000
##      .Modesty        0.294      0.033      8.956      0.000
##      .Tender_Mnddnss  0.162      0.020      8.097      0.000
##      .Competence      0.136      0.022      6.253      0.000
##      .Order           0.308      0.037      8.379      0.000
##      .Dutifulness     0.163      0.024      6.824      0.000
##      .Anxiety         0.205      0.025      8.258      0.000
##      .Angry_Hostility  0.332      0.037      8.919      0.000
##      .Depression      0.252      0.029      8.592      0.000
##      .Self_Conscsnss  0.182      0.022      8.097      0.000
##      .Impulsiveness    0.304      0.035      8.714      0.000
##      .Vulnerability    0.163      0.021      7.911      0.000
##      .Fantasy         0.290      0.033      8.773      0.000
##      .Aesthetics       0.460      0.050      9.232      0.000
##      .Feelings        0.266      0.031      8.644      0.000
##      .Actions         0.200      0.024      8.211      0.000
##      .Ideas           0.419      0.046      9.171      0.000
##      .Values          0.154      0.020      7.723      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 9419.2 9686.8 1467.5
## fit4 345 9527.7 9725.9 1617.9      150.46      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.  $\chi^2_{diff}(21) = 150.46$

## 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*.