

# Confirmatory Factor Analysis and SEM

## Contents

|                                     |           |
|-------------------------------------|-----------|
| <b>Confirmatory Factor Analysis</b> | <b>1</b>  |
| Diagram . . . . .                   | 2         |
| Output . . . . .                    | 2         |
| Modification Indices . . . . .      | 8         |
| Re-specifying the Model . . . . .   | 9         |
| <b>Structural Equation Modeling</b> | <b>23</b> |

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```
library(mosaic)
library(ggplot2)
library(dplyr)
library(psych)
```

```
#install.packages("lavaan")
library(lavaan)

#install.packages("semPlot")
library(semPlot)
```

## Confirmatory Factor Analysis

Now, instead of taking a shot in the dark about the factor structure, we are going in with a clear idea about which items we think load on which factors. Our goal is to test how well our model of the factor structure actually fits the data.

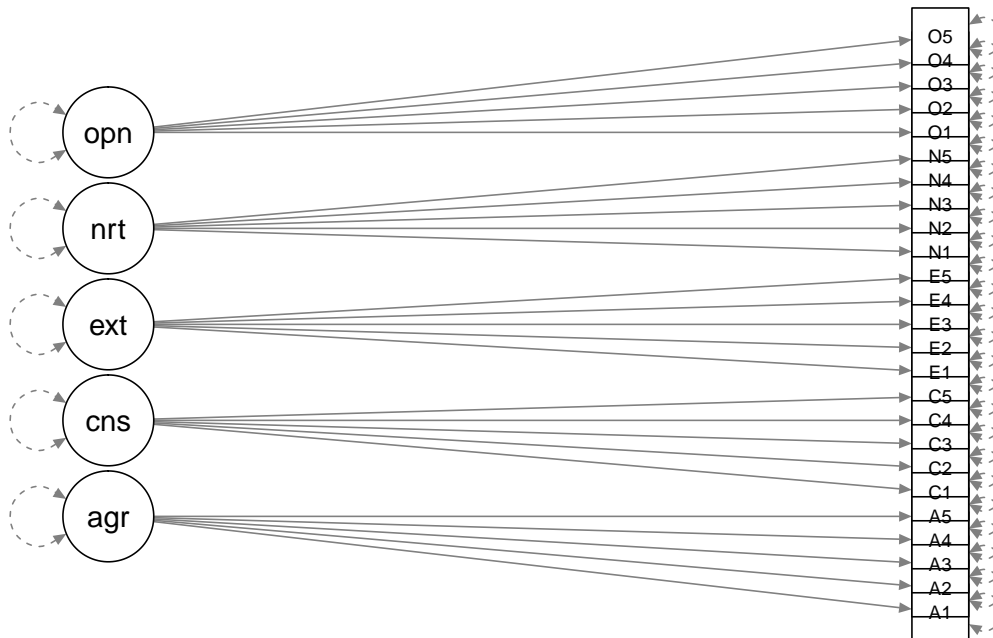
First we specify the model.

```
bf_model <- ' agreeable =~ A1 + A2 + A3 + A4 + A5
               conscient =~ C1 + C2 + C3 + C4 + C5
               extrov =~ E1 + E2 + E3 + E4 + E5
               neurot =~ N1 + N2 + N3 + N4 + N5
               openness =~ O1 + O2 + O3 + O4 + O5 '
```

## Diagram

Plot the model to make sure it is what you want. Here we are using the `semPaths()` and `semPlotModel()` from the `semPlot` package. The `rotation = 2` option forces the exogenous variables to be on the left side.

```
semPaths(semPlotModel(bf_model), rotation = 2)
```



## Output

Then fit the CFA model with `cfa()` and ask for the relevant output.

```
bf_fit <- cfa(bf_model, data = bfi)
```

```
summary(bf_fit, fit.measures = TRUE, rsq=TRUE)
```

```
## lavaan (0.5-23.1097) converged normally after 55 iterations
##
##                                     Used      Total
##   Number of observations                2436      2800
##
##   Estimator                          ML
##   Minimum Function Test Statistic    4165.467
##   Degrees of freedom                  265
##   P-value (Chi-square)                0.000
##
## Model test baseline model:
##
```

```

## Minimum Function Test Statistic      18222.116
## Degrees of freedom                    300
## P-value                              0.000
##
## User model versus baseline model:
##
## Comparative Fit Index (CFI)           0.782
## Tucker-Lewis Index (TLI)             0.754
##
## Loglikelihood and Information Criteria:
##
## Loglikelihood user model (H0)         -99840.238
## Loglikelihood unrestricted model (H1) -97757.504
##
## Number of free parameters             60
## Akaike (AIC)                         199800.476
## Bayesian (BIC)                       200148.363
## Sample-size adjusted Bayesian (BIC)   199957.729
##
## Root Mean Square Error of Approximation:
##
## RMSEA                                0.078
## 90 Percent Confidence Interval         0.076 0.080
## P-value RMSEA <= 0.05                 0.000
##
## Standardized Root Mean Square Residual:
##
## SRMR                                0.075
##
## Parameter Estimates:
##
## Information                          Expected
## Standard Errors                      Standard
##
## Latent Variables:
##      Estimate  Std.Err  z-value  P(>|z|)
## agreeable =~
##   A1           1.000
##   A2          -1.579    0.108  -14.650    0.000
##   A3          -2.030    0.134  -15.093    0.000
##   A4          -1.564    0.115  -13.616    0.000
##   A5          -1.804    0.121  -14.852    0.000
## conscient =~
##   C1           1.000
##   C2           1.148    0.057   20.152    0.000

```

```

##      C3          1.036    0.054   19.172    0.000
##      C4         -1.421    0.065  -21.924    0.000
##      C5         -1.489    0.072  -20.694    0.000
##      extrov =~
##      E1          1.000
##      E2          1.226    0.051   23.899    0.000
##      E3         -0.921    0.041  -22.431    0.000
##      E4         -1.121    0.047  -23.977    0.000
##      E5         -0.808    0.039  -20.648    0.000
##      neurot =~
##      N1          1.000
##      N2          0.947    0.024   39.899    0.000
##      N3          0.884    0.025   35.919    0.000
##      N4          0.692    0.025   27.753    0.000
##      N5          0.628    0.026   24.027    0.000
##      openness =~
##      O1          1.000
##      O2         -1.020    0.068  -14.962    0.000
##      O3          1.373    0.072   18.942    0.000
##      O4          0.437    0.048    9.160    0.000
##      O5         -0.960    0.060  -16.056    0.000
##
## Covariances:
##      Estimate Std.Err z-value P(>|z|)
##      agreeable ~~
##      conscient -0.110  0.012  -9.254  0.000
##      extrov    0.304  0.025  12.293  0.000
##      neurot    0.141  0.018   7.712  0.000
##      openness -0.093  0.011  -8.446  0.000
##      conscient ~~
##      extrov   -0.224  0.020 -11.121  0.000
##      neurot   -0.250  0.025 -10.117  0.000
##      openness  0.130  0.014   9.190  0.000
##      extrov ~~
##      neurot    0.292  0.032   9.131  0.000
##      openness -0.265  0.021 -12.347  0.000
##      neurot ~~
##      openness -0.093  0.022  -4.138  0.000
##
## Variances:
##      Estimate Std.Err z-value P(>|z|)
##      .A1       1.745   0.052  33.725  0.000
##      .A2       0.807   0.028  28.396  0.000
##      .A3       0.754   0.032  23.339  0.000
##      .A4       1.632   0.051  31.796  0.000

```

|    |           |       |       |        |       |
|----|-----------|-------|-------|--------|-------|
| ## | .A5       | 0.852 | 0.032 | 26.800 | 0.000 |
| ## | .C1       | 1.063 | 0.035 | 30.073 | 0.000 |
| ## | .C2       | 1.130 | 0.039 | 28.890 | 0.000 |
| ## | .C3       | 1.170 | 0.039 | 30.194 | 0.000 |
| ## | .C4       | 0.960 | 0.040 | 24.016 | 0.000 |
| ## | .C5       | 1.640 | 0.059 | 27.907 | 0.000 |
| ## | .E1       | 1.814 | 0.058 | 31.047 | 0.000 |
| ## | .E2       | 1.332 | 0.049 | 26.928 | 0.000 |
| ## | .E3       | 1.108 | 0.038 | 29.522 | 0.000 |
| ## | .E4       | 1.088 | 0.041 | 26.732 | 0.000 |
| ## | .E5       | 1.251 | 0.040 | 31.258 | 0.000 |
| ## | .N1       | 0.793 | 0.037 | 21.575 | 0.000 |
| ## | .N2       | 0.836 | 0.036 | 23.458 | 0.000 |
| ## | .N3       | 1.222 | 0.043 | 28.271 | 0.000 |
| ## | .N4       | 1.654 | 0.052 | 31.977 | 0.000 |
| ## | .N5       | 1.969 | 0.060 | 32.889 | 0.000 |
| ## | .O1       | 0.865 | 0.032 | 27.216 | 0.000 |
| ## | .O2       | 1.990 | 0.063 | 31.618 | 0.000 |
| ## | .O3       | 0.691 | 0.039 | 17.717 | 0.000 |
| ## | .O4       | 1.346 | 0.040 | 34.036 | 0.000 |
| ## | .O5       | 1.380 | 0.045 | 30.662 | 0.000 |
| ## | agreeable | 0.234 | 0.030 | 7.839  | 0.000 |
| ## | conscient | 0.463 | 0.036 | 12.810 | 0.000 |
| ## | extrov    | 0.846 | 0.062 | 13.693 | 0.000 |
| ## | neurot    | 1.689 | 0.073 | 23.034 | 0.000 |
| ## | openness  | 0.404 | 0.033 | 12.156 | 0.000 |

##

## R-Square:

| ## | Estimate |
|----|----------|
| ## | A1 0.118 |
| ## | A2 0.420 |
| ## | A3 0.562 |
| ## | A4 0.260 |
| ## | A5 0.472 |
| ## | C1 0.303 |
| ## | C2 0.350 |
| ## | C3 0.298 |
| ## | C4 0.493 |
| ## | C5 0.385 |
| ## | E1 0.318 |
| ## | E2 0.488 |
| ## | E3 0.393 |
| ## | E4 0.494 |
| ## | E5 0.306 |
| ## | N1 0.680 |

```
##      N2      0.644
##      N3      0.519
##      N4      0.328
##      N5      0.253
##      O1      0.318
##      O2      0.174
##      O3      0.524
##      O4      0.054
##      O5      0.212
```

```
inspect(bf_fit, what = "std") #for standardized estimates
```

```
## $lambda
```

```
##      agrebl cnsent extrov neurot opnnss
## A1  0.344  0.000  0.000  0.000  0.000
## A2 -0.648  0.000  0.000  0.000  0.000
## A3 -0.749  0.000  0.000  0.000  0.000
## A4 -0.510  0.000  0.000  0.000  0.000
## A5 -0.687  0.000  0.000  0.000  0.000
## C1  0.000  0.551  0.000  0.000  0.000
## C2  0.000  0.592  0.000  0.000  0.000
## C3  0.000  0.546  0.000  0.000  0.000
## C4  0.000 -0.702  0.000  0.000  0.000
## C5  0.000 -0.620  0.000  0.000  0.000
## E1  0.000  0.000  0.564  0.000  0.000
## E2  0.000  0.000  0.699  0.000  0.000
## E3  0.000  0.000 -0.627  0.000  0.000
## E4  0.000  0.000 -0.703  0.000  0.000
## E5  0.000  0.000 -0.553  0.000  0.000
## N1  0.000  0.000  0.000  0.825  0.000
## N2  0.000  0.000  0.000  0.803  0.000
## N3  0.000  0.000  0.000  0.721  0.000
## N4  0.000  0.000  0.000  0.573  0.000
## N5  0.000  0.000  0.000  0.503  0.000
## O1  0.000  0.000  0.000  0.000  0.564
## O2  0.000  0.000  0.000  0.000 -0.418
## O3  0.000  0.000  0.000  0.000  0.724
## O4  0.000  0.000  0.000  0.000  0.233
## O5  0.000  0.000  0.000  0.000 -0.461
```

```
##
```

```
## $theta
```

```
##      A1      A2      A3      A4      A5      C1      C2      C3      C4      C5      E1      E2
## A1  0.882
## A2  0.000  0.580
## A3  0.000  0.000  0.438
```

```

## A4 0.000 0.000 0.000 0.740
## A5 0.000 0.000 0.000 0.000 0.528
## C1 0.000 0.000 0.000 0.000 0.000 0.697
## C2 0.000 0.000 0.000 0.000 0.000 0.000 0.650
## C3 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.702
## C4 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.507
## C5 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.615
## E1 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.682
## E2 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.512
## E3 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
## E4 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
## E5 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
## N1 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
## N2 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
## N3 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
## N4 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
## N5 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
## O1 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
## O2 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
## O3 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
## O4 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
## O5 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
##      E3      E4      E5      N1      N2      N3      N4      N5      O1      O2      O3      O4
## A1
## A2
## A3
## A4
## A5
## C1
## C2
## C3
## C4
## C5
## E1
## E2
## E3 0.607
## E4 0.000 0.506
## E5 0.000 0.000 0.694
## N1 0.000 0.000 0.000 0.320
## N2 0.000 0.000 0.000 0.000 0.356
## N3 0.000 0.000 0.000 0.000 0.000 0.481
## N4 0.000 0.000 0.000 0.000 0.000 0.000 0.672
## N5 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.747
## O1 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.682
## O2 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.826

```

```

## 03 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.476
## 04 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.946
## 05 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000
##    05
## A1
## A2
## A3
## A4
## A5
## C1
## C2
## C3
## C4
## C5
## E1
## E2
## E3
## E4
## E5
## N1
## N2
## N3
## N4
## N5
## O1
## O2
## O3
## O4
## O5 0.788
##
## $psi
##          agrebl cnsent extrov neurot opnnss
## agreeable  1.000
## conscient -0.334  1.000
## extrov     0.683 -0.357  1.000
## neurot     0.223 -0.283  0.244  1.000
## openness  -0.303  0.301 -0.453 -0.112  1.000

```

## Modification Indices

Because our model is not a great fit to our data, we might want to ask for the *modification indices* with the `modindices()` function. `lavaan` will give you a set of changes you can make that will increase the fit on the model. The `mi` value is the amount a reduction in the chi-square statistics that each change would bring—so the higher the better because a



reduction in chi-square means and increase in fit!

```
modindices(bf_fit) %>%  
  arrange(desc(mi)) %>%  
  select(lhs, op, rhs, mi) %>%  
  head(10)
```

```
##           lhs op rhs      mi  
## 1           N1 ~~   N2 418.8124  
## 2      extrov =~   N4 200.7898  
## 3    openness =~   E3 153.7152  
## 4           N3 ~~   N4 134.1036  
## 5    openness =~   E4 122.5581  
## 6   conscient =~   E5 121.4990  
## 7      extrov =~   O3 114.2021  
## 8      extrov =~   O4 113.8627  
## 9      neurot =~   C5 108.7538  
## 10     extrov =~   A5 108.5874
```

## Re-specifying the Model

Maybe we want to add error covariances based on modification indices. I recommend only doing this if it makes theoretical sense. Also, whatever theoretical rule you use to justify making these error correlations, if it applies to other sets of items, then add the correlations there too. Be consistent! **If you just make changes based on the modification indices without thinking carefully about the theory behind them, then you are doing exploratory factor analysis.**

```
bf_model_re1 <- ' agreeable =~ A1 + A2 + A3 + A4 + A5  
                 conscient =~ C1 + C2 + C3 + C4 + C5  
                 extrov =~ E1 + E2 + E3 + E4 + E5  
                 neurot =~ N1 + N2 + N3 + N4 + N5  
                 openness =~ O1 + O2 + O3 + O4 + O5  
  
                 N1 ~~ N2  
                 N3 ~~ N4'
```

How would you ask for a diagram of this model?

```
#diagram here.
```

```
bf_fit_re1 <- cfa(bf_model_re1, data = bfi)  
  
summary(bf_fit_re1, fit.measures = TRUE, rsq=TRUE)
```

```
## lavaan (0.5-23.1097) converged normally after 57 iterations  
##
```

|   | Used        | Total |
|---|-------------|-------|
| ## Number of observations                   | 2436        | 2800  |
| ## Estimator                                | ML          |       |
| ## Minimum Function Test Statistic          | 3808.150    |       |
| ## Degrees of freedom                       | 263         |       |
| ## P-value (Chi-square)                     | 0.000       |       |
| ## Model test baseline model:               |             |       |
| ## Minimum Function Test Statistic          | 18222.116   |       |
| ## Degrees of freedom                       | 300         |       |
| ## P-value                                  | 0.000       |       |
| ## User model versus baseline model:        |             |       |
| ## Comparative Fit Index (CFI)              | 0.802       |       |
| ## Tucker-Lewis Index (TLI)                 | 0.774       |       |
| ## Loglikelihood and Information Criteria:  |             |       |
| ## Loglikelihood user model (H0)            | -99661.580  |       |
| ## Loglikelihood unrestricted model (H1)    | -97757.504  |       |
| ## Number of free parameters                | 62          |       |
| ## Akaike (AIC)                             | 199447.159  |       |
| ## Bayesian (BIC)                           | 199806.642  |       |
| ## Sample-size adjusted Bayesian (BIC)      | 199609.654  |       |
| ## Root Mean Square Error of Approximation: |             |       |
| ## RMSEA                                    | 0.074       |       |
| ## 90 Percent Confidence Interval           | 0.072 0.076 |       |
| ## P-value RMSEA <= 0.05                    | 0.000       |       |
| ## Standardized Root Mean Square Residual:  |             |       |
| ## SRMR                                     | 0.073       |       |
| ## Parameter Estimates:                     |             |       |
| ## Information                              | Expected    |       |
| ## Standard Errors                          | Standard    |       |
| ## Latent Variables:                        |             |       |

|                 | Estimate | Std.Err | z-value | P(> z ) |
|-----------------|----------|---------|---------|---------|
| ## agreeable =~ |          |         |         |         |
| ## A1           | 1.000    |         |         |         |
| ## A2           | -1.591   | 0.109   | -14.606 | 0.000   |
| ## A3           | -2.046   | 0.136   | -15.039 | 0.000   |
| ## A4           | -1.569   | 0.116   | -13.566 | 0.000   |
| ## A5           | -1.801   | 0.122   | -14.774 | 0.000   |
| ## conscient =~ |          |         |         |         |
| ## C1           | 1.000    |         |         |         |
| ## C2           | 1.147    | 0.057   | 19.964  | 0.000   |
| ## C3           | 1.042    | 0.055   | 19.069  | 0.000   |
| ## C4           | -1.441   | 0.066   | -21.863 | 0.000   |
| ## C5           | -1.512   | 0.073   | -20.685 | 0.000   |
| ## extrov =~    |          |         |         |         |
| ## E1           | 1.000    |         |         |         |
| ## E2           | 1.234    | 0.051   | 24.092  | 0.000   |
| ## E3           | -0.911   | 0.041   | -22.370 | 0.000   |
| ## E4           | -1.120   | 0.047   | -24.074 | 0.000   |
| ## E5           | -0.805   | 0.039   | -20.678 | 0.000   |
| ## neurot =~    |          |         |         |         |
| ## N1           | 1.000    |         |         |         |
| ## N2           | 0.937    | 0.025   | 37.799  | 0.000   |
| ## N3           | 1.261    | 0.053   | 23.708  | 0.000   |
| ## N4           | 1.071    | 0.049   | 21.667  | 0.000   |
| ## N5           | 0.861    | 0.038   | 22.879  | 0.000   |
| ## openness =~  |          |         |         |         |
| ## O1           | 1.000    |         |         |         |
| ## O2           | -1.016   | 0.068   | -14.911 | 0.000   |
| ## O3           | 1.377    | 0.073   | 18.930  | 0.000   |
| ## O4           | 0.442    | 0.048   | 9.251   | 0.000   |
| ## O5           | -0.958   | 0.060   | -16.032 | 0.000   |
| ##              |          |         |         |         |
| ## Covariances: |          |         |         |         |
| ##              | Estimate | Std.Err | z-value | P(> z ) |
| ## .N1 ~~       |          |         |         |         |
| ## .N2          | 0.735    | 0.046   | 15.889  | 0.000   |
| ## .N3 ~~       |          |         |         |         |
| ## .N4          | -0.134   | 0.052   | -2.565  | 0.010   |
| ## agreeable ~~ |          |         |         |         |
| ## conscient    | -0.108   | 0.012   | -9.225  | 0.000   |
| ## extrov       | 0.302    | 0.025   | 12.257  | 0.000   |
| ## neurot       | 0.102    | 0.015   | 6.975   | 0.000   |
| ## openness     | -0.093   | 0.011   | -8.437  | 0.000   |
| ## conscient ~~ |          |         |         |         |
| ## extrov       | -0.222   | 0.020   | -11.116 | 0.000   |

```

##      neurot      -0.220    0.021  -10.395    0.000
##      openness     0.128    0.014    9.138    0.000
##      extrov ~~
##      neurot      0.298    0.028   10.596    0.000
##      openness    -0.264    0.021  -12.318    0.000
##      neurot ~~
##      openness    -0.072    0.018   -3.964    0.000
##
## Variances:
##              Estimate Std.Err  z-value  P(>|z|)
##      .A1          1.747    0.052   33.734    0.000
##      .A2          0.802    0.028   28.294    0.000
##      .A3          0.746    0.032   23.110    0.000
##      .A4          1.632    0.051   31.798    0.000
##      .A5          0.860    0.032   26.959    0.000
##      .C1          1.070    0.035   30.215    0.000
##      .C2          1.141    0.039   29.091    0.000
##      .C3          1.172    0.039   30.258    0.000
##      .C4          0.950    0.040   23.849    0.000
##      .C5          1.624    0.058   27.777    0.000
##      .E1          1.812    0.058   31.087    0.000
##      .E2          1.311    0.049   26.774    0.000
##      .E3          1.122    0.038   29.759    0.000
##      .E4          1.086    0.040   26.820    0.000
##      .E5          1.254    0.040   31.329    0.000
##      .N1          1.415    0.055   25.794    0.000
##      .N2          1.413    0.052   26.915    0.000
##      .N3          0.843    0.065   12.874    0.000
##      .N4          1.237    0.063   19.494    0.000
##      .N5          1.843    0.060   30.884    0.000
##      .01          0.866    0.032   27.241    0.000
##      .02          1.994    0.063   31.661    0.000
##      .03          0.688    0.039   17.600    0.000
##      .04          1.344    0.040   34.018    0.000
##      .05          1.382    0.045   30.693    0.000
##      agreeable    0.232    0.030    7.804    0.000
##      conscient    0.455    0.036   12.704    0.000
##      extrov       0.849    0.062   13.733    0.000
##      neurot       1.068    0.069   15.442    0.000
##      openness     0.403    0.033   12.144    0.000
##
## R-Square:
##              Estimate
##      A1          0.117
##      A2          0.423

```

```
##      A3      0.566
##      A4      0.260
##      A5      0.467
##      C1      0.298
##      C2      0.344
##      C3      0.297
##      C4      0.499
##      C5      0.390
##      E1      0.319
##      E2      0.497
##      E3      0.386
##      E4      0.495
##      E5      0.305
##      N1      0.430
##      N2      0.399
##      N3      0.668
##      N4      0.498
##      N5      0.301
##      O1      0.318
##      O2      0.173
##      O3      0.526
##      O4      0.055
##      O5      0.211
```

```
inspect(bf_fit_re1, what = "std")
```

```
## $lambda
##      agrebl cnsent extrov neurot opnss
## A1  0.343  0.000  0.000  0.000  0.000
## A2 -0.650  0.000  0.000  0.000  0.000
## A3 -0.752  0.000  0.000  0.000  0.000
## A4 -0.510  0.000  0.000  0.000  0.000
## A5 -0.683  0.000  0.000  0.000  0.000
## C1  0.000  0.546  0.000  0.000  0.000
## C2  0.000  0.587  0.000  0.000  0.000
## C3  0.000  0.545  0.000  0.000  0.000
## C4  0.000 -0.706  0.000  0.000  0.000
## C5  0.000 -0.625  0.000  0.000  0.000
## E1  0.000  0.000  0.565  0.000  0.000
## E2  0.000  0.000  0.705  0.000  0.000
## E3  0.000  0.000 -0.621  0.000  0.000
## E4  0.000  0.000 -0.704  0.000  0.000
## E5  0.000  0.000 -0.552  0.000  0.000
## N1  0.000  0.000  0.000  0.656  0.000
## N2  0.000  0.000  0.000  0.631  0.000
```

```

## N3  0.000  0.000  0.000  0.818  0.000
## N4  0.000  0.000  0.000  0.705  0.000
## N5  0.000  0.000  0.000  0.548  0.000
## O1  0.000  0.000  0.000  0.000  0.564
## O2  0.000  0.000  0.000  0.000 -0.416
## O3  0.000  0.000  0.000  0.000  0.725
## O4  0.000  0.000  0.000  0.000  0.235
## O5  0.000  0.000  0.000  0.000 -0.460
##
## $theta
##      A1      A2      A3      A4      A5      C1      C2      C3      C4      C5
## A1  0.883
## A2  0.000  0.577
## A3  0.000  0.000  0.434
## A4  0.000  0.000  0.000  0.740
## A5  0.000  0.000  0.000  0.000  0.533
## C1  0.000  0.000  0.000  0.000  0.000  0.702
## C2  0.000  0.000  0.000  0.000  0.000  0.000  0.656
## C3  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.703
## C4  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.501
## C5  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.610
## E1  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
## E2  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
## E3  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
## E4  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
## E5  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
## N1  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
## N2  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
## N3  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
## N4  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
## N5  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
## O1  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
## O2  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
## O3  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
## O4  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
## O5  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
##      E1      E2      E3      E4      E5      N1      N2      N3      N4      N5
## A1
## A2
## A3
## A4
## A5
## C1
## C2
## C3

```

```

## C4
## C5
## E1  0.681
## E2  0.000  0.503
## E3  0.000  0.000  0.614
## E4  0.000  0.000  0.000  0.505
## E5  0.000  0.000  0.000  0.000  0.695
## N1  0.000  0.000  0.000  0.000  0.000  0.570
## N2  0.000  0.000  0.000  0.000  0.000  0.520  0.601
## N3  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.332
## N4  0.000  0.000  0.000  0.000  0.000  0.000  0.000 -0.131  0.502
## N5  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.699
## O1  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
## O2  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
## O3  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
## O4  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
## O5  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
##      O1      O2      O3      O4      O5
## A1
## A2
## A3
## A4
## A5
## C1
## C2
## C3
## C4
## C5
## E1
## E2
## E3
## E4
## E5
## N1
## N2
## N3
## N4
## N5
## O1  0.682
## O2  0.000  0.827
## O3  0.000  0.000  0.474
## O4  0.000  0.000  0.000  0.945
## O5  0.000  0.000  0.000  0.000  0.789
##
## $psi

```

```
##          agrebl cnsent extrov neurot opnss
## agreeable 1.000
## conscient -0.333 1.000
## extrov    0.680 -0.358 1.000
## neurot    0.204 -0.315 0.313 1.000
## openness  -0.304 0.299 -0.451 -0.110 1.000
```

```
modindices(bf_fit_re1) %>%
  arrange(desc(mi)) %>%
  select(lhs, op, rhs, mi) %>%
  head(10)
```

```
##      lhs op rhs      mi
## 1  openness =~ E3 160.1243
## 2   extrov =~ N4 157.7845
## 3   neurot =~ O4 146.2368
## 4   neurot =~ C5 135.1787
## 5   neurot =~ C2 131.4783
## 6  conscient =~ E5 124.7340
## 7   extrov =~ O4 123.9378
## 8  openness =~ E4 119.2854
## 9   extrov =~ A5 117.0221
## 10      C1 ~~ C2 113.4368
```

We might also want to remove A1 – “Am indifferent to the feelings of others,” and O4 – “Spend time reflecting on things,” based on crappy loadings.

```
bf_model_re2 <- ' agreeable =~ A2 + A3 + A4 + A5
                  conscient =~ C1 + C2 + C3 + C4 + C5
                  extrov =~ E1 + E2 + E3 + E4 + E5
                  neurot =~ N1 + N2 + N3 + N4 + N5
                  openness =~ O1 + O2 + O3 + O5

                  N1 ~~ N2
                  N3 ~~ N4'
```

```
bf_fit_re2 <- cfa(bf_model_re2, data = bfi)
```

```
summary(bf_fit_re2, fit.measures = TRUE, rsq=TRUE)
```

```
## lavaan (0.5-23.1097) converged normally after 51 iterations
##
##                                     Used      Total
##   Number of observations              2454      2800
##
##   Estimator                          ML
##   Minimum Function Test Statistic    3145.804
```



```

## Degrees of freedom                218
## P-value (Chi-square)              0.000
##
## Model test baseline model:
##
## Minimum Function Test Statistic    17305.746
## Degrees of freedom                 253
## P-value                            0.000
##
## User model versus baseline model:
##
## Comparative Fit Index (CFI)        0.828
## Tucker-Lewis Index (TLI)          0.801
##
## Loglikelihood and Information Criteria:
##
## Loglikelihood user model (H0)      -92351.755
## Loglikelihood unrestricted model (H1) -90778.853
##
## Number of free parameters          58
## Akaike (AIC)                      184819.510
## Bayesian (BIC)                    185156.227
## Sample-size adjusted Bayesian (BIC) 184971.947
##
## Root Mean Square Error of Approximation:
##
## RMSEA                             0.074
## 90 Percent Confidence Interval      0.072 0.076
## P-value RMSEA <= 0.05              0.000
##
## Standardized Root Mean Square Residual:
##
## SRMR                              0.068
##
## Parameter Estimates:
##
## Information                        Expected
## Standard Errors                    Standard
##
## Latent Variables:
##      Estimate Std.Err z-value P(>|z|)
## agreeable =~
## A2            1.000
## A3            1.317    0.050  26.458    0.000
## A4            1.023    0.050  20.395    0.000

```

```

##      A5              1.195      0.047      25.593      0.000
##  conscient =~
##      C1              1.000
##      C2              1.149      0.057      20.078      0.000
##      C3              1.045      0.054      19.183      0.000
##      C4             -1.435      0.065     -21.951      0.000
##      C5             -1.506      0.073     -20.751      0.000
##  extrov =~
##      E1              1.000
##      E2              1.239      0.051      24.081      0.000
##      E3             -0.924      0.041     -22.528      0.000
##      E4             -1.130      0.047     -24.134      0.000
##      E5             -0.815      0.039     -20.764      0.000
##  neurot =~
##      N1              1.000
##      N2              0.944      0.025      37.718      0.000
##      N3              1.265      0.053      23.692      0.000
##      N4              1.068      0.049      21.602      0.000
##      N5              0.865      0.038      22.888      0.000
##  openness =~
##      O1              1.000
##      O2             -1.027      0.069     -14.809      0.000
##      O3              1.389      0.075      18.478      0.000
##      O5             -0.940      0.060     -15.592      0.000
##
## Covariances:
##              Estimate  Std.Err  z-value  P(>|z|)
##  .N1 ~~
##  .N2              0.730      0.046      15.799      0.000
##  .N3 ~~
##  .N4             -0.121      0.052      -2.333      0.020
##  agreeable ~~
##  conscient        0.171      0.016      10.921      0.000
##  extrov          -0.475      0.028     -16.868      0.000
##  neurot          -0.158      0.021      -7.639      0.000
##  openness         0.144      0.015       9.584      0.000
##  conscient ~~
##  extrov          -0.218      0.020     -11.040      0.000
##  neurot          -0.216      0.021     -10.317      0.000
##  openness         0.132      0.014       9.315      0.000
##  extrov ~~
##  neurot           0.296      0.028      10.644      0.000
##  openness        -0.278      0.022     -12.706      0.000
##  neurot ~~
##  openness        -0.090      0.018      -4.933      0.000

```

```
##
## Variances:
##      Estimate Std.Err z-value P(>|z|)
##      .A2      0.844   0.029  28.941  0.000
##      .A3      0.767   0.033  23.287  0.000
##      .A4      1.631   0.051  31.781  0.000
##      .A5      0.831   0.032  26.084  0.000
##      .C1      1.069   0.035  30.303  0.000
##      .C2      1.139   0.039  29.150  0.000
##      .C3      1.172   0.039  30.328  0.000
##      .C4      0.950   0.040  23.977  0.000
##      .C5      1.629   0.058  27.923  0.000
##      .E1      1.816   0.058  31.341  0.000
##      .E2      1.321   0.049  27.153  0.000
##      .E3      1.106   0.037  29.828  0.000
##      .E4      1.082   0.040  27.022  0.000
##      .E5      1.254   0.040  31.486  0.000
##      .N1      1.425   0.055  25.951  0.000
##      .N2      1.407   0.052  26.838  0.000
##      .N3      0.850   0.065  13.012  0.000
##      .N4      1.251   0.063  19.798  0.000
##      .N5      1.836   0.059  30.931  0.000
##      .O1      0.876   0.032  27.275  0.000
##      .O2      1.995   0.063  31.654  0.000
##      .O3      0.698   0.040  17.329  0.000
##      .O5      1.400   0.045  30.962  0.000
##      agreeable 0.547   0.036  15.372  0.000
##      conscient  0.456   0.036  12.768  0.000
##      extrov     0.836   0.061  13.715  0.000
##      neurot     1.061   0.069  15.411  0.000
##      openness   0.396   0.033  11.949  0.000
```

```
##
## R-Square:
##      Estimate
##      A2      0.393
##      A3      0.553
##      A4      0.260
##      A5      0.485
##      C1      0.299
##      C2      0.346
##      C3      0.298
##      C4      0.497
##      C5      0.389
##      E1      0.315
##      E2      0.493
```

```
##      E3      0.392
##      E4      0.497
##      E5      0.307
##      N1      0.427
##      N2      0.402
##      N3      0.666
##      N4      0.492
##      N5      0.302
##      O1      0.311
##      O2      0.173
##      O3      0.523
##      O5      0.200
```

```
inspect(bf_fit_re2, what = "std")
```

```
## $lambda
##      agrebl cnsent extrov neurot opnss
## A2  0.627  0.000  0.000  0.000  0.000
## A3  0.744  0.000  0.000  0.000  0.000
## A4  0.510  0.000  0.000  0.000  0.000
## A5  0.696  0.000  0.000  0.000  0.000
## C1  0.000  0.547  0.000  0.000  0.000
## C2  0.000  0.588  0.000  0.000  0.000
## C3  0.000  0.546  0.000  0.000  0.000
## C4  0.000 -0.705  0.000  0.000  0.000
## C5  0.000 -0.623  0.000  0.000  0.000
## E1  0.000  0.000  0.561  0.000  0.000
## E2  0.000  0.000  0.702  0.000  0.000
## E3  0.000  0.000 -0.626  0.000  0.000
## E4  0.000  0.000 -0.705  0.000  0.000
## E5  0.000  0.000 -0.554  0.000  0.000
## N1  0.000  0.000  0.000  0.653  0.000
## N2  0.000  0.000  0.000  0.634  0.000
## N3  0.000  0.000  0.000  0.816  0.000
## N4  0.000  0.000  0.000  0.701  0.000
## N5  0.000  0.000  0.000  0.550  0.000
## O1  0.000  0.000  0.000  0.000  0.558
## O2  0.000  0.000  0.000  0.000 -0.416
## O3  0.000  0.000  0.000  0.000  0.723
## O5  0.000  0.000  0.000  0.000 -0.447
##
## $theta
##      A2      A3      A4      A5      C1      C2      C3      C4      C5      E1
## A2  0.607
## A3  0.000  0.447
```

|       |       |       |       |       |       |       |        |       |       |       |       |
|-------|-------|-------|-------|-------|-------|-------|--------|-------|-------|-------|-------|
| ## A4 | 0.000 | 0.000 | 0.740 |       |       |       |        |       |       |       |       |
| ## A5 | 0.000 | 0.000 | 0.000 | 0.515 |       |       |        |       |       |       |       |
| ## C1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.701 |       |        |       |       |       |       |
| ## C2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.654 |        |       |       |       |       |
| ## C3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.702  |       |       |       |       |
| ## C4 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000  | 0.503 |       |       |       |
| ## C5 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000  | 0.000 | 0.611 |       |       |
| ## E1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000  | 0.000 | 0.000 | 0.685 |       |
| ## E2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000  | 0.000 | 0.000 | 0.000 | 0.000 |
| ## E3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000  | 0.000 | 0.000 | 0.000 | 0.000 |
| ## E4 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000  | 0.000 | 0.000 | 0.000 | 0.000 |
| ## E5 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000  | 0.000 | 0.000 | 0.000 | 0.000 |
| ## N1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000  | 0.000 | 0.000 | 0.000 | 0.000 |
| ## N2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000  | 0.000 | 0.000 | 0.000 | 0.000 |
| ## N3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000  | 0.000 | 0.000 | 0.000 | 0.000 |
| ## N4 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000  | 0.000 | 0.000 | 0.000 | 0.000 |
| ## N5 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000  | 0.000 | 0.000 | 0.000 | 0.000 |
| ## O1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000  | 0.000 | 0.000 | 0.000 | 0.000 |
| ## O2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000  | 0.000 | 0.000 | 0.000 | 0.000 |
| ## O3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000  | 0.000 | 0.000 | 0.000 | 0.000 |
| ## O5 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000  | 0.000 | 0.000 | 0.000 | 0.000 |
| ##    | E2    | E3    | E4    | E5    | N1    | N2    | N3     | N4    | N5    | O1    |       |
| ## A2 |       |       |       |       |       |       |        |       |       |       |       |
| ## A3 |       |       |       |       |       |       |        |       |       |       |       |
| ## A4 |       |       |       |       |       |       |        |       |       |       |       |
| ## A5 |       |       |       |       |       |       |        |       |       |       |       |
| ## C1 |       |       |       |       |       |       |        |       |       |       |       |
| ## C2 |       |       |       |       |       |       |        |       |       |       |       |
| ## C3 |       |       |       |       |       |       |        |       |       |       |       |
| ## C4 |       |       |       |       |       |       |        |       |       |       |       |
| ## C5 |       |       |       |       |       |       |        |       |       |       |       |
| ## E1 |       |       |       |       |       |       |        |       |       |       |       |
| ## E2 | 0.507 |       |       |       |       |       |        |       |       |       |       |
| ## E3 | 0.000 | 0.608 |       |       |       |       |        |       |       |       |       |
| ## E4 | 0.000 | 0.000 | 0.503 |       |       |       |        |       |       |       |       |
| ## E5 | 0.000 | 0.000 | 0.000 | 0.693 |       |       |        |       |       |       |       |
| ## N1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.573 |       |        |       |       |       |       |
| ## N2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.515 | 0.598 |        |       |       |       |       |
| ## N3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.334  |       |       |       |       |
| ## N4 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | -0.118 | 0.508 |       |       |       |
| ## N5 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000  | 0.000 | 0.698 |       |       |
| ## O1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000  | 0.000 | 0.000 | 0.689 |       |
| ## O2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000  | 0.000 | 0.000 | 0.000 | 0.000 |
| ## O3 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000  | 0.000 | 0.000 | 0.000 | 0.000 |
| ## O5 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000  | 0.000 | 0.000 | 0.000 | 0.000 |

```
##      02      03      05
## A2
## A3
## A4
## A5
## C1
## C2
## C3
## C4
## C5
## E1
## E2
## E3
## E4
## E5
## N1
## N2
## N3
## N4
## N5
## O1
## O2  0.827
## O3  0.000  0.477
## O5  0.000  0.000  0.800
##
## $psi
##           agrebl cnsent extrov neurot opnnss
## agreeable  1.000
## conscient  0.343  1.000
## extrov     -0.702 -0.352  1.000
## neurot     -0.208 -0.311  0.314  1.000
## openness   0.310  0.309 -0.483 -0.139  1.000
```

It is still not a great fit to the data, but I don't think I'd want to make any of these modifications.

```
modindices(bf_fit_re2) %>%
  arrange(desc(mi)) %>%
  select(lhs, op, rhs, mi) %>%
  head(10)
```

```
##      lhs op rhs      mi
## 1  extrov =~ N4 160.70218
## 2  openness =~ E3 140.06928
## 3  neurot =~ C5 135.79120
## 4  openness =~ E4 129.60464
```

```
## 5      neurot =~ C2 128.91871
## 6  conscient =~ E5 127.34527
## 7      C1 ~~ C2 110.30471
## 8      O2 ~~ O5  98.82617
## 9      extrov =~ A5  89.36109
## 10     extrov =~ N3  87.78938
```

We can compare teh CFIs for the 3 models with the `fitmeasures()` function.

```
fitmeasures(bf_fit)[9]
```

```
##      cfi
## 0.7823657
```

```
fitmeasures(bf_fit_re1)[9]
```

```
##      cfi
## 0.8021913
```

```
fitmeasures(bf_fit_re2)[9]
```

```
##      cfi
## 0.8283089
```

## Structural Equation Modeling

In real life you should not proceed to the structural equation modeling phase unless you have a good fitting measurement model (CFA). For demonstration purposes let's add gender, age, and education into the model as predictors of the 5 personality factors.

```
bf_model_sem <- ' agreeable =~ A2 + A3 + A4 + A5
                  conscient =~ C1 + C2 + C3 + C4 + C5
                  extrov =~ E1 + E2 + E3 + E4 + E5
                  neurot =~ N1 + N2 + N3 + N4 + N5
                  openness =~ O1 + O2 + O3 + O5

                  N1 ~~ N2
                  N3 ~~ N4

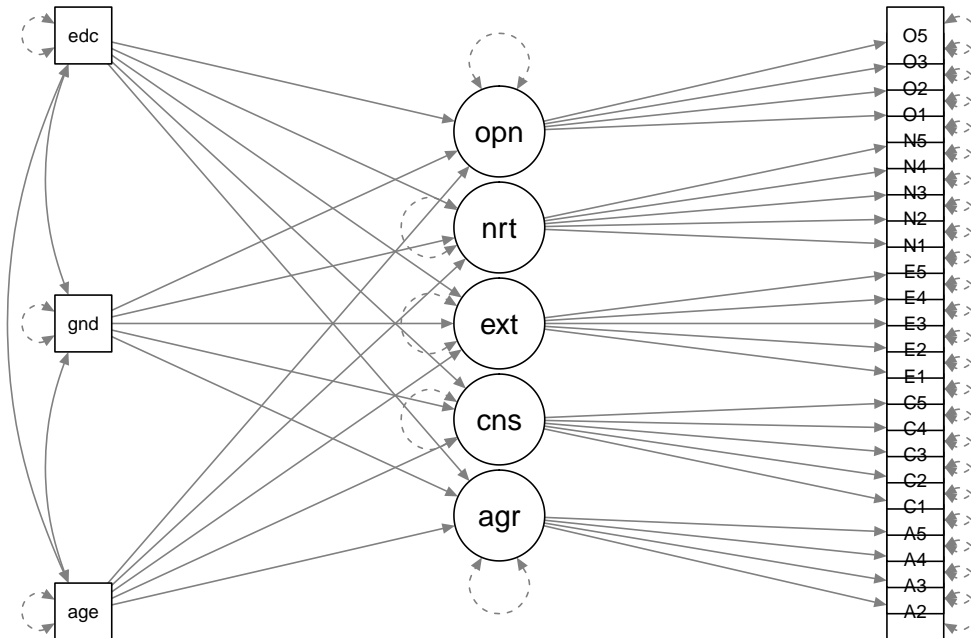
                  agreeable ~ age + gender + education
                  conscient ~ age + gender + education
                  extrov ~ age + gender + education
                  neurot ~ age + gender + education
                  openness ~ age + gender + education

                  age ~~ gender
```

```
age ~~ education
gender ~~ education
'
```

Let's make the graph.

```
semPaths(semPlotModel(bf_model_sem), rotation = 2)
```



Instead of the `cfa()` function we will use the `sem()` function.

```
bf_fit_sem <- sem(bf_model_sem, data = bfi)
```

```
summary(bf_fit_sem, fit.measures = TRUE, rsq=TRUE)
```

```
## lavaan (0.5-23.1097) converged normally after 91 iterations
##
##                                     Used      Total
##   Number of observations                2253      2800
##
##   Estimator                             ML
##   Minimum Function Test Statistic      3288.796
##   Degrees of freedom                    272
##   P-value (Chi-square)                  0.000
##
## Model test baseline model:
##
##   Minimum Function Test Statistic      16549.044
##   Degrees of freedom                    325
##   P-value                              0.000
```



```

##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                0.814
##   Tucker-Lewis Index (TLI)                  0.778
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)              -97728.434
##   Loglikelihood unrestricted model (H1)      -96084.035
##
##   Number of free parameters                  79
##   Akaike (AIC)                             195614.867
##   Bayesian (BIC)                           196066.749
##   Sample-size adjusted Bayesian (BIC)       195815.753
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                     0.070
##   90 Percent Confidence Interval             0.068  0.072
##   P-value RMSEA <= 0.05                     0.000
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                     0.064
##
## Parameter Estimates:
##
##   Information                               Expected
##   Standard Errors                           Standard
##
## Latent Variables:
##           Estimate  Std.Err  z-value  P(>|z|)
## agreeable =~
##   A2           1.000
##   A3           1.307    0.053   24.813    0.000
##   A4           1.019    0.053   19.300    0.000
##   A5           1.191    0.050   23.956    0.000
## conscient =~
##   C1           1.000
##   C2           1.161    0.063   18.400    0.000
##   C3           1.093    0.061   17.948    0.000
##   C4          -1.488    0.073  -20.360    0.000
##   C5          -1.588    0.082  -19.397    0.000
## extrov =~

```

```

##      E1              1.000
##      E2              1.234      0.054      22.996      0.000
##      E3             -0.954      0.043     -22.002      0.000
##      E4             -1.139      0.049     -23.207      0.000
##      E5             -0.826      0.041     -20.101      0.000
##  neurot =~
##      N1              1.000
##      N2              0.952      0.027      35.750      0.000
##      N3              1.230      0.052      23.636      0.000
##      N4              0.996      0.048      20.889      0.000
##      N5              0.885      0.040      22.366      0.000
##  openness =~
##      O1              1.000
##      O2             -1.040      0.071     -14.575      0.000
##      O3              1.364      0.074      18.319      0.000
##      O5             -0.961      0.063     -15.359      0.000
##
## Regressions:
##              Estimate      Std.Err      z-value      P(>|z|)
## agreeable ~
##   age              0.008      0.002      4.738      0.000
##   gender            0.343      0.038      9.110      0.000
##   education        -0.011      0.016     -0.704      0.481
## conscient ~
##   age              0.007      0.002      4.440      0.000
##   gender            0.129      0.034      3.852      0.000
##   education         0.002      0.014      0.142      0.887
## extrov ~
##   age             -0.004      0.002     -2.155      0.031
##   gender          -0.263      0.046     -5.661      0.000
##   education         0.002      0.020      0.095      0.924
## neurot ~
##   age            -0.012      0.002     -5.049      0.000
##   gender           0.286      0.052      5.480      0.000
##   education      -0.016      0.022     -0.735      0.462
## openness ~
##   age              0.003      0.002      1.850      0.064
##   gender          -0.139      0.035     -3.993      0.000
##   education         0.065      0.015      4.289      0.000
##
## Covariances:
##              Estimate      Std.Err      z-value      P(>|z|)
## .N1 ~~
## .N2              0.674      0.047      14.403      0.000
## .N3 ~~

```

```

##      .N4                -0.034    0.050   -0.679    0.497
##      age ~~
##      gender             0.234    0.106    2.219    0.026
##      education          2.943    0.257   11.443    0.000
##      gender ~~
##      education          0.004    0.011    0.386    0.699
##      .agreeable ~~
##      .conscient         0.140    0.015    9.615    0.000
##      .extrov            -0.439    0.027  -16.045    0.000
##      .neurot            -0.156    0.021   -7.488    0.000
##      .openness          0.132    0.015    8.947    0.000
##      .conscient ~~
##      .extrov            -0.195    0.019  -10.234    0.000
##      .neurot            -0.207    0.021   -9.907    0.000
##      .openness          0.120    0.014    8.691    0.000
##      .extrov ~~
##      .neurot             0.291    0.028   10.240    0.000
##      .openness          -0.279    0.022  -12.501    0.000
##      .neurot ~~
##      .openness          -0.084    0.019   -4.405    0.000
##
## Variances:
##      Estimate Std.Err z-value P(>|z|)
##      .A2       0.821   0.030  27.790  0.000
##      .A3       0.776   0.034  23.026  0.000
##      .A4       1.556   0.051  30.440  0.000
##      .A5       0.840   0.033  25.484  0.000
##      .C1       1.065   0.036  29.356  0.000
##      .C2       1.162   0.041  28.345  0.000
##      .C3       1.164   0.040  28.954  0.000
##      .C4       0.932   0.041  22.805  0.000
##      .C5       1.608   0.061  26.441  0.000
##      .E1       1.791   0.059  30.139  0.000
##      .E2       1.333   0.050  26.474  0.000
##      .E3       1.050   0.037  28.208  0.000
##      .E4       1.063   0.041  25.982  0.000
##      .E5       1.216   0.040  30.125  0.000
##      .N1       1.367   0.056  24.554  0.000
##      .N2       1.376   0.054  25.388  0.000
##      .N3       0.912   0.064  14.318  0.000
##      .N4       1.358   0.063  21.647  0.000
##      .N5       1.777   0.061  29.202  0.000
##      .O1       0.859   0.033  26.292  0.000
##      .O2       1.960   0.065  30.283  0.000
##      .O3       0.693   0.040  17.468  0.000

```

```
##      .05          1.395    0.047    29.596    0.000
##      age         113.628    3.385    33.563    0.000
##      gender       0.221    0.007    33.563    0.000
##      education    1.235    0.037    33.563    0.000
##      .agreeable   0.484    0.033    14.452    0.000
##      .conscient   0.406    0.035    11.741    0.000
##      .extrov      0.800    0.061    13.120    0.000
##      .neurot      1.050    0.069    15.153    0.000
##      .openness    0.388    0.033    11.681    0.000
```

```
##
```

```
## R-Square:
```

```
##      Estimate
##      A2        0.387
##      A3        0.532
##      A4        0.257
##      A5        0.466
##      C1        0.281
##      C2        0.325
##      C3        0.299
##      C4        0.497
##      C5        0.395
##      E1        0.314
##      E2        0.483
##      E3        0.415
##      E4        0.500
##      E5        0.314
##      N1        0.442
##      N2        0.417
##      N3        0.643
##      N4        0.442
##      N5        0.323
##      O1        0.317
##      O2        0.180
##      O3        0.518
##      O5        0.209
##      agreeable  0.066
##      conscient  0.023
##      extrov     0.022
##      neurot     0.031
##      openness   0.028
```

```
#standardized item loadings
```

```
inspect(bf_fit_sem, what = "std")$lambda
```

```
##      agrebl cnsent extrov neurot opnnss age gender eductn
```

```
## A2      0.622  0.000  0.000  0.000  0.000  0      0      0
## A3      0.730  0.000  0.000  0.000  0.000  0      0      0
## A4      0.507  0.000  0.000  0.000  0.000  0      0      0
## A5      0.683  0.000  0.000  0.000  0.000  0      0      0
## C1      0.000  0.530  0.000  0.000  0.000  0      0      0
## C2      0.000  0.570  0.000  0.000  0.000  0      0      0
## C3      0.000  0.547  0.000  0.000  0.000  0      0      0
## C4      0.000 -0.705  0.000  0.000  0.000  0      0      0
## C5      0.000 -0.628  0.000  0.000  0.000  0      0      0
## E1      0.000  0.000  0.560  0.000  0.000  0      0      0
## E2      0.000  0.000  0.695  0.000  0.000  0      0      0
## E3      0.000  0.000 -0.644  0.000  0.000  0      0      0
## E4      0.000  0.000 -0.707  0.000  0.000  0      0      0
## E5      0.000  0.000 -0.561  0.000  0.000  0      0      0
## N1      0.000  0.000  0.000  0.665  0.000  0      0      0
## N2      0.000  0.000  0.000  0.646  0.000  0      0      0
## N3      0.000  0.000  0.000  0.802  0.000  0      0      0
## N4      0.000  0.000  0.000  0.665  0.000  0      0      0
## N5      0.000  0.000  0.000  0.568  0.000  0      0      0
## O1      0.000  0.000  0.000  0.000  0.563  0      0      0
## O2      0.000  0.000  0.000  0.000 -0.425  0      0      0
## O3      0.000  0.000  0.000  0.000  0.719  0      0      0
## O5      0.000  0.000  0.000  0.000 -0.457  0      0      0
## age     0.000  0.000  0.000  0.000  0.000  1      0      0
## gender  0.000  0.000  0.000  0.000  0.000  0      1      0
## education 0.000  0.000  0.000  0.000  0.000  0      0      1
```

```
#standardized path estimates
```

```
inspect(bf_fit_sem, what = "std")$beta
```

```
##          agrebl cnsent extrov neurot opnnss      age gender eductn
## agreeable      0      0      0      0      0  0.117  0.224 -0.017
## conscient      0      0      0      0      0  0.113  0.094  0.004
## extrov         0      0      0      0      0 -0.053 -0.136  0.002
## neurot         0      0      0      0      0 -0.122  0.129 -0.018
## openness       0      0      0      0      0  0.049 -0.103  0.114
## age            0      0      0      0      0  0.000  0.000  0.000
## gender         0      0      0      0      0  0.000  0.000  0.000
## education      0      0      0      0      0  0.000  0.000  0.000
```

```
#correlations bewteen latent variables and exogenous variables
```

```
inspect(bf_fit_sem, what = "std")$psi
```

```
##          agrebl cnsent extrov neurot opnnss age      gender eductn
## agreeable  0.934
## conscient  0.316  0.977
```

|              |        |        |        |        |       |       |       |       |
|--------------|--------|--------|--------|--------|-------|-------|-------|-------|
| ## extrov    | -0.705 | -0.342 | 0.978  |        |       |       |       |       |
| ## neurot    | -0.219 | -0.317 | 0.317  | 0.969  |       |       |       |       |
| ## openness  | 0.304  | 0.302  | -0.502 | -0.131 | 0.972 |       |       |       |
| ## age       | 0.000  | 0.000  | 0.000  | 0.000  | 0.000 | 1.000 |       |       |
| ## gender    | 0.000  | 0.000  | 0.000  | 0.000  | 0.000 | 0.047 | 1.000 |       |
| ## education | 0.000  | 0.000  | 0.000  | 0.000  | 0.000 | 0.248 | 0.008 | 1.000 |