A Mild Introduction to Structural Equation Modeling Using `lavaan`

UseR! Oslo Group Workshop

28 May 2020

Contents

Data preparation

Install and load relevant R packages

```
# Install R packages (if needed)
# install.packages(c("lavaan", "semPlot", "MPsychoR", "corrplot"))

## Load relevant libraries
library(lavaan)
library(semPlot)
library(MPsychoR)
library(corrplot)
```

Data input

```
# Select the data
data("Bergh")
View(Bergh)
attach(Bergh)

# Sample size
nrow(Bergh)
```

```
## [1] 861
```

```
## Create mean scores per construct
Bergh$Open <- (O1+O2+O3)/3
Bergh$Agree <- (A1+A2+A3)/3
Bergh$Prejudice <- (EP+SP+DP+HP)/4
```

Model 1: Regression model with manifest variables only

Specifying, estimating, and evaluating the model

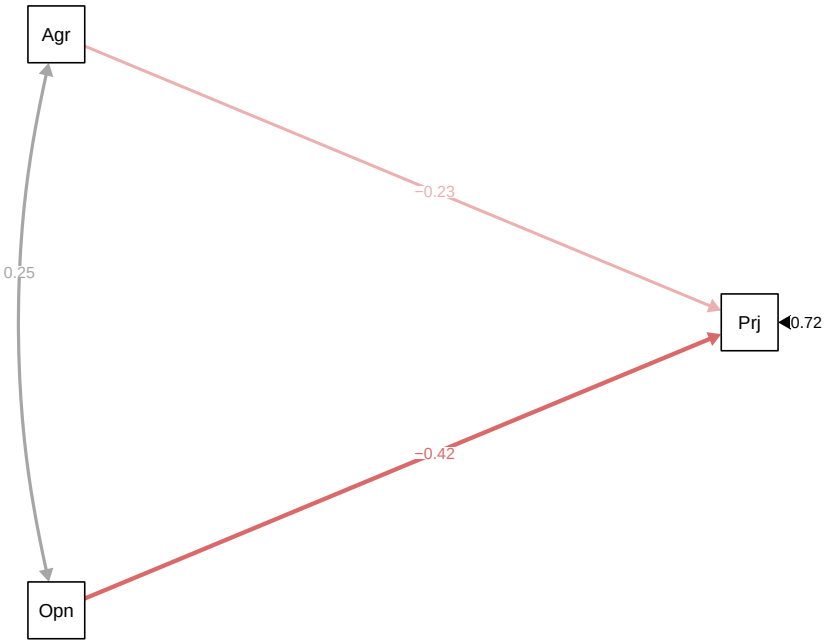
```
# Step 1: Model specification
model1 <- '
            # Structural model
            Prejudice ~ b1*Open + b2*Agree

            # Covariance structure of exogenous variables
            Open ~~ Open + Agree
            Agree ~~ Agree

'

# Step 2: Model estimation
model1.fit <- sem(model1,
                  data = Bergh,
                  meanstructure = FALSE,
                  estimator = "ML")
```

```r
# Step 3: Evaluate the model
# Summary
summary(model1.fit,
        rsquare = TRUE,
        fit.measures = TRUE,
        standardized = TRUE)
```

```
## lavaan 0.6-5 ended normally after 21 iterations
##
##   Estimator                                         ML
##   Optimization method                           NLMINB
##   Number of free parameters                          6
##
##   Number of observations                           861
##
## Model Test User Model:
##
##   Test statistic                                 0.000
##   Degrees of freedom                                 0
##
## Model Test Baseline Model:
##
##   Test statistic                               335.486
##   Degrees of freedom                                 3
##   P-value                                        0.000
##
## User Model versus Baseline Model:
##
##   Comparative Fit Index (CFI)                    1.000
##   Tucker-Lewis Index (TLI)                       1.000
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)              -1689.786
##   Loglikelihood unrestricted model (H1)      -1689.786
##
##   Akaike (AIC)                                3391.572
##   Bayesian (BIC)                              3420.121
##   Sample-size adjusted Bayesian (BIC)         3401.066
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.000
##   90 Percent confidence interval - lower         0.000
##   90 Percent confidence interval - upper         0.000
##   P-value RMSEA <= 0.05                             NA
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.000
##
## Parameter Estimates:
##
```

```
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard errors                             Standard
##
## Regressions:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   Prejudice ~
##     Open      (b1)   -0.612    0.043  -14.118    0.000   -0.612   -0.423
##     Agree     (b2)   -0.324    0.043   -7.522    0.000   -0.324   -0.225
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   Open ~~
##     Agree             0.049    0.007    7.148    0.000    0.049    0.251
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##     Open              0.192    0.009   20.748    0.000    0.192    1.000
##     Agree             0.194    0.009   20.748    0.000    0.194    1.000
##    .Prejudice         0.291    0.014   20.748    0.000    0.291    0.723
##
## R-Square:
##                    Estimate
##     Prejudice         0.277
```

```r
# Visualize the path model
semPaths(model1.fit,
         rotation = 2,
         layout = "tree2",
         what = "std",
         posCol = "black",
         edge.width = 0.5,
         style = "Lisrel",
         fade = T,
         edge.label.position = 0.55)
```




```
# Fitted values of the covariance matrix
fitted(model1.fit)
```

```
## $cov
##           Prejdc Open   Agree
## Prejudice  0.402
## Open      -0.133  0.192
## Agree     -0.093  0.049  0.194
```

```
# List all parameter values
parameterEstimates(model1.fit)
```

```
##         lhs op       rhs label    est    se       z pvalue ci.lower ci.upper
## 1 Prejudice  ~      Open    b1 -0.612 0.043 -14.118      0   -0.697   -0.527
## 2 Prejudice  ~     Agree    b2 -0.324 0.043  -7.522      0   -0.408   -0.239
## 3      Open ~~      Open        0.192 0.009  20.748      0    0.174    0.210
## 4      Open ~~     Agree        0.049 0.007   7.148      0    0.035    0.062
## 5     Agree ~~     Agree        0.194 0.009  20.748      0    0.176    0.213
## 6 Prejudice ~~ Prejudice        0.291 0.014  20.748      0    0.263    0.318
```

```
# Step 4: Further hypothesis testing
# H0: b1=b2
lavTestWald(model1.fit, constraints = "b1==b2")
```

```
## $stat
## [1] 17.76479
##
## $df
## [1] 1
##
## $p.value
## [1] 2.499661e-05
##
## $se
## [1] "standard"
```

ADD-ON–Model 1 with bootstrapping of standard errors

```
# Step 2: Model estimation with bootstrapping
set.seed(616)
model1.fit.boot <- sem(model1,
                       data = Bergh,
                       meanstructure = FALSE,
                       estimator = "ML",
                       se = "bootstrap",
                       bootstrap = 1000)

# Step 3: Evaluate the model
# Summary
summary(model1.fit.boot,
        rsquare = TRUE,
        fit.measures = TRUE,
        standardized = TRUE,
        ci = TRUE)
```

```
## lavaan 0.6-5 ended normally after 21 iterations
##
##   Estimator                                         ML
##   Optimization method                           NLMINB
##   Number of free parameters                          6
##
##   Number of observations                           861
##
## Model Test User Model:
##
##   Test statistic                                 0.000
##   Degrees of freedom                                 0
##
## Model Test Baseline Model:
##
##   Test statistic                               335.486
##   Degrees of freedom                                 3
##   P-value                                        0.000
##
## User Model versus Baseline Model:
##
##   Comparative Fit Index (CFI)                    1.000
##   Tucker-Lewis Index (TLI)                       1.000
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)              -1689.786
##   Loglikelihood unrestricted model (H1)      -1689.786
##
##   Akaike (AIC)                                3391.572
##   Bayesian (BIC)                              3420.121
##   Sample-size adjusted Bayesian (BIC)         3401.066
##
## Root Mean Square Error of Approximation:
##
```

```
##   RMSEA                                          0.000
##   90 Percent confidence interval - lower         0.000
##   90 Percent confidence interval - upper         0.000
##   P-value RMSEA <= 0.05                             NA
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.000
##
## Parameter Estimates:
##
##   Standard errors                             Bootstrap
##   Number of requested bootstrap draws             1000
##   Number of successful bootstrap draws            1000
##
## Regressions:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   Prejudice ~
##     Open      (b1)   -0.612    0.044  -13.905    0.000   -0.704   -0.528
##     Agree     (b2)   -0.324    0.043   -7.576    0.000   -0.410   -0.238
##    Std.lv  Std.all
##
##    -0.612   -0.423
##    -0.324   -0.225
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   Open ~~
##     Agree             0.049    0.007    6.802    0.000    0.034    0.061
##    Std.lv  Std.all
##
##     0.049    0.251
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##     Open              0.192    0.009   22.345    0.000    0.174    0.209
##     Agree             0.194    0.008   24.159    0.000    0.177    0.211
##    .Prejudice         0.291    0.017   17.440    0.000    0.258    0.323
##    Std.lv  Std.all
##     0.192    1.000
##     0.194    1.000
##     0.291    0.723
##
## R-Square:
##                    Estimate
##     Prejudice         0.277
```

```
# List all parameter values
parameterEstimates(model1.fit.boot, ci = TRUE, boot.ci.type = "basic")
```

```
##         lhs op       rhs label    est    se       z pvalue ci.lower ci.upper
## 1 Prejudice  ~      Open    b1 -0.612 0.044 -13.905      0   -0.696   -0.520
## 2 Prejudice  ~     Agree    b2 -0.324 0.043  -7.576      0   -0.409   -0.238
## 3      Open ~~      Open        0.192 0.009  22.345      0    0.175    0.210
## 4      Open ~~     Agree        0.049 0.007   6.802      0    0.036    0.063
```

```
## 5     Agree ~~     Agree        0.194 0.008  24.159      0    0.178    0.212
## 6 Prejudice ~~ Prejudice        0.291 0.017  17.440      0    0.258    0.324
```

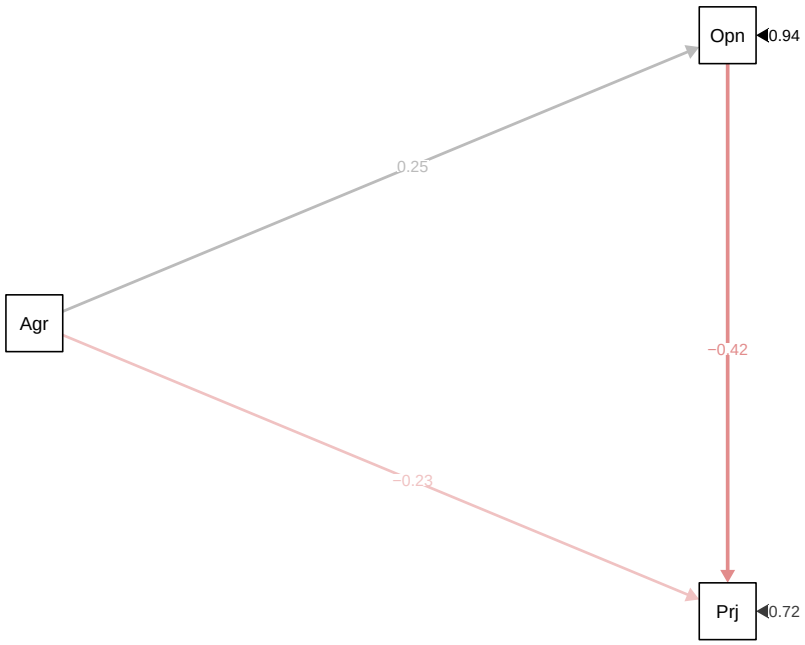
Model 2: Mediation model with manifest variables only

```
# Step 1: Model specification
model2 <- '
            # Structural model
            Prejudice ~ b1*Open + b2*Agree
            Open ~ b3*Agree

            # Covariance structure of exogenous variables
            Agree ~~ Agree

            # New parameters (indirect effect)
            ind := b1*b3

'

# Step 2: Model estimation
model2.fit <- sem(model2,
                  data = Bergh,
                  meanstructure = FALSE,
                  estimator = "ML")

# Step 3: Evaluate the model
# Summary
summary(model2.fit,
        rsquare = TRUE,
        fit.measures = TRUE,
        standardized = TRUE)
```

```
## lavaan 0.6-5 ended normally after 19 iterations
##
##   Estimator                                         ML
##   Optimization method                           NLMINB
##   Number of free parameters                          6
##
##   Number of observations                           861
##
## Model Test User Model:
##
##   Test statistic                                 0.000
##   Degrees of freedom                                 0
##
## Model Test Baseline Model:
##
##   Test statistic                               335.486
##   Degrees of freedom                                 3
##   P-value                                        0.000
##
## User Model versus Baseline Model:
```

```
##
##   Comparative Fit Index (CFI)                    1.000
##   Tucker-Lewis Index (TLI)                       1.000
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)              -1689.786
##   Loglikelihood unrestricted model (H1)      -1689.786
##
##   Akaike (AIC)                                3391.572
##   Bayesian (BIC)                              3420.121
##   Sample-size adjusted Bayesian (BIC)         3401.066
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.000
##   90 Percent confidence interval - lower         0.000
##   90 Percent confidence interval - upper         0.000
##   P-value RMSEA <= 0.05                             NA
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.000
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard errors                             Standard
##
## Regressions:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   Prejudice ~
##     Open      (b1)   -0.612    0.043  -14.118    0.000   -0.612   -0.423
##     Agree     (b2)   -0.324    0.043   -7.522    0.000   -0.324   -0.225
##   Open ~
##     Agree     (b3)    0.250    0.033    7.614    0.000    0.250    0.251
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##     Agree             0.194    0.009   20.748    0.000    0.194    1.000
##    .Prejudice         0.291    0.014   20.748    0.000    0.291    0.723
##    .Open              0.180    0.009   20.748    0.000    0.180    0.937
##
## R-Square:
##                    Estimate
##     Prejudice         0.277
##     Open              0.063
##
## Defined Parameters:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##     ind              -0.153    0.023   -6.701    0.000   -0.153   -0.106
```

```r
# Visualize the path model
semPaths(model2.fit,
         rotation = 2,
         layout = "tree2",
         what = "std",
         posCol = "black",
         edge.width = 0.5,
         style = "Lisrel",
         fade = T,
         edge.label.position = 0.55)
```



Model 3: Measurement model (CFA)

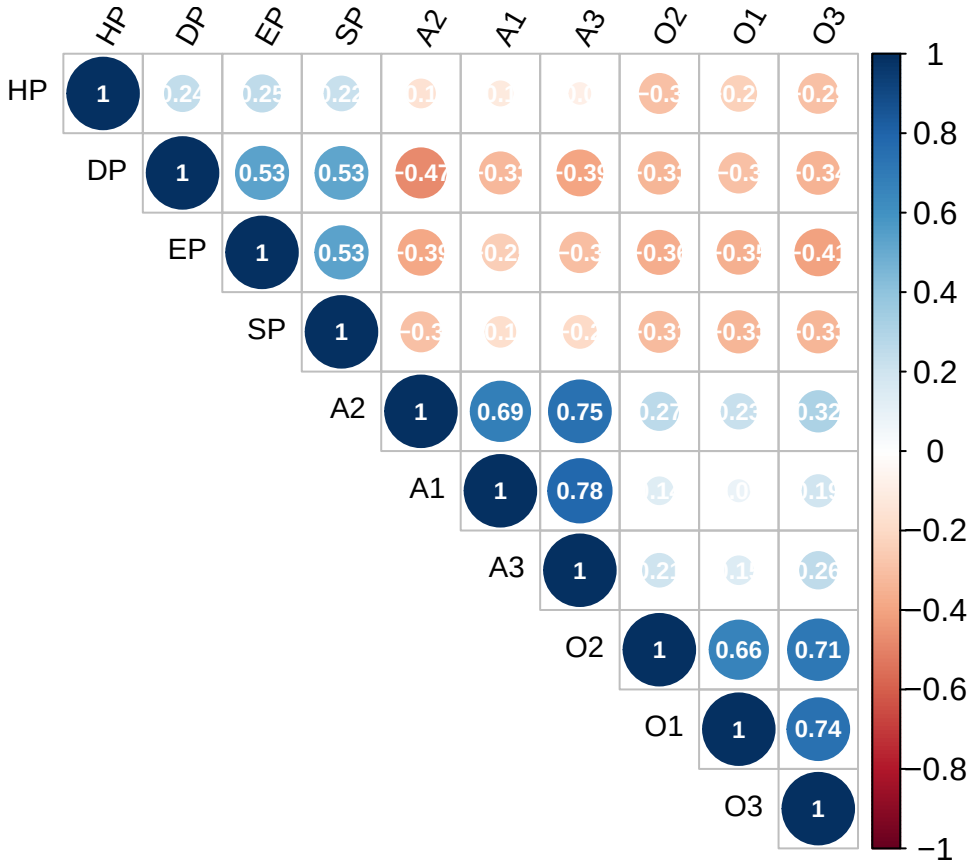
Correlation matrix

```r
# Extract the correlation matrix
Bergh.cor <- cor(Bergh[,1:10], method = "pearson", use = "pairwise.complete.obs")
Bergh.cor
```

```
##            EP         SP         HP         DP         A1         A2         A3
## EP  1.0000000  0.5328577  0.2545270  0.5314828 -0.2486889 -0.3889079 -0.3031269
## SP  0.5328577  1.0000000  0.2219292  0.5252140 -0.1710822 -0.2973829 -0.1987969
## HP  0.2545270  0.2219292  1.0000000  0.2415626 -0.1120012 -0.1510590 -0.0827062
## DP  0.5314828  0.5252140  0.2415626  1.0000000 -0.3292610 -0.4709318 -0.3936544
## A1 -0.2486889 -0.1710822 -0.1120012 -0.3292610  1.0000000  0.6867541  0.7835360
## A2 -0.3889079 -0.2973829 -0.1510590 -0.4709318  0.6867541  1.0000000  0.7453925
## A3 -0.3031269 -0.1987969 -0.0827062 -0.3936544  0.7835360  0.7453925  1.0000000
## O1 -0.3543605 -0.3317130 -0.2332906 -0.2994080  0.0861290  0.2293831  0.1488831
## O2 -0.3622272 -0.3127873 -0.2972669 -0.3327277  0.1393367  0.2698570  0.2082816
## O3 -0.4089230 -0.3300734 -0.2930209 -0.3407396  0.1904259  0.3178221  0.2584276
##            O1         O2         O3
```

```
## EP -0.3543605 -0.3622272 -0.4089230
## SP -0.3317130 -0.3127873 -0.3300734
## HP -0.2332906 -0.2972669 -0.2930209
## DP -0.2994080 -0.3327277 -0.3407396
## A1  0.0861290  0.1393367  0.1904259
## A2  0.2293831  0.2698570  0.3178221
## A3  0.1488831  0.2082816  0.2584276
## O1  1.0000000  0.6624692  0.7444363
## O2  0.6624692  1.0000000  0.7140617
## O3  0.7444363  0.7140617  1.0000000
```

```r
# Correlogram
corrplot(Bergh.cor, type = "upper", order = "hclust",
         tl.col = "black", tl.srt = 60,
         addCoef.col = "white",
         number.cex = 0.75,
         cl.cex = 1,
         tl.cex = 0.9)
```



Variables that represent the same underlying concept (i.e., agreeableness, openness, and prejudice) correlate positively, significantly, and substantially. Do they really measure the same concept?

Specifying, estimating, and evaluating the model

```r
# Step 1: Model specification
model3 <- '
```

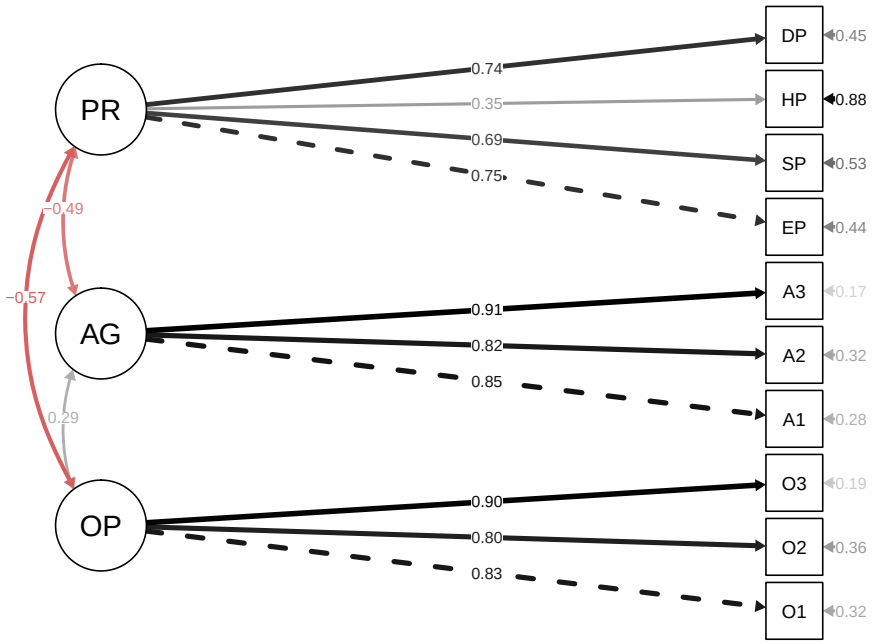
```
            # Measurement models
            OP =~ O1 + O2 + O3
            AG =~ A1 + A2 + A3
            PR =~ EP + SP + HP + DP

            # Covariance structure
            OP ~~ OP + AG + PR
            AG ~~ AG + PR
            PR ~~ PR

'

# Step 2: Model estimation
model3.fit <- sem(model3,
                  data = Bergh,
                  meanstructure = FALSE,
                  estimator = "ML")

# Step 3: Evaluate the model
# Summary
summary(model3.fit,
        rsquare = TRUE,
        fit.measures = TRUE,
        standardized = TRUE)
```

```
## lavaan 0.6-5 ended normally after 54 iterations
##
##   Estimator                                         ML
##   Optimization method                           NLMINB
##   Number of free parameters                         23
##
##   Number of observations                           861
##
## Model Test User Model:
##
##   Test statistic                               186.620
##   Degrees of freedom                                32
##   P-value (Chi-square)                           0.000
##
## Model Test Baseline Model:
##
##   Test statistic                              4270.205
##   Degrees of freedom                                45
##   P-value                                        0.000
##
## User Model versus Baseline Model:
##
##   Comparative Fit Index (CFI)                    0.963
##   Tucker-Lewis Index (TLI)                       0.949
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)              -5672.807
##   Loglikelihood unrestricted model (H1)      -5579.497
```

```
##
##   Akaike (AIC)                               11391.614
##   Bayesian (BIC)                             11501.050
##   Sample-size adjusted Bayesian (BIC)        11428.008
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.075
##   90 Percent confidence interval - lower         0.065
##   90 Percent confidence interval - upper         0.085
##   P-value RMSEA <= 0.05                          0.000
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.054
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard errors                             Standard
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   OP =~
##     O1                1.000                               0.400    0.827
##     O2                0.934    0.036   26.185    0.000    0.374    0.799
##     O3                1.149    0.040   28.900    0.000    0.460    0.898
##   AG =~
##     A1                1.000                               0.426    0.846
##     A2                0.910    0.032   28.812    0.000    0.388    0.823
##     A3                1.030    0.032   31.899    0.000    0.439    0.914
##   PR =~
##     EP                1.000                               0.530    0.746
##     SP                0.886    0.051   17.348    0.000    0.469    0.686
##     HP                1.030    0.112    9.160    0.000    0.545    0.350
##     DP                0.746    0.041   18.308    0.000    0.395    0.741
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   OP ~~
##     AG                0.049    0.007    7.105    0.000    0.286    0.286
##     PR               -0.122    0.011  -11.371    0.000   -0.573   -0.573
##   AG ~~
##     PR               -0.110    0.011  -10.241    0.000   -0.485   -0.485
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##     OP                0.160    0.011   14.156    0.000    1.000    1.000
##     AG                0.182    0.012   14.822    0.000    1.000    1.000
##     PR                0.281    0.025   11.385    0.000    1.000    1.000
##    .O1                0.074    0.005   14.555    0.000    0.074    0.317
##    .O2                0.079    0.005   15.837    0.000    0.079    0.361
##    .O3                0.051    0.005    9.630    0.000    0.051    0.194
```

```
##    .A1                0.072    0.005   14.461    0.000    0.072    0.284
##    .A2                0.072    0.005   15.697    0.000    0.072    0.322
##    .A3                0.038    0.004    9.152    0.000    0.038    0.165
##    .EP                0.224    0.016   14.198    0.000    0.224    0.444
##    .SP                0.248    0.015   16.146    0.000    0.248    0.530
##    .HP                2.137    0.107   20.052    0.000    2.137    0.878
##    .DP                0.128    0.009   14.376    0.000    0.128    0.451
##
## R-Square:
##                    Estimate
##     O1                0.683
##     O2                0.639
##     O3                0.806
##     A1                0.716
##     A2                0.678
##     A3                0.835
##     EP                0.556
##     SP                0.470
##     HP                0.122
##     DP                0.549
```

```r
# Visualize the path model
semPaths(model3.fit,
         rotation = 2,
         layout = "tree2",
         what = "std",
         posCol = "black",
         edge.width = 0.5,
         style = "Lisrel",
         fade = T,
         edge.label.position = 0.55)
```



Model 3b: Refined CFA of personality

Some researcher had reason to believe that the indicators `A1` and `A3` may covary beyond having the same underlying construct (Agreeableness). This may be due to similar wording in questions to the study participants or a similar method with which `A1` and `A3` have been assessed. To represent this in the original measurement model (`Model 3`), we add the residual covariance between these two indicators (i.e., `A1 ~~ A3`) and evaluate the extent to which this improves/changes the model fit.

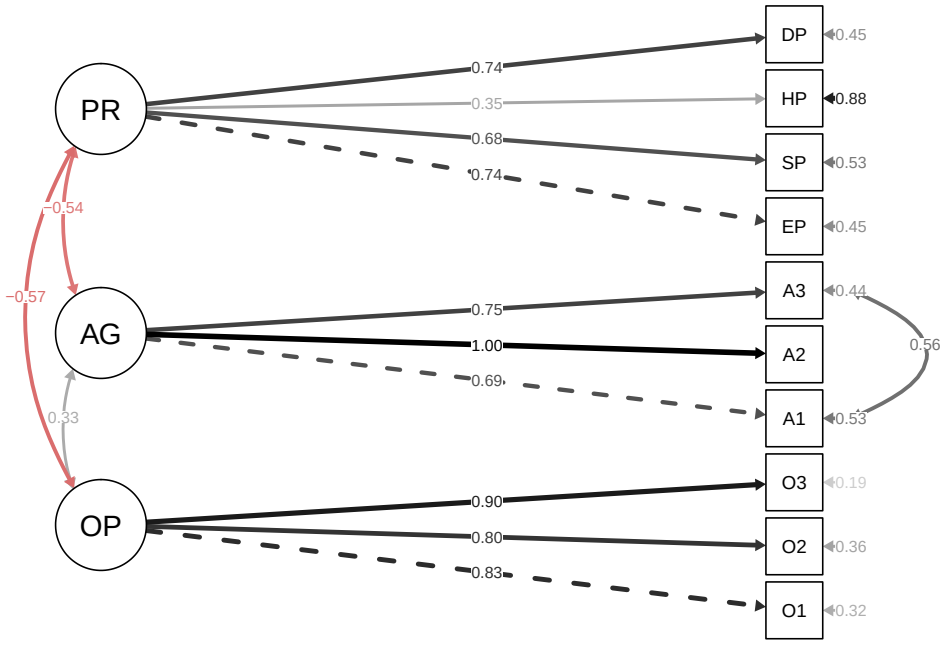
```
# Step 1: Model specification
model3b <- '
            # Measurement models
            OP =~ O1 + O2 + O3
            AG =~ A1 + A2 + A3
            PR =~ EP + SP + HP + DP

            # Covariance structure
            OP ~~ OP + AG + PR
            AG ~~ AG + PR
            PR ~~ PR

            # Residual covariance
            A1 ~~ A3

'

# Step 2: Model estimation
model3b.fit <- sem(model3b,
                   data = Bergh,
                   meanstructure = FALSE,
                   estimator = "ML")

# Step 3: Evaluate the model
# Summary
summary(model3b.fit,
        rsquare = TRUE,
        fit.measures = TRUE,
        standardized = TRUE)
```

```
## lavaan 0.6-5 ended normally after 62 iterations
##
##   Estimator                                         ML
##   Optimization method                           NLMINB
##   Number of free parameters                         24
##
##   Number of observations                           861
##
## Model Test User Model:
##
##   Test statistic                               118.256
##   Degrees of freedom                                31
##   P-value (Chi-square)                           0.000
##
## Model Test Baseline Model:
##
##   Test statistic                              4270.205
```

```
##   Degrees of freedom                                45
##   P-value                                        0.000
##
## User Model versus Baseline Model:
##
##   Comparative Fit Index (CFI)                    0.979
##   Tucker-Lewis Index (TLI)                       0.970
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)              -5638.625
##   Loglikelihood unrestricted model (H1)      -5579.497
##
##   Akaike (AIC)                               11325.249
##   Bayesian (BIC)                             11439.444
##   Sample-size adjusted Bayesian (BIC)        11363.226
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.057
##   90 Percent confidence interval - lower         0.046
##   90 Percent confidence interval - upper         0.068
##   P-value RMSEA <= 0.05                          0.131
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.043
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard errors                             Standard
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   OP =~
##     O1                1.000                               0.400    0.827
##     O2                0.934    0.036   26.188    0.000    0.374    0.799
##     O3                1.149    0.040   28.921    0.000    0.460    0.898
##   AG =~
##     A1                1.000                               0.346    0.687
##     A2                1.361    0.086   15.756    0.000    0.471    0.999
##     A3                1.036    0.033   31.662    0.000    0.358    0.746
##   PR =~
##     EP                1.000                               0.529    0.744
##     SP                0.887    0.051   17.460    0.000    0.469    0.685
##     HP                1.031    0.112    9.177    0.000    0.545    0.349
##     DP                0.750    0.040   18.535    0.000    0.397    0.744
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   OP ~~
##     AG                0.046    0.006    7.516    0.000    0.330    0.330
```

```
##     PR                -0.121    0.011  -11.372    0.000   -0.573   -0.573
##   AG ~~
##     PR                -0.098    0.010   -9.409    0.000   -0.536   -0.536
##  .A1 ~~
##    .A3                 0.066    0.008    8.266    0.000    0.066    0.560
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##     OP                0.160    0.011   14.158    0.000    1.000    1.000
##     AG                0.120    0.012    9.879    0.000    1.000    1.000
##     PR                0.279    0.024   11.413    0.000    1.000    1.000
##    .O1                0.074    0.005   14.570    0.000    0.074    0.317
##    .O2                0.079    0.005   15.846    0.000    0.079    0.361
##    .O3                0.051    0.005    9.643    0.000    0.051    0.194
##    .A1                0.134    0.009   14.890    0.000    0.134    0.528
##    .A2                0.000    0.012    0.027    0.979    0.000    0.001
##    .A3                0.102    0.008   12.293    0.000    0.102    0.444
##    .EP                0.225    0.016   14.456    0.000    0.225    0.447
##    .SP                0.249    0.015   16.300    0.000    0.249    0.531
##    .HP                2.138    0.106   20.073    0.000    2.138    0.878
##    .DP                0.127    0.009   14.467    0.000    0.127    0.447
##
## R-Square:
##                    Estimate
##     O1                0.683
##     O2                0.639
##     O3                0.806
##     A1                0.472
##     A2                0.999
##     A3                0.556
##     EP                0.553
##     SP                0.469
##     HP                0.122
##     DP                0.553
```

```r
# Visualize the path model
semPaths(model3b.fit,
         rotation = 2,
         layout = "tree2",
         what = "std",
         posCol = "black",
         edge.width = 0.5,
         style = "Lisrel",
         fade = T,
         edge.label.position = 0.55)
```




```
## Model comparison: Model 3 vs. refined Model 3
anova(model3.fit, model3b.fit)
```

```
## Chi-Squared Difference Test
##
##             Df   AIC   BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## model3b.fit 31 11325 11439 118.26
## model3.fit  32 11392 11501 186.62     68.364       1  < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Model 4: Structural equation model

```
# Step 1: Model specification
model4 <- '
            # Measurement models
            OP =~ O1 + O2 + O3
            AG =~ A1 + A2 + A3
            PR =~ EP + SP + HP + DP

            # Residual covariance
            A1 ~~ A3

            # Structural model
            PR ~ b1*OP + b2*AG

'

# Step 2: Model estimation
model4.fit <- sem(model4,
                  data = Bergh,
                  meanstructure = FALSE,
```

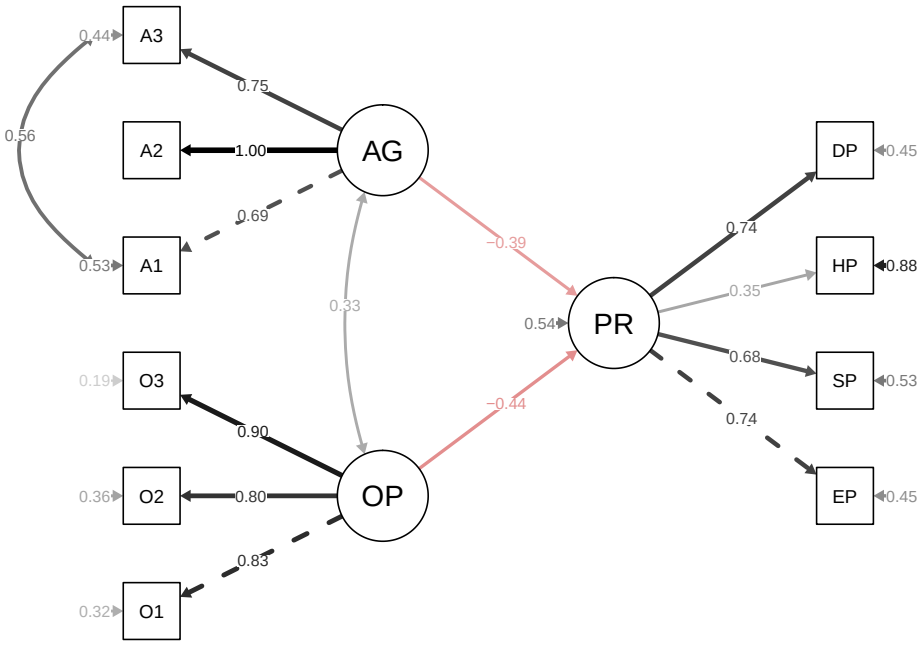
```
                  estimator = "ML")

# Step 3: Evaluate the model
# Summary
summary(model4.fit,
        rsquare = TRUE,
        fit.measures = TRUE,
        standardized = TRUE)
```

```
## lavaan 0.6-5 ended normally after 55 iterations
##
##   Estimator                                         ML
##   Optimization method                           NLMINB
##   Number of free parameters                         24
##
##   Number of observations                           861
##
## Model Test User Model:
##
##   Test statistic                               118.256
##   Degrees of freedom                                31
##   P-value (Chi-square)                           0.000
##
## Model Test Baseline Model:
##
##   Test statistic                              4270.205
##   Degrees of freedom                                45
##   P-value                                        0.000
##
## User Model versus Baseline Model:
##
##   Comparative Fit Index (CFI)                    0.979
##   Tucker-Lewis Index (TLI)                       0.970
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)              -5638.625
##   Loglikelihood unrestricted model (H1)      -5579.497
##
##   Akaike (AIC)                               11325.249
##   Bayesian (BIC)                             11439.444
##   Sample-size adjusted Bayesian (BIC)        11363.226
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.057
##   90 Percent confidence interval - lower         0.046
##   90 Percent confidence interval - upper         0.068
##   P-value RMSEA <= 0.05                          0.131
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.043
##
```

```
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard errors                             Standard
##
## Latent Variables:
##                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   OP =~
##     O1               1.000                               0.400    0.827
##     O2               0.934    0.036   26.188    0.000    0.374    0.799
##     O3               1.149    0.040   28.921    0.000    0.460    0.898
##   AG =~
##     A1               1.000                               0.346    0.687
##     A2               1.361    0.086   15.756    0.000    0.471    0.999
##     A3               1.036    0.033   31.662    0.000    0.358    0.746
##   PR =~
##     EP               1.000                               0.529    0.744
##     SP               0.887    0.051   17.460    0.000    0.469    0.685
##     HP               1.031    0.112    9.177    0.000    0.545    0.349
##     DP               0.750    0.040   18.535    0.000    0.397    0.744
##
## Regressions:
##                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   PR ~
##     OP        (b1)   -0.587    0.053  -11.106    0.000   -0.444   -0.444
##     AG        (b2)   -0.595    0.058  -10.172    0.000   -0.390   -0.390
##
## Covariances:
##                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##  .A1 ~~
##    .A3               0.066    0.008    8.266    0.000    0.066    0.560
##   OP ~~
##     AG               0.046    0.006    7.516    0.000    0.330    0.330
##
## Variances:
##                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##    .O1               0.074    0.005   14.570    0.000    0.074    0.317
##    .O2               0.079    0.005   15.846    0.000    0.079    0.361
##    .O3               0.051    0.005    9.643    0.000    0.051    0.194
##    .A1               0.134    0.009   14.890    0.000    0.134    0.528
##    .A2               0.000    0.012    0.027    0.979    0.000    0.001
##    .A3               0.102    0.008   12.293    0.000    0.102    0.444
##    .EP               0.225    0.016   14.456    0.000    0.225    0.447
##    .SP               0.249    0.015   16.300    0.000    0.249    0.531
##    .HP               2.138    0.106   20.073    0.000    2.138    0.878
##    .DP               0.127    0.009   14.467    0.000    0.127    0.447
##     OP               0.160    0.011   14.158    0.000    1.000    1.000
##     AG               0.120    0.012    9.879    0.000    1.000    1.000
##    .PR               0.150    0.015    9.937    0.000    0.536    0.536
##
## R-Square:
##                   Estimate
##     O1               0.683
```

```
##      O2                0.639
##      O3                0.806
##      A1                0.472
##      A2                0.999
##      A3                0.556
##      EP                0.553
##      SP                0.469
##      HP                0.122
##      DP                0.553
##      PR                0.464
```

```r
# Visualize the path model
semPaths(model4.fit,
         rotation = 2,
         layout = "tree2",
         what = "std",
         posCol = "black",
         edge.width = 0.5,
         style = "Lisrel",
         fade = T,
         edge.label.position = 0.55)
```




```r
## Hypothesis testing
lavTestWald(model4.fit, constraints = "b1 == b2")
```

```
## $stat
## [1] 0.009016331
##
## $df
## [1] 1
##
## $p.value
## [1] 0.9243511
##
## $se
```

```
## [1] "standard"
```

ADD-ON–Model 5: Multi-group SEM (Gender differences in the structural parameters)

```
# Step 1: Model specification
model5 <- '
            # Measurement models
            OP =~ O1 + O2 + O3
            AG =~ A1 + A2 + A3
            PR =~ EP + SP + HP + DP

            # Covariance structure
            OP ~~ OP + AG
            AG ~~ AG

            # Residual covariance
            A1 ~~ A3

            # Structural model
            PR ~ c(a1,b1)*OP + c(a2,b2)*AG

'

# Step 2: Model estimation
# Only allow for differences in the structural parameters
# Keep all other parameters equal (measurement invariance)
model5.fit <- sem(model5,
                  data = Bergh,
                  meanstructure = FALSE,
                  estimator = "ML",
                  group = "gender",
                  group.equal = c("loadings", "residuals"))

# Step 3: Evaluate the model
# Summary
summary(model5.fit,
        rsquare = TRUE,
        fit.measures = TRUE,
        standardized = TRUE)
```

```
## lavaan 0.6-5 ended normally after 60 iterations
##
##   Estimator                                         ML
##   Optimization method                           NLMINB
##   Number of free parameters                         48
##   Number of equality constraints                    17
##   Row rank of the constraints matrix                17
##
##   Number of observations per group:
##     male                                           249
##     female                                         612
##
## Model Test User Model:
##
```

```
##   Test statistic                                208.998
##   Degrees of freedom                                79
##   P-value (Chi-square)                           0.000
##   Test statistic for each group:
##     male                                         83.323
##     female                                      125.675
##
## Model Test Baseline Model:
##
##   Test statistic                               4207.254
##   Degrees of freedom                                90
##   P-value                                        0.000
##
## User Model versus Baseline Model:
##
##   Comparative Fit Index (CFI)                    0.968
##   Tucker-Lewis Index (TLI)                       0.964
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)              -5575.804
##   Loglikelihood unrestricted model (H1)      -5471.305
##
##   Akaike (AIC)                               11213.608
##   Bayesian (BIC)                             11361.109
##   Sample-size adjusted Bayesian (BIC)        11262.661
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.062
##   90 Percent confidence interval - lower         0.052
##   90 Percent confidence interval - upper         0.072
##   P-value RMSEA <= 0.05                          0.028
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.067
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard errors                             Standard
##
##
## Group 1 [male]:
##
## Latent Variables:
##                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   OP =~
##     O1                1.000                               0.410    0.833
##     O2      (.p2.)    0.932    0.036   26.006    0.000    0.382    0.806
##     O3      (.p3.)    1.148    0.040   28.727    0.000    0.471    0.902
##   AG =~
```

```
##     A1                1.000                                0.346    0.689
##     A2       (.p5.)   1.327    0.089   14.919    0.000     0.459    0.993
##     A3       (.p6.)   1.021    0.033   31.242    0.000     0.353    0.744
##   PR =~
##     EP                1.000                                0.552    0.761
##     SP       (.p8.)   0.822    0.049   16.706    0.000     0.454    0.685
##     HP       (.p9.)   1.029    0.114    9.020    0.000     0.568    0.363
##     DP       (.10.)   0.733    0.041   17.857    0.000     0.405    0.748
##
## Regressions:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   PR ~
##     OP        (a1)   -0.620    0.097   -6.403    0.000   -0.461   -0.461
##     AG        (a2)   -0.510    0.108   -4.719    0.000   -0.320   -0.320
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   OP ~~
##     AG                0.059    0.011    5.315    0.000    0.414    0.414
##  .A1 ~~
##    .A3                0.058    0.009    6.338    0.000    0.058    0.502
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##     OP                0.168    0.019    9.083    0.000    1.000    1.000
##     AG                0.120    0.015    7.753    0.000    1.000    1.000
##    .O1       (.17.)   0.074    0.005   14.561    0.000    0.074    0.306
##    .O2       (.18.)   0.079    0.005   15.870    0.000    0.079    0.351
##    .O3       (.19.)   0.051    0.005    9.612    0.000    0.051    0.186
##    .A1       (.20.)   0.132    0.009   14.304    0.000    0.132    0.525
##    .A2       (.21.)   0.003    0.012    0.244    0.807    0.003    0.013
##    .A3       (.22.)   0.101    0.008   11.859    0.000    0.101    0.447
##    .EP       (.23.)   0.221    0.016   14.053    0.000    0.221    0.421
##    .SP       (.24.)   0.233    0.014   16.504    0.000    0.233    0.531
##    .HP       (.25.)   2.133    0.106   20.044    0.000    2.133    0.869
##    .DP       (.26.)   0.129    0.009   14.552    0.000    0.129    0.440
##    .PR                0.172    0.026    6.590    0.000    0.564    0.564
##
## R-Square:
##                    Estimate
##     O1                0.694
##     O2                0.649
##     O3                0.814
##     A1                0.475
##     A2                0.987
##     A3                0.553
##     EP                0.579
##     SP                0.469
##     HP                0.131
##     DP                0.560
##     PR                0.436
##
##
## Group 2 [female]:
```

```
##
## Latent Variables:
##                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   OP =~
##     O1               1.000                               0.394    0.822
##     O2      (.p2.)   0.932    0.036   26.006    0.000    0.367    0.794
##     O3      (.p3.)   1.148    0.040   28.727    0.000    0.452    0.895
##   AG =~
##     A1               1.000                               0.343    0.686
##     A2      (.p5.)   1.327    0.089   14.919    0.000    0.455    0.993
##     A3      (.p6.)   1.021    0.033   31.242    0.000    0.351    0.741
##   PR =~
##     EP               1.000                               0.511    0.736
##     SP      (.p8.)   0.822    0.049   16.706    0.000    0.420    0.656
##     HP      (.p9.)   1.029    0.114    9.020    0.000    0.526    0.339
##     DP      (.10.)   0.733    0.041   17.857    0.000    0.375    0.722
##
## Regressions:
##                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   PR ~
##     OP        (b1)  -0.586    0.060   -9.722    0.000   -0.451   -0.451
##     AG        (b2)  -0.568    0.066   -8.614    0.000   -0.381   -0.381
##
## Covariances:
##                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   OP ~~
##     AG               0.037    0.007    5.683    0.000    0.276    0.276
##  .A1 ~~
##    .A3               0.067    0.008    8.011    0.000    0.067    0.576
##
## Variances:
##                   Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##     OP               0.155    0.012   12.660    0.000    1.000    1.000
##     AG               0.118    0.013    9.258    0.000    1.000    1.000
##    .O1      (.17.)   0.074    0.005   14.561    0.000    0.074    0.324
##    .O2      (.18.)   0.079    0.005   15.870    0.000    0.079    0.370
##    .O3      (.19.)   0.051    0.005    9.612    0.000    0.051    0.199
##    .A1      (.20.)   0.132    0.009   14.304    0.000    0.132    0.529
##    .A2      (.21.)   0.003    0.012    0.244    0.807    0.003    0.014
##    .A3      (.22.)   0.101    0.008   11.859    0.000    0.101    0.450
##    .EP      (.23.)   0.221    0.016   14.053    0.000    0.221    0.459
##    .SP      (.24.)   0.233    0.014   16.504    0.000    0.233    0.569
##    .HP      (.25.)   2.133    0.106   20.044    0.000    2.133    0.885
##    .DP      (.26.)   0.129    0.009   14.552    0.000    0.129    0.478
##    .PR               0.145    0.017    8.743    0.000    0.556    0.556
##
## R-Square:
##                   Estimate
##     O1               0.676
##     O2               0.630
##     O3               0.801
##     A1               0.471
##     A2               0.986
##     A3               0.550
```

```
##     EP                0.541
##     SP                0.431
##     HP                0.115
##     DP                0.522
##     PR                0.444
```

```
# Hypothesis testing
lavTestWald(model5.fit, constraints = "a1==b1")
```

```
## $stat
## [1] 0.0955577
##
## $df
## [1] 1
##
## $p.value
## [1] 0.7572271
##
## $se
## [1] "standard"
```

```
lavTestWald(model5.fit, constraints = "a2==b2")
```

```
## $stat
## [1] 0.2275054
##
## $df
## [1] 1
##
## $p.value
## [1] 0.6333798
##
## $se
## [1] "standard"
```

ADD-ON–Model 6: Multi-group SEM with equal structural parameters

```
# Step 1: Model specification
model6 <- '
            # Measurement models
            OP =~ O1 + O2 + O3
            AG =~ A1 + A2 + A3
            PR =~ EP + SP + HP + DP

            # Covariance structure
            OP ~~ OP + AG
            AG ~~ AG

            # Residual covariance
            A1 ~~ A3

            # Structural model
```

```
            PR ~ OP + AG

'

# Step 2: Model estimation
model6.fit <- sem(model6,
                  data = Bergh,
                  meanstructure = FALSE,
                  estimator = "ML",
                  group = "gender",
                  group.equal = c("loadings",
                                  "residuals",
                                  "regressions"))

# Summary
summary(model6.fit,
        rsquare = TRUE,
        fit.measures = TRUE,
        standardized = TRUE)
```

```
## lavaan 0.6-5 ended normally after 59 iterations
##
##   Estimator                                         ML
##   Optimization method                           NLMINB
##   Number of free parameters                         48
##   Number of equality constraints                    19
##   Row rank of the constraints matrix                19
##
##   Number of observations per group:
##     male                                           249
##     female                                         612
##
## Model Test User Model:
##
##   Test statistic                               209.237
##   Degrees of freedom                                81
##   P-value (Chi-square)                           0.000
##   Test statistic for each group:
##     male                                        83.388
##     female                                     125.849
##
## Model Test Baseline Model:
##
##   Test statistic                              4207.254
##   Degrees of freedom                                90
##   P-value                                        0.000
##
## User Model versus Baseline Model:
##
##   Comparative Fit Index (CFI)                    0.969
##   Tucker-Lewis Index (TLI)                       0.965
##
## Loglikelihood and Information Criteria:
##
```

```
##   Loglikelihood user model (H0)              -5575.924
##   Loglikelihood unrestricted model (H1)      -5471.305
##
##   Akaike (AIC)                               11209.847
##   Bayesian (BIC)                             11347.832
##   Sample-size adjusted Bayesian (BIC)        11255.736
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.061
##   90 Percent confidence interval - lower         0.051
##   90 Percent confidence interval - upper         0.071
##   P-value RMSEA <= 0.05                          0.041
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.067
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard errors                             Standard
##
##
## Group 1 [male]:
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   OP =~
##     O1                1.000                               0.411    0.833
##     O2      (.p2.)    0.932    0.036   26.007    0.000    0.383    0.806
##     O3      (.p3.)    1.148    0.040   28.723    0.000    0.471    0.902
##   AG =~
##     A1                1.000                               0.346    0.690
##     A2      (.p5.)    1.322    0.088   14.987    0.000    0.458    0.991
##     A3      (.p6.)    1.022    0.033   31.242    0.000    0.354    0.745
##   PR =~
##     EP                1.000                               0.554    0.762
##     SP      (.p8.)    0.822    0.049   16.716    0.000    0.456    0.686
##     HP      (.p9.)    1.029    0.114    9.019    0.000    0.570    0.364
##     DP      (.10.)    0.733    0.041   17.855    0.000    0.406    0.749
##
## Regressions:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   PR ~
##     OP      (.15.)   -0.593    0.053  -11.116    0.000   -0.439   -0.439
##     AG      (.16.)   -0.554    0.058   -9.488    0.000   -0.346   -0.346
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   OP ~~
##     AG                0.059    0.011    5.315    0.000    0.414    0.414
##  .A1 ~~
```

```
##    .A3                0.058    0.009    6.303    0.000    0.058    0.500
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##     OP                0.169    0.019    9.099    0.000    1.000    1.000
##     AG                0.120    0.015    7.760    0.000    1.000    1.000
##    .O1       (.17.)   0.074    0.005   14.560    0.000    0.074    0.306
##    .O2       (.18.)   0.079    0.005   15.867    0.000    0.079    0.351
##    .O3       (.19.)   0.051    0.005    9.610    0.000    0.051    0.186
##    .A1       (.20.)   0.132    0.009   14.287    0.000    0.132    0.524
##    .A2       (.21.)   0.004    0.012    0.312    0.755    0.004    0.017
##    .A3       (.22.)   0.100    0.008   11.834    0.000    0.100    0.445
##    .EP       (.23.)   0.221    0.016   14.050    0.000    0.221    0.419
##    .SP       (.24.)   0.233    0.014   16.496    0.000    0.233    0.529
##    .HP       (.25.)   2.133    0.106   20.044    0.000    2.133    0.868
##    .DP       (.26.)   0.129    0.009   14.562    0.000    0.129    0.439
##    .PR                0.172    0.026    6.611    0.000    0.561    0.561
##
## R-Square:
##                    Estimate
##     O1                0.694
##     O2                0.649
##     O3                0.814
##     A1                0.476
##     A2                0.983
##     A3                0.555
##     EP                0.581
##     SP                0.471
##     HP                0.132
##     DP                0.561
##     PR                0.439
##
##
## Group 2 [female]:
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   OP =~
##     O1                1.000                               0.393    0.822
##     O2        (.p2.)  0.932    0.036   26.007    0.000    0.367    0.794
##     O3        (.p3.)  1.148    0.040   28.723    0.000    0.452    0.895
##   AG =~
##     A1                1.000                               0.344    0.688
##     A2        (.p5.)  1.322    0.088   14.987    0.000    0.455    0.991
##     A3        (.p6.)  1.022    0.033   31.242    0.000    0.351    0.743
##   PR =~
##     EP                1.000                               0.511    0.735
##     SP        (.p8.)  0.822    0.049   16.716    0.000    0.420    0.656
##     HP        (.p9.)  1.029    0.114    9.019    0.000    0.525    0.338
##     DP        (.10.)  0.733    0.041   17.855    0.000    0.374    0.722
##
## Regressions:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   PR ~
```

```
##     OP      (.15.)   -0.593    0.053  -11.116    0.000   -0.457   -0.457
##     AG      (.16.)   -0.554    0.058   -9.488    0.000   -0.374   -0.374
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   OP ~~
##     AG                0.038    0.007    5.698    0.000    0.277    0.277
##  .A1 ~~
##    .A3                0.066    0.008    7.978    0.000    0.066    0.575
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##     OP                0.155    0.012   12.667    0.000    1.000    1.000
##     AG                0.118    0.013    9.279    0.000    1.000    1.000
##    .O1      (.17.)    0.074    0.005   14.560    0.000    0.074    0.324
##    .O2      (.18.)    0.079    0.005   15.867    0.000    0.079    0.370
##    .O3      (.19.)    0.051    0.005    9.610    0.000    0.051    0.199
##    .A1      (.20.)    0.132    0.009   14.287    0.000    0.132    0.527
##    .A2      (.21.)    0.004    0.012    0.312    0.755    0.004    0.017
##    .A3      (.22.)    0.100    0.008   11.834    0.000    0.100    0.448
##    .EP      (.23.)    0.221    0.016   14.050    0.000    0.221    0.459
##    .SP      (.24.)    0.233    0.014   16.496    0.000    0.233    0.569
##    .HP      (.25.)    2.133    0.106   20.044    0.000    2.133    0.885
##    .DP      (.26.)    0.129    0.009   14.562    0.000    0.129    0.479
##    .PR                0.145    0.017    8.747    0.000    0.557    0.557
##
## R-Square:
##                    Estimate
##     O1                0.676
##     O2                0.630
##     O3                0.801
##     A1                0.473
##     A2                0.983
##     A3                0.552
##     EP                0.541
##     SP                0.431
##     HP                0.115
##     DP                0.521
##     PR                0.443
```

```
# Model comparison
anova(model5.fit, model6.fit)
```

```
## Chi-Squared Difference Test
##
##            Df   AIC   BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## model5.fit 79 11214 11361 209.00
## model6.fit 81 11210 11348 209.24     0.2392       2     0.8873
```

R session info

```
sessionInfo()
```

```
## R version 3.6.3 (2020-02-29)
## Platform: x86_64-apple-darwin15.6.0 (64-bit)
## Running under: macOS Sierra 10.12.6
##
## Matrix products: default
## BLAS:   /Library/Frameworks/R.framework/Versions/3.6/Resources/lib/libRblas.0.dylib
## LAPACK: /Library/Frameworks/R.framework/Versions/3.6/Resources/lib/libRlapack.dylib
##
## locale:
## [1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8
##
## attached base packages:
## [1] stats     graphics  grDevices utils     datasets  methods   base
##
## other attached packages:
## [1] corrplot_0.84   MPsychoR_0.10-7 semPlot_1.1.2   lavaan_0.6-5
##
## loaded via a namespace (and not attached):
##   [1] nlme_3.1-144        RColorBrewer_1.1-2  mi_1.0
##   [4] tools_3.6.3         backports_1.1.6     R6_2.4.1
##   [7] d3Network_0.5.2.1   rpart_4.1-15        Hmisc_4.3-1
##  [10] colorspace_1.4-1    nnet_7.3-12         tidyselect_1.0.0
##  [13] gridExtra_2.3       mnormt_1.5-7        compiler_3.6.3
##  [16] qgraph_1.6.5        fdrtool_1.2.15      htmlTable_1.13.3
##  [19] regsem_1.5.2        scales_1.1.0        checkmate_2.0.0
##  [22] psych_1.9.12.31     pbapply_1.4-2       sem_3.1-9
##  [25] stringr_1.4.0       digest_0.6.25       pbivnorm_0.6.0
##  [28] foreign_0.8-75      minqa_1.2.4         rmarkdown_2.1
##  [31] base64enc_0.1-3     jpeg_0.1-8.1        pkgconfig_2.0.3
##  [34] htmltools_0.4.0     lme4_1.1-23         lisrelToR_0.1.4
##  [37] htmlwidgets_1.5.1   rlang_0.4.6         huge_1.3.4
##  [40] rstudioapi_0.11     gtools_3.8.1        acepack_1.4.1
##  [43] dplyr_0.8.5         zip_2.0.4           magrittr_1.5
##  [46] OpenMx_2.17.3       Formula_1.2-3       Matrix_1.2-18
##  [49] Rcpp_1.0.4.6        munsell_0.5.0       abind_1.4-5
##  [52] rockchalk_1.8.144   lifecycle_0.2.0     whisker_0.4
##  [55] stringi_1.4.6       yaml_2.2.1          carData_3.0-3
##  [58] MASS_7.3-51.5       plyr_1.8.6          matrixcalc_1.0-3
##  [61] grid_3.6.3          parallel_3.6.3      crayon_1.3.4
##  [64] lattice_0.20-40     kutils_1.69         splines_3.6.3
##  [67] knitr_1.28          pillar_1.4.3        igraph_1.2.5
##  [70] rjson_0.2.20        boot_1.3-24         corpcor_1.6.9
##  [73] BDgraph_2.62        codetools_0.2-16    reshape2_1.4.4
##  [76] stats4_3.6.3        XML_3.99-0.3        glue_1.4.0
##  [79] evaluate_0.14       latticeExtra_0.6-29 data.table_1.12.8
##  [82] png_0.1-7           vctrs_0.2.4         nloptr_1.2.2.1
##  [85] gtable_0.3.0        purrr_0.3.4         assertthat_0.2.1
##  [88] ggplot2_3.3.0       xfun_0.13           openxlsx_4.1.4
##  [91] xtable_1.8-4        coda_0.19-3         Rsolnp_1.16
```

```
##  [94] survival_3.1-8      glasso_1.11         truncnorm_1.0-8
##  [97] tibble_3.0.1        arm_1.10-1          cluster_2.1.0
## [100] statmod_1.4.34      ellipsis_0.3.0
```