A Mild Introduction to Structural Equation Modeling Using

lavaan

### UseR! Oslo Group Workshop 28 May 2020

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# 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")

*# 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) Standard errors | | | model | Structured Standard | | | |
| ##  ## ## ## | Regressions: Prejudice ~ |  | Estimate | Std.Err | z-value | P(>|z|) | Std.lv | Std.all |
| ## | 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

*# 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)

Chart, line chart

Description automatically generated

*# 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 |

*# 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)

Chart

Description automatically generated

# Model 3: Measurement model (CFA)

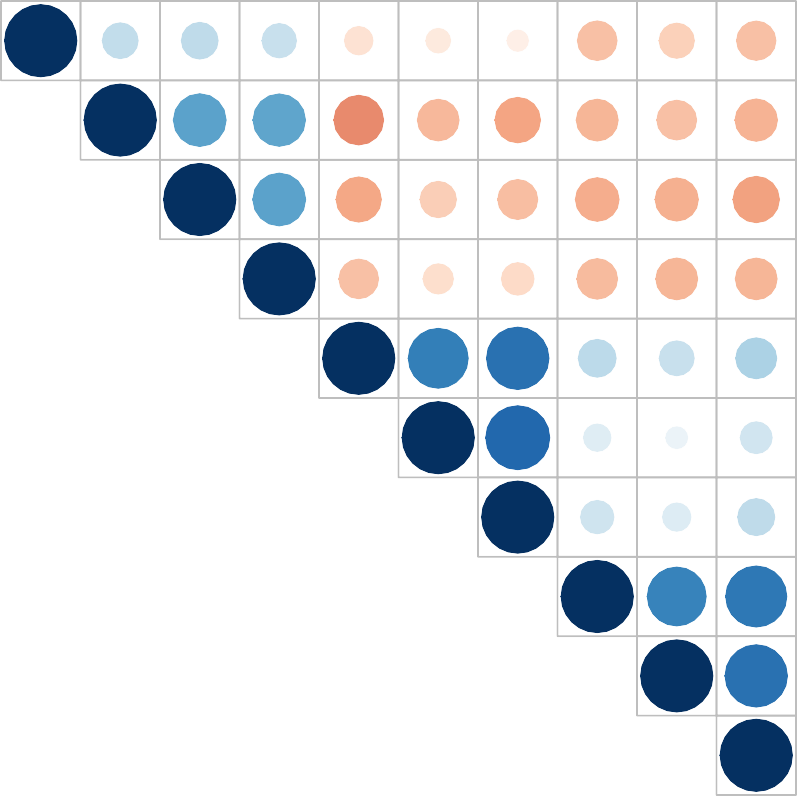
## Correlation matrix

*# 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 | | | | | | | |
| *# 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) | | | | | | | | | | | | | |
| HP | **1** | | **0.24** | **0.25** | **0.22** | **−0.15** | **−0.11** | **−0.08** | **−0.3** | **−0.23** | **−0.29** |  | 1 |
|  | DP | | **1** | **0.53** | **0.53** | **−0.47** | **−0.33** | **−0.39** | **−0.33** | **−0.3** | **−0.34** |  | 0.8 |
|  |  | | EP | **1** | **0.53** | **−0.39** | **−0.25** | **−0.3** | **−0.36** | **−0.35** | **−0.41** |  | 0.6 |
|  |  | |  | SP | **1** | **−0.3** | **−0.17** | **−0.2** | **−0.31** | **−0.33** | **−0.33** |  | 0.4 |
|  |  | |  |  | A2 | **1** | **0.69** | **0.75** | **0.27** | **0.23** | **0.32** |  | 0.2 |
|  |  | |  |  |  | A1 | **1** | **0.78** | **0.14** | **0.09** | **0.19** |  | 0 |
|  |  | |  |  |  |  | A3 | **1** | **0.21** | **0.15** | **0.26** |  | −0.2 |
|  |  | |  |  |  |  |  | O2 | **1** | **0.66** | **0.71** |  | −0.4 |
|  |  | |  |  |  |  |  |  | O1 | **1** | **0.74** |  | −0.6 |
|  |  | |  |  |  |  |  |  |  | O3 | **1** |  | −0.8 |
|  |  | |  |  |  |  |  |  |  |  |  |  | −1 |

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?

HP

DP

EP

SP

A2

A1

A3

O2

O1

O3

## Specifying, estimating, and evaluating the model

*# 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) Standard errors | | model | Structured 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  Covariances: | 0.746 | 0.041 | 18.308 | 0.000 | 0.395 | 0.741 |
| ## 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 |

*# 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)

Diagram

Description automatically generated

# 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) Standard errors | | | model | Structured 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  Regressions: | 0.750 | | 0.040 | 18.535 | 0.000 | 0.397 | 0.744 |
| ## | | | 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  Covariances: | (b2) | -0.595 | 0.058 | -10.172 | 0.000 | -0.390 | -0.390 |
| ## | | | 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 |

*# 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)

Diagram, schematic

Description automatically generated

*## 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 <- 1

# 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

1

*# 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  Covariances: | (a2) | -0.510 | 0.108 | -4.719 | 0.000 | -0.320 | -0.320 |
| ## 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 pa- rameters

*# Step 1: Model specification*

model6 <- 1

# 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

1

*# 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 ##  ## Variances: | | | 0.058 | 0.009 | 6.303 | 0.000 | 0.058 | 0.500 |
| ## 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  ## OP =~  ## O1 1.000 | | | | Std.Err | z-value | P(>|z|) | Std.lv  0.393 | Std.all  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 |  |