Structural Equation Modeling

P.13 - Common Method Bias

06.12.2021

Lab Description

In this assignment you will learn how to fit *Structural Equation Models* (SEM) while accounting for *Common Method Bias*. For this practical you will need the following packages: `lavaan`, `semPlot`, and `haven`. You can install and load these packages using the following code:

```r
# Install packages.
install.packages(c("lavaan", "semPlot", "haven"))

# Load the packages.
library(lavaan)
library(semPlot)
library(haven)
```

Please note that the data for following assignment are kindly provided by dr. Pieter de Rooij from *Breda University of Applied Sciences*. We acquired permission to use the data in the course *Research Master: Structural Equation Modeling and Analysis of Longitudinal Data*. Should you want to use the data outside the scope of this course, please make sure to obtain written approval from dr. Pieter de Rooij (at rooy.h@buas.nl).

More about the data

This dataset contains 27 items that seek to measure 9 dimensions (i.e., constructs) of visitors' experiences when they attend a performance in the performing arts sector (e.g., drama, dance, musical, stand up comedy, opera, classical music). Each construct is indicated by 3 items as shown in *Table 1*. Scales were rated on 5 point *Likert* scales (i.e. from 1 = totally disagree to 5 = totally agree).

Table 1: Latent constructs and manifest variables in `data.sav`.

Dimensions	Variable	Item text
Artistic value	artval1	The concert/ show had artistic value.
	artval2	The concert/ show was a form of art.
	artval3	The concert/ show was of a high artistic level.
Beauty	beauty1	The concert/ how was beautiful.
	beauty2	I enjoyed the concert/ show.
	beauty3	The concert/ how was a beautiful experience.
Cultural relaxation	relax1	Through my visit to the concert/ show I had a nice evening out.
	relax2	Through my visit to the concert/ show I had the feeling I was away from it all.
	relax3	Through my visit to the concert/ show I have been able to relax.
Cultural stimulation	stim1	Through my visit to the concert/ show I got food for thought.
	stim2	Through my visit to the concert/ show I felt intellectually stimulated.
	stim3	Through my visit to the concert/ show I have been challenged to think about certain things.
Cultural transmission	trans1	Through my visit to the concert/ show I transmitted my cultural interests to important others (children, grandchildren, family, friends.)
	trans2	Through my visit to the concert/ show I have shared my cultural interests with important others (children, grandchildren, family, friends.)
	trans3	Through my visit to the concert/ show I have brought people that are important to me into contact with this form of art.
Social attraction	attr1	During my visit to the concert/ show I was with people that like the same things as I do.
	attr2	During my visit to the concert/ show I had the feeling I was with like-minded people.
	attr3	During my visit to the concert/ show I was with people that have similar interests as me.
Social bonding	bond1	My visit to the concert/ show was a nice opportunity to be together with family and friends.
	bond2	Through my visit to the concert/ show I had a nice evening out with family or friends.
	bond3	Through my visit to the concert/ show I have been able to strengthen the bonds with family or friends.
Social distinction	dist1	My visit to the concert/ show is a good topic for conversation at drinks or other social activities.
	dist2	I like to tell other people how I experienced the concert/ show.
	dist3	People in my social environment appreciate a visit to this concert/ show.

Table 1 – continued

Dimensions	Variable	Item text
Social duty	duty1	Through my visit to the concert/ show I spent a pleasant time with colleagues or business relations.
	duty2	Through my visit to the concert/ show I met interesting people from my professional network.
	duty3	Through my visit to the concert/ show I strengthened my professional network.

Questions

Start by loading the *SPSS* dataset `data.sav` into `R` using the `haven` package.

- *Hint.* Check out the `read_spss` function from the `R` package `haven`.

Set the working directory to the location where your data file has been downloaded and load the data.

```r
# For example.
setwd("/Users/mihai/Downloads")

# Load data.
data <- read_spss("data.sav")

# Inspect the data.
View(data)
```

List the variables.

```r
# List variables.
str(data)
```

Specify which fit measures we are interested in:

```r
# Fit indices to print.
fit_indices <- c("chisq", "df", "pvalue", "cfi", "tli", "rmsea", "rmsea.pvalue", "srmr")
```

1. Estimate a *CFA* model for the 9 constructs. Evaluate the fit of this model.

```r
# Model syntax.
model_q_1 <- "
    # Measurement part.
    artval  =~ exp_artval1 + exp_artval2 + exp_artval3
    attr    =~ exp_attr1   + exp_attr2   + exp_attr3
    beaty   =~ exp_beauty1 + exp_beauty2 + exp_beauty3
    bond    =~ exp_bond1   + exp_bond2   + exp_bond3
    dist    =~ exp_dist1   + exp_dist2   + exp_dist3
    duty    =~ exp_duty1   + exp_duty2   + exp_duty3
    esc     =~ exp_esc1    + exp_esc2    + exp_esc3
    stim    =~ exp_stim1   + exp_stim2   + exp_stim3
    trans   =~ exp_trans1  + exp_trans2  + exp_trans3
"
```

```
# Fit model.
model_q_1_fit <- cfa(model_q_1, data = data)

# Visualize the model.
semPaths(
    model_q_1_fit,
    what = "path",
    whatLabels = "omit",
    sizeMan = 6.5,
    sizeLat = 6,
    style = "lisrel",
    layout = "spring",
    mar = c(1.5, 1.5, 1.5, 1.5)
)
```
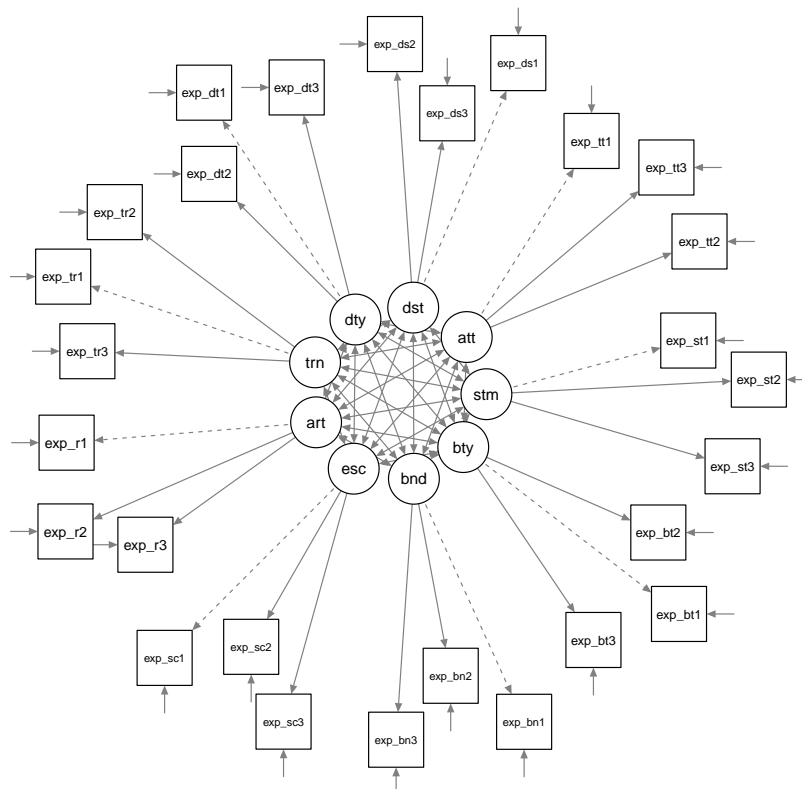


```
# Model summary.
summary(model_q_1_fit, standardized = TRUE)
```

```
## lavaan 0.6-9 ended normally after 100 iterations
##
##   Estimator                                         ML
##   Optimization method                           NLMINB
##   Number of model parameters                        90
##
##   Number of observations                           646
##
## Model Test User Model:
##
```

```
##   Test statistic                              1226.111
##   Degrees of freedom                               288
##   P-value (Chi-square)                           0.000
##
## Parameter Estimates:
##
##   Standard errors                           Standard
##   Information                               Expected
##   Information saturated (h1) model        Structured
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   artval =~
##     exp_artval1       1.000                               0.981    0.898
##     exp_artval2       0.896    0.031   29.289    0.000    0.879    0.839
##     exp_artval3       1.109    0.032   34.305    0.000    1.088    0.907
##   attr =~
##     exp_attr1         1.000                               0.468    0.551
##     exp_attr2         1.400    0.117   11.950    0.000    0.655    0.657
##     exp_attr3         1.622    0.146   11.081    0.000    0.760    0.583
##   beaty =~
##     exp_beauty1       1.000                               0.901    0.885
##     exp_beauty2       0.925    0.028   33.354    0.000    0.833    0.898
##     exp_beauty3       0.933    0.027   34.827    0.000    0.841    0.916
##   bond =~
##     exp_bond1         1.000                               0.868    0.780
##     exp_bond2         0.754    0.043   17.721    0.000    0.654    0.711
##     exp_bond3         1.042    0.057   18.153    0.000    0.905    0.727
##   dist =~
##     exp_dist1         1.000                               0.662    0.678
##     exp_dist2         0.919    0.061   15.030    0.000    0.608    0.736
##     exp_dist3         0.663    0.060   11.097    0.000    0.439    0.508
##   duty =~
##     exp_duty1         1.000                               0.576    0.422
##     exp_duty2         1.615    0.161   10.059    0.000    0.930    0.837
##     exp_duty3         1.628    0.162   10.042    0.000    0.938    0.850
##   esc =~
##     exp_esc1          1.000                               0.499    0.603
##     exp_esc2          1.168    0.082   14.281    0.000    0.583    0.721
##     exp_esc3          1.299    0.083   15.620    0.000    0.649    0.839
##   stim =~
##     exp_stim1         1.000                               0.768    0.678
##     exp_stim2         1.270    0.073   17.408    0.000    0.975    0.830
##     exp_stim3         1.218    0.073   16.786    0.000    0.936    0.782
##   trans =~
##     exp_trans1        1.000                               0.829    0.667
##     exp_trans2        1.039    0.064   16.311    0.000    0.861    0.762
##     exp_trans3        1.239    0.075   16.410    0.000    1.027    0.768
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
```

5

```
##    artval ~~
##       attr          0.179    0.027     6.632    0.000    0.390    0.390
##       beaty         0.712    0.050    14.176    0.000    0.805    0.805
##       bond          0.189    0.041     4.670    0.000    0.222    0.222
##       dist          0.228    0.034     6.614    0.000    0.351    0.351
##       duty          0.101    0.027     3.701    0.000    0.179    0.179
##       esc           0.251    0.028     8.896    0.000    0.512    0.512
##       stim          0.476    0.045    10.634    0.000    0.632    0.632
##       trans         0.398    0.045     8.890    0.000    0.489    0.489
##    attr ~~
##       beaty         0.191    0.026     7.443    0.000    0.453    0.453
##       bond          0.316    0.033     9.652    0.000    0.778    0.778
##       dist          0.269    0.028     9.490    0.000    0.866    0.866
##       duty          0.136    0.021     6.374    0.000    0.505    0.505
##       esc           0.145    0.018     8.010    0.000    0.620    0.620
##       stim          0.228    0.027     8.416    0.000    0.635    0.635
##       trans         0.315    0.034     9.351    0.000    0.812    0.812
##    beaty ~~
##       bond          0.333    0.040     8.364    0.000    0.426    0.426
##       dist          0.291    0.034     8.627    0.000    0.489    0.489
##       duty          0.055    0.024     2.321    0.020    0.107    0.107
##       esc           0.347    0.031    11.061    0.000    0.772    0.772
##       stim          0.334    0.037     8.948    0.000    0.482    0.482
##       trans         0.355    0.041     8.712    0.000    0.475    0.475
##    bond ~~
##       dist          0.401    0.039    10.186    0.000    0.698    0.698
##       duty          0.149    0.029     5.198    0.000    0.298    0.298
##       esc           0.315    0.031    10.138    0.000    0.726    0.726
##       stim          0.239    0.036     6.628    0.000    0.359    0.359
##       trans         0.565    0.051    11.043    0.000    0.785    0.785
##    dist ~~
##       duty          0.148    0.025     5.893    0.000    0.389    0.389
##       esc           0.224    0.024     9.151    0.000    0.677    0.677
##       stim          0.307    0.034     8.986    0.000    0.604    0.604
##       trans         0.387    0.040     9.686    0.000    0.705    0.705
##    duty ~~
##       esc           0.041    0.015     2.827    0.005    0.143    0.143
##       stim          0.179    0.029     6.270    0.000    0.405    0.405
##       trans         0.228    0.034     6.733    0.000    0.477    0.477
##    esc ~~
##       stim          0.184    0.024     7.800    0.000    0.479    0.479
##       trans         0.234    0.028     8.493    0.000    0.566    0.566
##    stim ~~
##       trans         0.429    0.044     9.733    0.000    0.674    0.674
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)  Std.lv   Std.all
##    .exp_artval1     0.232    0.019    12.126    0.000    0.232    0.194
##    .exp_artval2     0.326    0.022    14.727    0.000    0.326    0.297
##    .exp_artval3     0.254    0.022    11.444    0.000    0.254    0.177
##    .exp_attr1       0.503    0.031    16.120    0.000    0.503    0.697
```

6

```
##    .exp_attr2        0.565    0.040   14.291   0.000    0.565    0.568
##    .exp_attr3        1.123    0.071   15.716   0.000    1.123    0.660
##    .exp_beauty1      0.226    0.016   13.764   0.000    0.226    0.217
##    .exp_beauty2      0.167    0.013   13.085   0.000    0.167    0.194
##    .exp_beauty3      0.135    0.011   11.810   0.000    0.135    0.160
##    .exp_bond1        0.484    0.037   13.136   0.000    0.484    0.391
##    .exp_bond2        0.419    0.028   14.902   0.000    0.419    0.495
##    .exp_bond3        0.732    0.050   14.584   0.000    0.732    0.472
##    .exp_dist1        0.514    0.036   14.192   0.000    0.514    0.540
##    .exp_dist2        0.312    0.025   12.494   0.000    0.312    0.458
##    .exp_dist3        0.553    0.033   16.510   0.000    0.553    0.742
##    .exp_duty1        1.531    0.089   17.254   0.000    1.531    0.822
##    .exp_duty2        0.371    0.048    7.797   0.000    0.371    0.300
##    .exp_duty3        0.338    0.047    7.131   0.000    0.338    0.277
##    .exp_esc1         0.436    0.027   16.447   0.000    0.436    0.636
##    .exp_esc2         0.314    0.021   15.007   0.000    0.314    0.480
##    .exp_esc3         0.177    0.016   10.915   0.000    0.177    0.296
##    .exp_stim1        0.695    0.045   15.381   0.000    0.695    0.541
##    .exp_stim2        0.431    0.039   11.048   0.000    0.431    0.312
##    .exp_stim3        0.554    0.043   12.996   0.000    0.554    0.388
##    .exp_trans1       0.860    0.055   15.639   0.000    0.860    0.556
##    .exp_trans2       0.537    0.039   13.779   0.000    0.537    0.420
##    .exp_trans3       0.734    0.054   13.597   0.000    0.734    0.410
##     artval           0.962    0.067   14.433   0.000    1.000    1.000
##     attr             0.219    0.032    6.857   0.000    1.000    1.000
##     beaty            0.812    0.057   14.163   0.000    1.000    1.000
##     bond             0.753    0.068   11.049   0.000    1.000    1.000
##     dist             0.438    0.050    8.797   0.000    1.000    1.000
##     duty             0.332    0.064    5.178   0.000    1.000    1.000
##     esc              0.249    0.031    7.967   0.000    1.000    1.000
##     stim             0.590    0.064    9.143   0.000    1.000    1.000
##     trans            0.688    0.077    8.984   0.000    1.000    1.000
```

```
# Fit measures.
fitMeasures(model_q_1_fit, fit.measures = fit_indices)
```

```
##        chisq         df      pvalue         cfi         tli    rmsea rmsea.pvalue
##     1226.111    288.000       0.000       0.906       0.885    0.071        0.000
##         srmr
##        0.059
```

2. Estimate a *CFA* model for the 9 constructs together with a *method factor* to control for potential *common method bias*. Model the *common method variance* with a single *latent method variable*. Implement equality constraints on the loadings of the method factor and also implement the necessary constraints for the associations between method and content factors.

```
# Model syntax.
model_q_2 <- "
    # Measurement part.
    artval  =~ exp_artval1 + exp_artval2 + exp_artval3
    attr    =~ exp_attr1   + exp_attr2   + exp_attr3
    beaty   =~ exp_beauty1 + exp_beauty2 + exp_beauty3
```

```
    bond    =~ exp_bond1   + exp_bond2   + exp_bond3
    dist    =~ exp_dist1   + exp_dist2   + exp_dist3
    duty    =~ exp_duty1   + exp_duty2   + exp_duty3
    esc     =~ exp_esc1    + exp_esc2    + exp_esc3
    stim    =~ exp_stim1   + exp_stim2   + exp_stim3
    trans   =~ exp_trans1  + exp_trans2  + exp_trans3

    # Common method variance latent variable with constrained loadings.
    cmv =~ NA * exp_artval1 +
            a * exp_artval1 + a * exp_artval2 + a * exp_artval3 +
            a * exp_attr1   + a * exp_attr2   + a * exp_attr3 +
            a * exp_beauty1 + a * exp_beauty2 + a * exp_beauty3 +
            a * exp_bond1   + a * exp_bond2   + a * exp_bond3 +
            a * exp_dist1   + a * exp_dist2   + a * exp_dist3 +
            a * exp_duty1   + a * exp_duty2   + a * exp_duty3 +
            a * exp_esc1    + a * exp_esc2    + a * exp_esc3 +
            a * exp_stim1   + a * exp_stim2   + a * exp_stim3 +
            a * exp_trans1  + a * exp_trans2  + a * exp_trans3

    # Fix variance of the `cmv` latent variable.
    cmv ~~ 1 * cmv

    # Fix covariances between the `cmv` and the other latent variables.
    artval ~~ 0 * cmv
    attr   ~~ 0 * cmv
    beaty  ~~ 0 * cmv
    bond   ~~ 0 * cmv
    dist   ~~ 0 * cmv
    duty   ~~ 0 * cmv
    esc    ~~ 0 * cmv
    stim   ~~ 0 * cmv
    trans  ~~ 0 * cmv
"

# Fit model.
model_q_2_fit <- cfa(model_q_2, data = data)

# Visualize the model.
semPaths(
    model_q_2_fit,
    what = "path",
    whatLabels = "omit",
    sizeMan = 6.5,
    sizeLat = 6,
    style = "lisrel",
    layout = "spring",
    mar = c(1.5, 1.5, 1.5, 1.5)
)
```
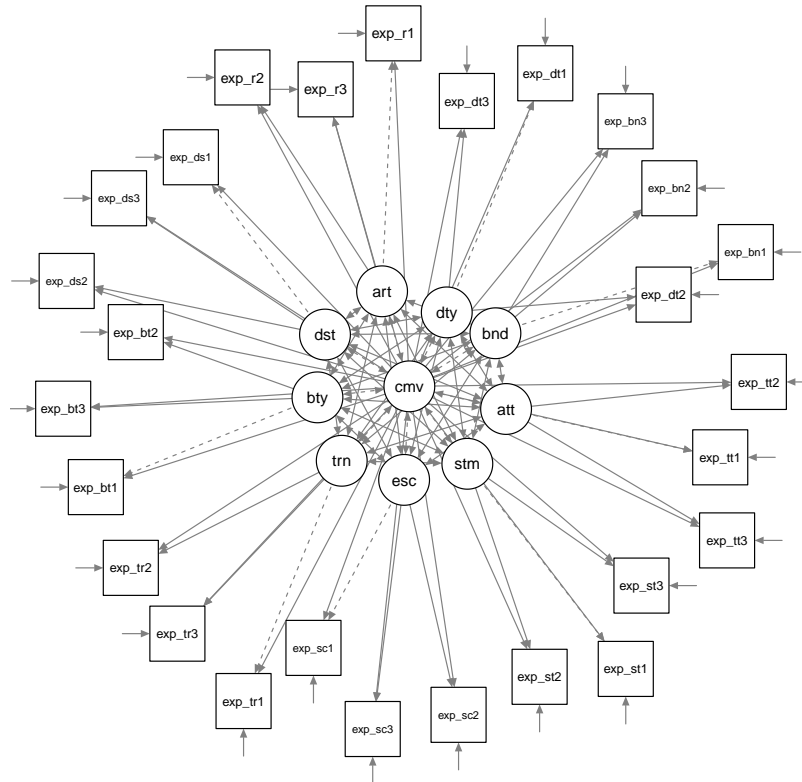
```r
# Regular tree layout.
semPaths(
    model_q_2_fit,
    what = "path",
    whatLabels = "omit",
    sizeMan = 3,
    sizeLat = 6,
    style = "lisrel",
    mar = c(1.5, 1.5, 1.5, 1.5)
)
```
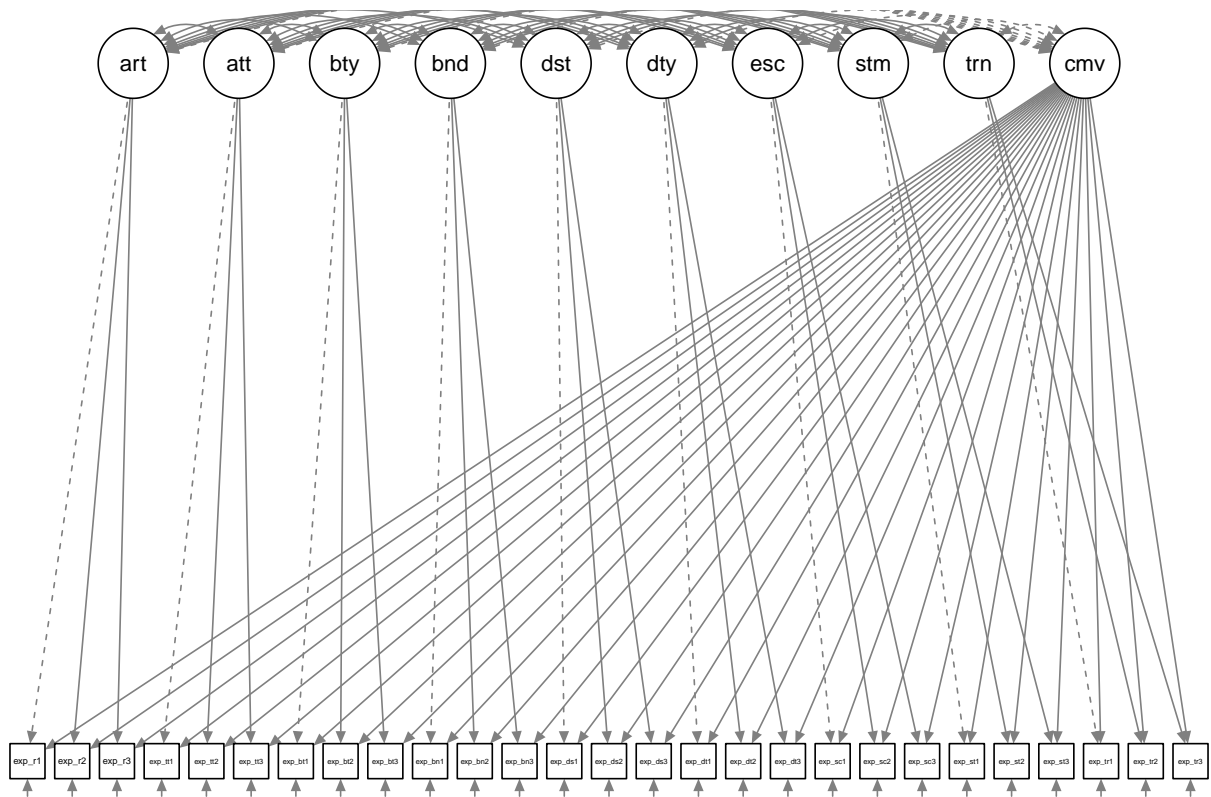
```
# Model summary.
summary(model_q_2_fit, standardized = TRUE)
```

```
## lavaan 0.6-9 ended normally after 188 iterations
##
##   Estimator                                      ML
##   Optimization method                        NLMINB
##   Number of model parameters                    117
##   Number of equality constraints                 26
##
##   Number of observations                        646
##
## Model Test User Model:
##
##   Test statistic                           1149.239
##   Degrees of freedom                            287
##   P-value (Chi-square)                        0.000
##
## Parameter Estimates:
##
##   Standard errors                          Standard
##   Information                              Expected
##   Information saturated (h1) model       Structured
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   artval =~
```

```
##     exp_artvl1       1.000                           0.899   0.793
##     exp_artvl2       0.930   0.036   26.106   0.000   0.835   0.740
##     exp_artvl3       1.106   0.037   29.591   0.000   0.994   0.814
##   attr =~
##     exp_attr1        1.000                           0.159   0.182
##     exp_attr2        1.839   0.506    3.631   0.000   0.293   0.303
##     exp_attr3        5.523   1.547    3.570   0.000   0.880   0.663
##   beaty =~
##     exp_beaty1       1.000                           0.767   0.746
##     exp_beaty2       0.867   0.034   25.174   0.000   0.665   0.718
##     exp_beaty3       0.926   0.034   26.960   0.000   0.711   0.757
##   bond =~
##     exp_bond1        1.000                           0.568   0.549
##     exp_bond2        0.490   0.068    7.211   0.000   0.279   0.320
##     exp_bond3        1.280   0.123   10.441   0.000   0.727   0.614
##   dist =~
##     exp_dist1        1.000                           0.409   0.426
##     exp_dist2        1.048   0.192    5.461   0.000   0.429   0.513
##     exp_dist3        0.419   0.123    3.412   0.001   0.171   0.186
##   duty =~
##     exp_duty1        1.000                           0.469   0.335
##     exp_duty2        1.966   0.242    8.125   0.000   0.922   0.766
##     exp_duty3        1.926   0.237    8.134   0.000   0.904   0.762
##   esc =~
##     exp_esc1         1.000                           0.090   0.110
##     exp_esc2         2.769   1.090    2.541   0.011   0.248   0.313
##     exp_esc3         5.779   2.365    2.443   0.015   0.518   0.668
##   stim =~
##     exp_stim1        1.000                           0.552   0.492
##     exp_stim2        1.615   0.131   12.281   0.000   0.891   0.740
##     exp_stim3        1.640   0.134   12.210   0.000   0.905   0.725
##   trans =~
##     exp_trans1       1.000                           0.666   0.541
##     exp_trans2       0.845   0.080   10.531   0.000   0.563   0.521
##     exp_trans3       1.457   0.126   11.566   0.000   0.970   0.737
##   cmv =~
##     exp_artvl1 (a)   0.495   0.018   27.018   0.000   0.495   0.437
##     exp_artvl2 (a)   0.495   0.018   27.018   0.000   0.495   0.438
##     exp_artvl3 (a)   0.495   0.018   27.018   0.000   0.495   0.405
##     exp_attr1  (a)   0.495   0.018   27.018   0.000   0.495   0.564
##     exp_attr2  (a)   0.495   0.018   27.018   0.000   0.495   0.512
##     exp_attr3  (a)   0.495   0.018   27.018   0.000   0.495   0.373
##     exp_beaty1 (a)   0.495   0.018   27.018   0.000   0.495   0.481
##     exp_beaty2 (a)   0.495   0.018   27.018   0.000   0.495   0.534
##     exp_beaty3 (a)   0.495   0.018   27.018   0.000   0.495   0.527
##     exp_bond1  (a)   0.495   0.018   27.018   0.000   0.495   0.478
##     exp_bond2  (a)   0.495   0.018   27.018   0.000   0.495   0.568
##     exp_bond3  (a)   0.495   0.018   27.018   0.000   0.495   0.418
##     exp_dist1  (a)   0.495   0.018   27.018   0.000   0.495   0.515
##     exp_dist2  (a)   0.495   0.018   27.018   0.000   0.495   0.592
##     exp_dist3  (a)   0.495   0.018   27.018   0.000   0.495   0.538
```

```
##      exp_duty1  (a)    0.495    0.018   27.018    0.000    0.495    0.354
##      exp_duty2  (a)    0.495    0.018   27.018    0.000    0.495    0.411
##      exp_duty3  (a)    0.495    0.018   27.018    0.000    0.495    0.417
##      exp_esc1   (a)    0.495    0.018   27.018    0.000    0.495    0.607
##      exp_esc2   (a)    0.495    0.018   27.018    0.000    0.495    0.624
##      exp_esc3   (a)    0.495    0.018   27.018    0.000    0.495    0.638
##      exp_stim1  (a)    0.495    0.018   27.018    0.000    0.495    0.441
##      exp_stim2  (a)    0.495    0.018   27.018    0.000    0.495    0.412
##      exp_stim3  (a)    0.495    0.018   27.018    0.000    0.495    0.397
##      exp_trans1 (a)    0.495    0.018   27.018    0.000    0.495    0.402
##      exp_trans2 (a)    0.495    0.018   27.018    0.000    0.495    0.458
##      exp_trans3 (a)    0.495    0.018   27.018    0.000    0.495    0.376
##
## Covariances:
##                   Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##    artval ~~
##      cmv             0.000                              0.000    0.000
##    attr ~~
##      cmv             0.000                              0.000    0.000
##    beaty ~~
##      cmv             0.000                              0.000    0.000
##    bond ~~
##      cmv             0.000                              0.000    0.000
##    dist ~~
##      cmv             0.000                              0.000    0.000
##    duty ~~
##      cmv             0.000                              0.000    0.000
##    esc ~~
##      cmv             0.000                              0.000    0.000
##    stim ~~
##      cmv             0.000                              0.000    0.000
##    trans ~~
##      cmv             0.000                              0.000    0.000
##    artval ~~
##      attr            0.031    0.013    2.318    0.020    0.214    0.214
##      beaty           0.529    0.046   11.471    0.000    0.766    0.766
##      bond           -0.101    0.032   -3.156    0.002   -0.198   -0.198
##      dist            0.028    0.027    1.027    0.304    0.076    0.076
##      duty            0.034    0.022    1.512    0.131    0.080    0.080
##      esc             0.029    0.014    2.097    0.036    0.364    0.364
##      stim            0.266    0.036    7.456    0.000    0.536    0.536
##      trans           0.171    0.037    4.675    0.000    0.287    0.287
##    attr ~~
##      beaty           0.008    0.009    0.881    0.378    0.064    0.064
##      bond            0.036    0.013    2.664    0.008    0.393    0.393
##      dist            0.028    0.011    2.434    0.015    0.421    0.421
##      duty            0.037    0.013    2.857    0.004    0.489    0.489
##      esc            -0.000    0.001   -0.305    0.760   -0.024   -0.024
##      stim            0.042    0.014    2.944    0.003    0.472    0.472
##      trans           0.062    0.020    3.061    0.002    0.584    0.584
##    beaty ~~
```

```
##      bond          -0.031    0.028   -1.099   0.272   -0.072   -0.072
##      dist           0.034    0.025    1.381   0.167    0.109    0.109
##      duty          -0.031    0.019   -1.599   0.110   -0.086   -0.086
##      esc            0.043    0.019    2.206   0.027    0.623    0.623
##      stim           0.126    0.027    4.744   0.000    0.298    0.298
##      trans          0.096    0.031    3.092   0.002    0.189    0.189
##   bond ~~
##      dist           0.036    0.023    1.609   0.108    0.156    0.156
##      duty           0.018    0.018    1.006   0.314    0.067    0.067
##      esc            0.006    0.005    1.143   0.253    0.111    0.111
##      stim           0.004    0.021    0.210   0.834    0.014    0.014
##      trans          0.237    0.036    6.526   0.000    0.625    0.625
##   dist ~~
##      duty           0.039    0.017    2.329   0.020    0.203    0.203
##      esc            0.002    0.004    0.659   0.510    0.067    0.067
##      stim           0.091    0.023    3.937   0.000    0.403    0.403
##      trans          0.100    0.028    3.600   0.000    0.366    0.366
##   duty ~~
##      esc           -0.008    0.004   -1.987   0.047   -0.195   -0.195
##      stim           0.080    0.019    4.198   0.000    0.309    0.309
##      trans          0.111    0.025    4.471   0.000    0.357    0.357
##   esc ~~
##      stim           0.008    0.005    1.561   0.118    0.156    0.156
##      trans          0.005    0.005    1.021   0.307    0.083    0.083
##   stim ~~
##      trans          0.184    0.030    6.047   0.000    0.502    0.502
##
## Variances:
##                   Estimate  Std.Err  z-value  P(>|z|)  Std.lv  Std.all
##      cmv            1.000                              1.000    1.000
##     .exp_artval1    0.233    0.019   12.067   0.000    0.233    0.181
##     .exp_artval2    0.332    0.023   14.474   0.000    0.332    0.260
##     .exp_artval3    0.259    0.023   11.446   0.000    0.259    0.174
##     .exp_attr1      0.499    0.030   16.499   0.000    0.499    0.649
##     .exp_attr2      0.604    0.037   16.384   0.000    0.604    0.646
##     .exp_attr3      0.744    0.133    5.594   0.000    0.744    0.422
##     .exp_beauty1    0.225    0.017   13.330   0.000    0.225    0.212
##     .exp_beauty2    0.171    0.013   13.507   0.000    0.171    0.199
##     .exp_beauty3    0.131    0.012   11.249   0.000    0.131    0.148
##     .exp_bond1      0.505    0.039   13.041   0.000    0.505    0.471
##     .exp_bond2      0.437    0.027   15.939   0.000    0.437    0.575
##     .exp_bond3      0.627    0.055   11.307   0.000    0.627    0.448
##     .exp_dist1      0.512    0.040   12.757   0.000    0.512    0.554
##     .exp_dist2      0.271    0.034    7.965   0.000    0.271    0.387
##     .exp_dist3      0.573    0.034   16.663   0.000    0.573    0.676
##     .exp_duty1      1.491    0.086   17.308   0.000    1.491    0.762
##     .exp_duty2      0.354    0.052    6.820   0.000    0.354    0.244
##     .exp_duty3      0.346    0.050    6.933   0.000    0.346    0.246
##     .exp_esc1       0.412    0.026   16.017   0.000    0.412    0.620
##     .exp_esc2       0.323    0.020   15.804   0.000    0.323    0.513
##     .exp_esc3       0.088    0.035    2.485   0.013    0.088    0.146
```

```
##     .exp_stim1          0.708    0.044   16.274    0.000    0.708    0.563
##     .exp_stim2          0.408    0.042    9.747    0.000    0.408    0.282
##     .exp_stim3          0.492    0.046   10.748    0.000    0.492    0.316
##     .exp_trans1         0.829    0.054   15.322    0.000    0.829    0.546
##     .exp_trans2         0.604    0.039   15.426    0.000    0.604    0.518
##     .exp_trans3         0.546    0.063    8.669    0.000    0.546    0.315
##      artval             0.807    0.064   12.620    0.000    1.000    1.000
##      attr               0.025    0.013    1.900    0.057    1.000    1.000
##      beaty              0.589    0.052   11.418    0.000    1.000    1.000
##      bond               0.323    0.050    6.432    0.000    1.000    1.000
##      dist               0.168    0.044    3.826    0.000    1.000    1.000
##      duty               0.220    0.054    4.074    0.000    1.000    1.000
##      esc                0.008    0.007    1.214    0.225    1.000    1.000
##      stim               0.304    0.049    6.254    0.000    1.000    1.000
##      trans              0.443    0.068    6.528    0.000    1.000    1.000
```

```r
# Fit measures.
fitMeasures(model_q_2_fit, fit.measures = fit_indices)
```

```
##      chisq          df      pvalue         cfi         tli     rmsea rmsea.pvalue
##   1149.239     287.000       0.000       0.913       0.894     0.068        0.000
##       srmr
##      0.084
```

3. Test both models against each other using the *Likelihood Ratio Test* (LRT). What do you conclude?

We can first compare the fit indices.

```r
# Put all fit measures together.
fit_measures_all <- data.frame(
    model_q_1 = fitMeasures(model_q_1_fit, fit.measures = fit_indices),
    model_q_2 = fitMeasures(model_q_2_fit, fit.measures = fit_indices)
)

# Print the measures with four decimals.
print(round(fit_measures_all, 4))
```

```
##                model_q_1 model_q_2
## chisq         1226.1107 1149.2392
## df             288.0000  287.0000
## pvalue           0.0000    0.0000
## cfi              0.9057    0.9134
## tli              0.8851    0.8940
## rmsea            0.0710    0.0682
## rmsea.pvalue     0.0000    0.0000
## srmr             0.0593    0.0843
```

Now we can also perform a *LRT*.

```r
# Perform LRT.
anova(model_q_2_fit, model_q_1_fit)
```

```
## Chi-Squared Difference Test
##
##                  Df    AIC    BIC  Chisq Chisq diff Df diff Pr(>Chisq)
```

```
## model_q_2_fit 287 41961 42368 1149.2
## model_q_1_fit 288 42036 42438 1226.1      76.871      1  < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

We see evidence that including a factor to account for common method bias improves the model fit. The model estimated at point *(1)* (i.e., `model_q_1`) does not fit equally well as the more complex model fit at point *(2)* (i.e., `model_q_2`). We prefer `model_q_2` with the method factor added.

4. Do you see other possibilities to improve the fit of the model?

What do you think?