Structural Equation Modeling

P.13 - Common Method Bias

November 15, 2022 (15:18:03)

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:

```
# 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.

Continued on next page

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.

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

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

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

List the variables.

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

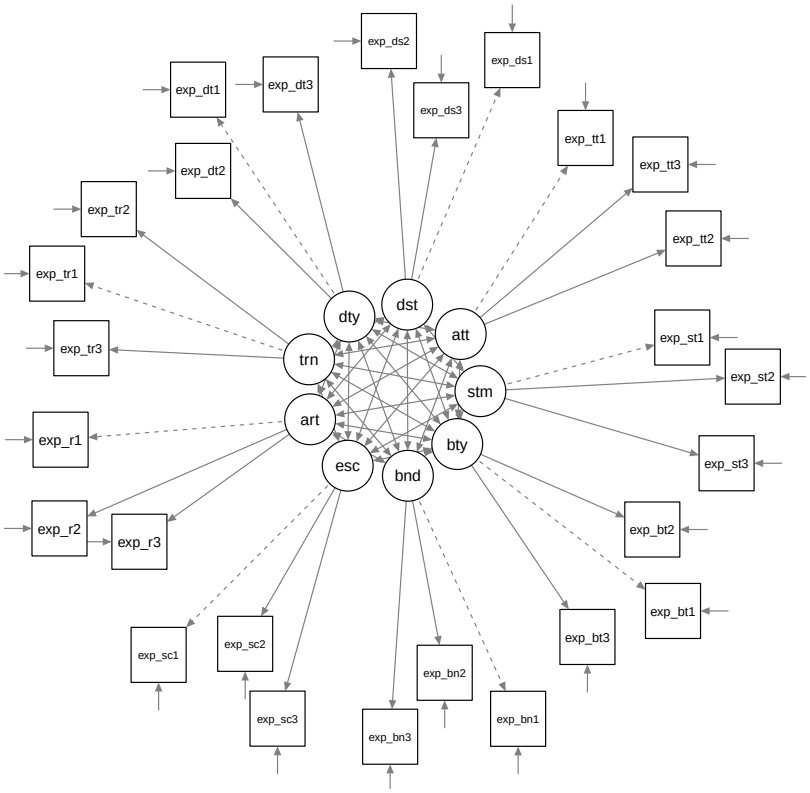
Specify which fit measures we are interested in:

```
# 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.

```
# 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
"
```

```r
# 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)
)
```




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

```
## lavaan 0.6-12 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
```

```
##   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
```

```
##    .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
```

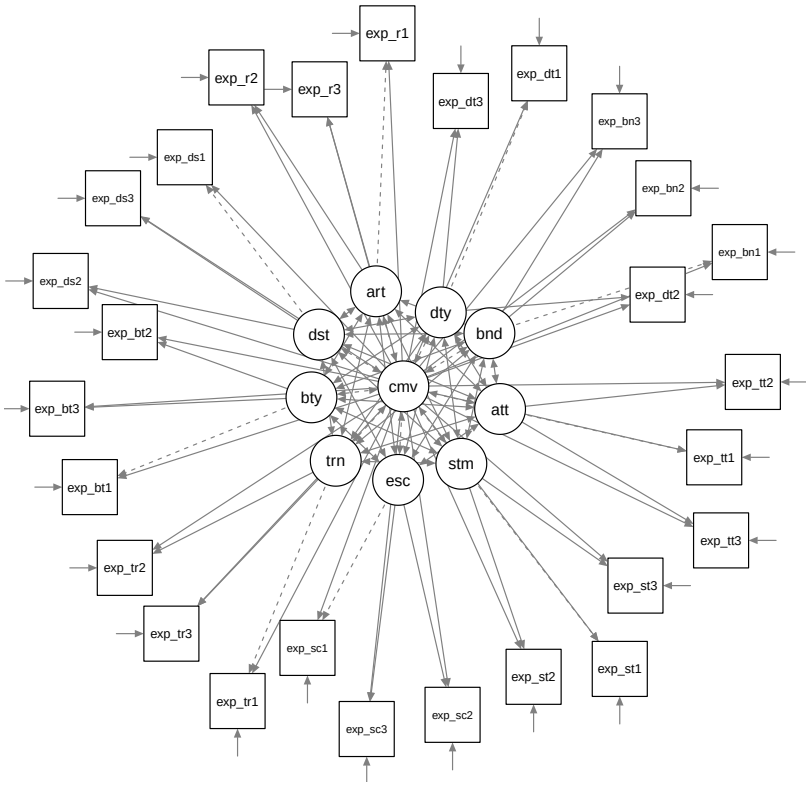
```
# Fit measures.
fitMeasures(model_q_1_fit, fit.measures = fit_indices)
```

```
##        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
```

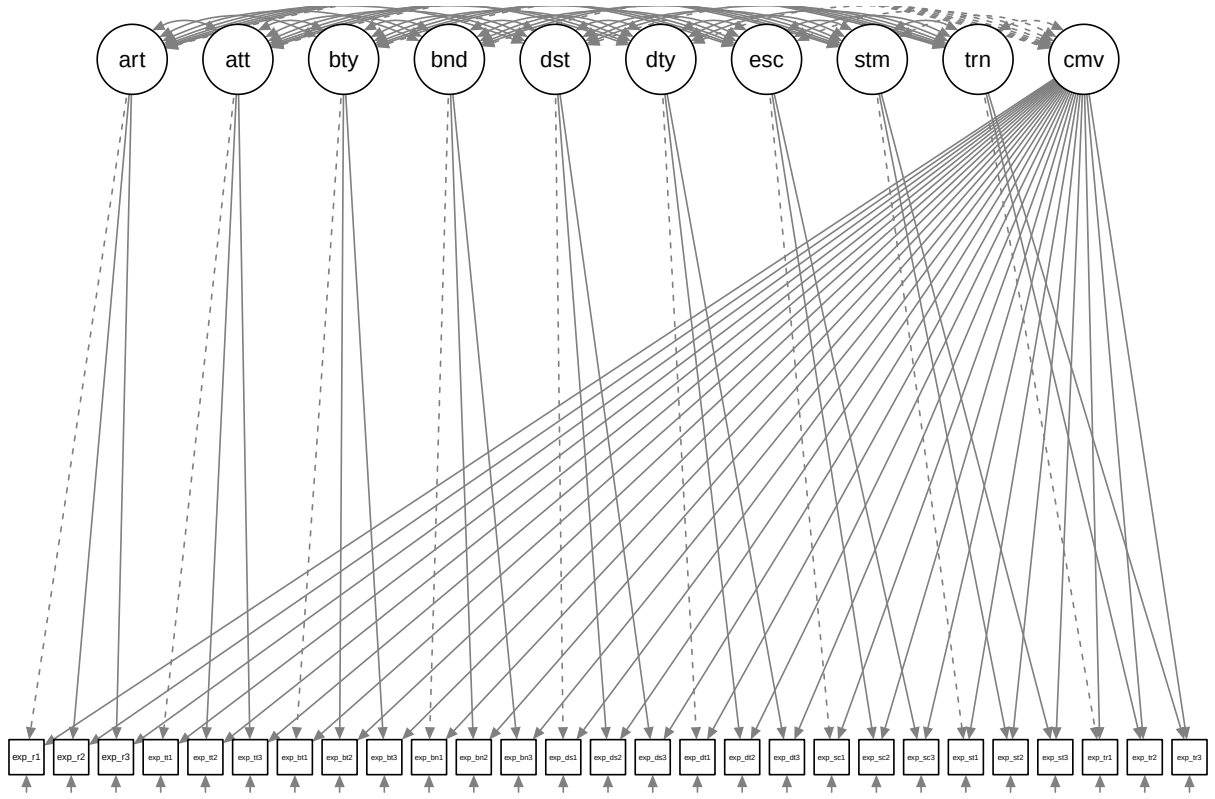
2. Estimate a *CFA* model for the 9 constructs together with a *method factor* to control for potential *common method bias*. Model the *common method variance* with a single *latent method variable*. Implement equality constraints on the loadings of the method factor and also implement the necessary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




```
# 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 0.6-12 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?