Factor Analysis and Measurement Invariance. Workshop 2.

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Definition

Measurement invariance tests for the **psychometric equivalence of a construct across different target cultures** (Greiff & Iliescu, 2017). Cross-cultural comparability is usually evaluated through multigroup confirmatory factor analysis (MGCFA), which is a technique capable of testing cross-national equivalence over several countries (Jöreskog, 1971; Meitinger, 2017) to claim that a construct is fully invariant.

How can you test M.I.?

Measurement invariance can be tested across four steps: **Configural, Metric, Scalar**, and **Strict** (see Putnick & Bornstein, 2016), following the recommendations by Hu and Bentler (1999), Cheung and Rensvold (2002), Chen (2007), and Meade et al. (2008). Either ML or MLR estimator are the usual choice (Maximum likelihood, and ML with robust standard errors) across tested steps. Applied decision rules to whether they complied or not with the type of studied invariance should be based on sample size, type of invariance, and fit-statistic used for comparison (see Meade et al., 2008).

Types of invariance to be tested

The nested models are progressively tested from configural to scalar invariance (Vandenberg & Lance, 2000). **Configural invariance** represents the baseline, which assumes that groups share the same conceptual framework without equality constraints on any parameter. **Metric invariance** requires equivalence of factor loadings, meaning that each item contributes to the latent construct similarly across different groups.

Types of invariance to be tested

Scalar invariance allows for the comparison of latent means across groups (Putnick & Bornstein, 2016). This type of invariance analysis derives from constraining intercepts to be equal among groups. If there is enough evidence for scalar invariance, then scores are considered invariant, i.e., equivalent (Chen, 2007; Tóth-Király et al., 2017). The previous types of invariance are necessary to claim that a construct is fully invariant. In **Strict invariance**, residuals are set to be equal across groups, although this is optional in cross-cultural research.

Kosic et al., 2021

Some examples from PYD research

Marique-Millones et al., 2021

Table 2 Invariance models for the 7Cs and risky behaviors

	Model fit		
	χ^2(df)	RMSEA	CFI
The 7Cs model			
Competence	52.45 (13)	.063	.965
Confidence	132.28 (27)	.072	.965
Character	153.31 (45)	.057	.937
Caring	52.90 (19)	.049	.983
Connection	152.48 (43)	.058	.944
Contribution	64.78 (14)	.069	.915
Creativity	177.01 (56)	.054	.969
Risky behaviors	7.51 (5)	.026	.963

Note. χ^2 = Chi-Square tests significant at p <. 01; df = degrees of freedom; CFI = Comparative Fit Index; RMSEA = Root Mean Square Error of Approximation. The represented models for each construct refer to the measurement weights model indicating construct invariance across samples

Uka et al., 2021

Table 3 Measurement invariance for the developmental assets across countries

	Model fit indices			
Model	S-Bχ^2 (df)	RMSEA	90% CIs RMSEA	CFI
Configural invariance	150.093 (76)	.071	.054–.087	.952
Metric invariance	170.356 (94)	.065	.049–.080	.951
Scalar invariance	242.115 (112)	.077	.064–.091	.917
Partial scalar invariance	204.404 (107)	.068	.054–.082	.937

Note. S-B χ^2 = Satorra-Bentler scaled χ^2; df = degrees of freedom; CIs = Confidence Intervals; RMSEA = Robust Root Mean Square Error of Approximation; CFI = Comparative Fit Index. Configural invariance tests whether all items/factors are associated with the assets allowing for subsequent tests to be conducted. Metric invariance tests whether all items/factors are associated with assets in the same way allowing the comparison of relations between these factors and other constructs. Scalar/partial invariance constrains factor loadings and intercepts to be equal among groups allowing to compare mean differences of the measured factors

Table 2 Fit statistics for multi-group confirmatory factor analyses for measures used with Slovene and Italian youth

	Model fit			
	χ^2	df	CFI	RMSEA
Measure				
Social support				
Configural invariance	75.44***	24	.909	.064
Metric invariance	78.69***	30	.914	.052
Scalar invariance	159.14***	37	.785	.072
Social competence				
Configural invariance	41.18***	22	.949	.041
Metric invariance	50.66***	28	.939	.039
Scalar invariance	58.72***	35	.936	.036
Positive identity				
Configural invariance	7.91	4	.995	.043
Metric invariance	9.40	7	.997	.026
Scalar invariance	15.45	11	.994	.028
Model test				
Unconstrained model	16.32***	4	.928	.077
Structural weights model	19.34***	7	.928	.058
Structural residuals model	21.62	12	.944	.039

Some examples from PYD research

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Mplus VERSION 8.3
MUTHEN & MUTHEN
04/20/2022   5:42 PM

INPUT INSTRUCTIONS

  TITLE: Multiple Group Configural Invariance Gender Confi, Metric and Scalar.

  DATA:
  FILE IS "C:\Dataset_PYD_Spain_and_Chile_For_MI.dat";
  VARIABLE:
  names= Gender Age Country d1 d2 d3 d4 d5 d6 d7 d8
  d9 d10 d11 d12 d13 d14 d15 d16 d17 d18 d19 d20 d21
  d22 d23 d24 d25 d26 d27 d28 d29 d30 d31 d32 d33 d34;
  grouping is Gender (1=Woman 2=Man);
  ANALYSIS:
  ESTIMATOR = MLR;
  ROTATION = TARGET (orthogonal);
  MODEL = CONFIGURAL METRIC SCALAR;
  OUTPUT:
   sampstat;

  MODEL:

  fg BY d1-d34 (*1);

  FS1 BY d1 d2 d3 d7 d8 d9 d4~0 d5~0 d6~0
  d10~0 d11~0 d12~0 d13~0 d14~0 d15~0 d16~0
  d17~0 d18~0 d19~0 d20~0 d21~0 d22~0 d23~0
  d24~0 d25~0 d26~0 d27~0 d28~0 d29~0 d30~0
  d31~0 d32~0 d33~0 d34~0(*1);

  FS2 BY d4 d6 d10 d12 d13 d14 d1~0 d2~0 d3~0
  d7~0 d8~0 d9~0 d5~0 d11~0 d15~0 d16~0 d17~0
  d18~0 d19~0 d20~0 d21~0 d22~0 d23~0 d24~0
  d25~0 d26~0 d27~0 d28~0 d29~0 d30~0 d31~0
  d32~0 d33~0 d34~0(*1);

  FS3 BY d5 d11 d15 d16 d17 d18 d19 d20
  d1~0 d2~0 d3~0 d7~0 d8~0 d9~0 d4~0 d6~0
  d10~0 d12~0 d13~0 d14~0 d21~0 d22~0 d23~0
  d24~0 d25~0 d26~0 d27~0 d28~0 d29~0 d30~0
  d31~0 d32~0 d33~0 d34~0(*1);

  FS4 BY d21 d22 d23 d24 d25 d26 d1~0 d2~0
  d3~0 d7~0 d8~0 d9~0 d4~0 d6~0 d10~0 d12~0
  d13~0 d14~0 d5~0 d11~0 d15~0 d16~0 d17~0
  d18~0 d19~0 d20~0 d27~0 d28~0 d29~0 d30~0
  d31~0 d32~0 d33~0 d34~0(*1);

  FS5 BY d27 d28 d29 d30 d31 d32 d33 d34
  d1~0 d2~0 d3~0 d7~0 d8~0 d9~0 d4~0 d6~0
  d10~0 d12~0 d13~0 d14~0 d5~0 d11~0 d15~0
  d16~0 d17~0 d18~0 d19~0 d20~0 d21~0 d22~0
  d23~0 d24~0 d25~0 d26~0(*1);
```

Global PYD

Competence

Confidence

Character

Caring

Connection

```
Mplus VERSION 8.3
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INPUT INSTRUCTIONS

  TITLE: Multiple Group Configural Invariance Country Confi, Metric and Scalar.

  DATA:
  FILE IS "C:\Dataset_PYD_Spain_and_Chile_For_MI.dat";
  VARIABLE:
  names= Gender Age Country d1 d2 d3 d4 d5 d6 d7 d8
  d9 d10 d11 d12 d13 d14 d15 d16 d17 d18 d19 d20 d21
  d22 d23 d24 d25 d26 d27 d28 d29 d30 d31 d32 d33 d34;
  grouping is Country (1=Spain 2=Chile);
  ANALYSIS:
  ESTIMATOR = MLR;
  ROTATION = TARGET (orthogonal);
  MODEL = CONFIGURAL METRIC SCALAR;
  OUTPUT:
   sampstat;

  MODEL:

  fg BY d1-d34 (*1);

  FS1 BY d1 d2 d3 d7 d8 d9 d4~0 d5~0 d6~0
  d10~0 d11~0 d12~0 d13~0 d14~0 d15~0 d16~0
  d17~0 d18~0 d19~0 d20~0 d21~0 d22~0 d23~0
  d24~0 d25~0 d26~0 d27~0 d28~0 d29~0 d30~0
  d31~0 d32~0 d33~0 d34~0(*1);

  FS2 BY d4 d6 d10 d12 d13 d14 d1~0 d2~0 d3~0
  d7~0 d8~0 d9~0 d5~0 d11~0 d15~0 d16~0 d17~0
  d18~0 d19~0 d20~0 d21~0 d22~0 d23~0 d24~0
  d25~0 d26~0 d27~0 d28~0 d29~0 d30~0 d31~0
  d32~0 d33~0 d34~0(*1);

  FS3 BY d5 d11 d15 d16 d17 d18 d19 d20
  d1~0 d2~0 d3~0 d7~0 d8~0 d9~0 d4~0 d6~0
  d10~0 d12~0 d13~0 d14~0 d21~0 d22~0 d23~0
  d24~0 d25~0 d26~0 d27~0 d28~0 d29~0 d30~0
  d31~0 d32~0 d33~0 d34~0(*1);

  FS4 BY d21 d22 d23 d24 d25 d26 d1~0 d2~0
  d3~0 d7~0 d8~0 d9~0 d4~0 d6~0 d10~0 d12~0
  d13~0 d14~0 d5~0 d11~0 d15~0 d16~0 d17~0
  d18~0 d19~0 d20~0 d27~0 d28~0 d29~0 d30~0
  d31~0 d32~0 d33~0 d34~0(*1);

  FS5 BY d27 d28 d29 d30 d31 d32 d33 d34
  d1~0 d2~0 d3~0 d7~0 d8~0 d9~0 d4~0 d6~0
  d10~0 d12~0 d13~0 d14~0 d5~0 d11~0 d15~0
  d16~0 d17~0 d18~0 d19~0 d20~0 d21~0 d22~0
  d23~0 d24~0 d25~0 d26~0(*1);
```

Some examples from PYD research

```
Multiple Group Configural Invariance Country Confi, Metric and Scalar.

SUMMARY OF ANALYSIS

Number of groups                                                 2
Number of observations
   Group SPAIN                                                 899
   Group CHILE                                                 261
   Total sample size                                          1160

Number of dependent variables                                   36
Number of independent variables                                  0
Number of continuous latent variables                            6

Observed dependent variables

  Continuous
   GENDER      AGE         D1          D2          D3          D4
   D5          D6          D7          D8          D9          D10
   D11         D12         D13         D14         D15         D16
   D17         D18         D19         D20         D21         D22
   D23         D24         D25         D26         D27         D28
   D29         D30         D31         D32         D33         D34

Continuous latent variables

  EFA factors
  *1:   FG          FS1         FS2         FS3         FS4         FS5

Variables with special functions

  Grouping variable     COUNTRY

Estimator                                                      MLR
Rotation                                                    TARGET
Row standardization                                         Varies
Type of rotation                                        ORTHOGONAL
Information matrix                                        OBSERVED
Maximum number of iterations                                  1000
Convergence criterion                                    0.500D-04
Maximum number of steepest descent iterations                   20
Optimization Specifications for the Exploratory Factor Analysis
Rotation Algorithm
  Number of random starts                                       30
  Maximum number of iterations                             1000000
  Derivative convergence criterion                       0.100D-04

Input data file(s)
  C:\Dataset_PYD_Spain_and_Chile_For_MI.dat

Input data format  FREE
```

Some examples from PYD research

```
MODEL FIT INFORMATION

Invariance Testing

                   Number of                        Degrees of
     Model         Parameters       Chi-Square       Freedom      P-Value

     Configural       N/A**
     Metric           N/A**
     Scalar           N/A**


**   Model did not terminate normally.  Refer to TECH9 output for more information.


MODEL RESULTS FOR THE CONFIGURAL MODEL

                    Estimate
```

Measurement Invariance by Country

```
TECHNICAL 9 OUTPUT

Error messages for the Configural Model:

THE MODEL ESTIMATION TERMINATED NORMALLY

     WARNING:  THE RESIDUAL COVARIANCE MATRIX (THETA) IN GROUP MAN IS NOT
     POSITIVE DEFINITE.  THIS COULD INDICATE A NEGATIVE VARIANCE/RESIDUAL
     VARIANCE FOR AN OBSERVED VARIABLE, A CORRELATION GREATER OR EQUAL TO ONE
     BETWEEN TWO OBSERVED VARIABLES, OR A LINEAR DEPENDENCY AMONG MORE THAN TWO
     OBSERVED VARIABLES.  CHECK THE RESULTS SECTION FOR MORE INFORMATION.
     PROBLEM INVOLVING VARIABLE D33.


Error messages for the Metric Model:

THE MODEL ESTIMATION TERMINATED NORMALLY

     WARNING:  THE RESIDUAL COVARIANCE MATRIX (THETA) IN GROUP WOMAN IS NOT
     POSITIVE DEFINITE.  THIS COULD INDICATE A NEGATIVE VARIANCE/RESIDUAL
     VARIANCE FOR AN OBSERVED VARIABLE, A CORRELATION GREATER OR EQUAL TO ONE
     BETWEEN TWO OBSERVED VARIABLES, OR A LINEAR DEPENDENCY AMONG MORE THAN TWO
     OBSERVED VARIABLES.  CHECK THE RESULTS SECTION FOR MORE INFORMATION.
     PROBLEM INVOLVING VARIABLE D33.


Error messages for the Scalar Model:

THE MODEL ESTIMATION TERMINATED NORMALLY

     WARNING:  THE RESIDUAL COVARIANCE MATRIX (THETA) IN GROUP WOMAN IS NOT
     POSITIVE DEFINITE.  THIS COULD INDICATE A NEGATIVE VARIANCE/RESIDUAL
     VARIANCE FOR AN OBSERVED VARIABLE, A CORRELATION GREATER OR EQUAL TO ONE
     BETWEEN TWO OBSERVED VARIABLES, OR A LINEAR DEPENDENCY AMONG MORE THAN TWO
     OBSERVED VARIABLES.  CHECK THE RESULTS SECTION FOR MORE INFORMATION.
     PROBLEM INVOLVING VARIABLE D33.
```

Measurement Invariance by Gender

```
MODEL FIT INFORMATION

Invariance Testing

                   Number of                 Degrees of
     Model         Parameters    Chi-Square   Freedom     P-Value

     Configural       522         2827.895       882       0.0000
     Metric           354         3057.801      1050       0.0000
     Scalar           326         3123.549      1078       0.0000

                                             Degrees of
     Models Compared             Chi-Square   Freedom     P-Value

     Metric against Configural     275.407       168       0.0000
     Scalar against Configural     335.168       196       0.0000
     Scalar against Metric          63.684        28       0.0001

MODEL FIT INFORMATION FOR THE CONFIGURAL MODEL

Number of Free Parameters                        522

Loglikelihood

          H0 Value                        -51824.390
          H0 Scaling Correction Factor        1.3880
            for MLR
          H1 Value                        -50174.517
          H1 Scaling Correction Factor        1.2491
            for MLR

Information Criteria

          Akaike (AIC)                    104692.779
          Bayesian (BIC)                  107332.103
          Sample-Size Adjusted BIC        105674.058
            (n* = (n + 2) / 24)

Chi-Square Test of Model Fit

          Value                             2827.895*
          Degrees of Freedom                     882
          P-Value                             0.0000
          Scaling Correction Factor           1.1669
            for MLR

Chi-Square Contribution and P-Value From Each Group (degrees of freedom = 441)

          WOMAN                             1887.443      0.000
          MAN                                940.452      0.000

*   The chi-square value for MLM, MLMV, MLR, ULSMV, WLSM and WLSMV cannot be used
    for chi-square difference testing in the regular way.  MLM, MLR and WLSM
    chi-square difference testing is described on the Mplus website.  MLMV, WLSMV,
    and ULSMV difference testing is done using the DIFFTEST option.

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                             0.062
          90 Percent C.I.                      0.059  0.064
          Probability RMSEA <= .05             0.000

CFI/TLI

          CFI                                  0.835
          TLI                                  0.764

SRMR (Standardized Root Mean Square Residual)

          Value                                0.053
```

```
MODEL FIT INFORMATION FOR THE METRIC MODEL

Number of Free Parameters                        354

Loglikelihood

          H0 Value                        -52019.259
          H0 Scaling Correction Factor        1.3752
            for MLR
          H1 Value                        -50174.517
          H1 Scaling Correction Factor        1.2491
            for MLR

Information Criteria

          Akaike (AIC)                    104746.518
          Bayesian (BIC)                  106536.404
          Sample-Size Adjusted BIC        105411.982
            (n* = (n + 2) / 24)

Chi-Square Test of Model Fit

          Value                             3057.801*
          Degrees of Freedom                    1050
          P-Value                             0.0000
          Scaling Correction Factor           1.2066
            for MLR

Chi-Square Contribution From Each Group

          WOMAN                             1887.207
          MAN                               1170.594

*   The chi-square value for MLM, MLMV, MLR, ULSMV, WLSM a
    for chi-square difference testing in the regular way.
    chi-square difference testing is described on the Mplu
    and ULSMV difference testing is done using the DIFFTES

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                             0.057
          90 Percent C.I.                      0.055  0.060
          Probability RMSEA <= .05             0.000

CFI/TLI

          CFI                                  0.830
          TLI                                  0.796

Chi-Square Test of Model Fit for the Baseline Model

          Value                            13053.665
          Degrees of Freedom                    1260
          P-Value                             0.0000

SRMR (Standardized Root Mean Square Residual)

          Value                                0.059
```

```
MODEL FIT INFORMATION FOR THE SCALAR MODEL

Number of Free Parameters                      326

Loglikelihood

          H0 Value                      -52053.135
          H0 Scaling Correction Factor      1.4019
            for MLR
          H1 Value                      -50174.517
          H1 Scaling Correction Factor      1.2491
            for MLR

Information Criteria

          Akaike (AIC)                  104758.270
          Bayesian (BIC)                106406.583
          Sample-Size Adjusted BIC      105371.099
            (n* = (n + 2) / 24)

Chi-Square Test of Model Fit

          Value                           3123.549*
          Degrees of Freedom                  1078
          P-Value                           0.0000
          Scaling Correction Factor         1.2029
            for MLR

Chi-Square Contribution From Each Group

          WOMAN                           1904.460
          MAN                             1219.089

*   The chi-square value for MLM, MLMV, MLR, ULSMV, WLSM and W
    for chi-square difference testing in the regular way.  MLM
    chi-square difference testing is described on the Mplus we
    and ULSMV difference testing is done using the DIFFTEST op

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                           0.057
          90 Percent C.I.                    0.055  0.060
          Probability RMSEA <= .05           0.000

CFI/TLI

          CFI                                0.827
          TLI                                0.797

Chi-Square Test of Model Fit for the Baseline Model

          Value                          13053.665
          Degrees of Freedom                  1260
          P-Value                           0.0000

SRMR (Standardized Root Mean Square Residual)

          Value                              0.060
```

Some examples from Trait EI research

TITLE: Multiple Group Omnibus Measurement Invariance.

DATA:

FILE IS "C:\full_new_dataset_clinical.dat";

VARIABLE:

names= education occupation civilstatus age gender

t1 t2 t3 t4 t5 t6 t7 t8 t9 t10 t11 t12 t13 t14 t15 t16 t17 t18 t19 t20 t21 t22 t23 t24 t25 t26 t27 t28 t29 t30;

usevar = t1 t2 t3 t4 t5 t6 t7 t8 t9 t10 t11 t12 t13 t14 t15 t16 t17 t18 t19 t20 t21 t22 t23 t24 t25 t26 t27 t28 t29 t30;

grouping is gender (1=Woman 2=Man);

ANALYSIS:

ESTIMATOR = MLR;

ROTATION = TARGET (orthogonal);

MODEL = CONFIGURAL METRIC SCALAR;

OUTPUT: sampstat;

```
MODEL:

fg BY t1-t30 (*1);

FS1 BY t5 t20 t9 t24 t12 t27 t4~0 t19~0
t7~0 t22~0 t15~0 t30~0 t1~0
t16~0 t2~0 t17~0 t8~0 t23~0 t13~0
t28~0 t6~0 t21~0 t10~0
t25~0 t11~0 t26~0 t3~0 t14~0 t18~0 t29~0(*1);

FS2 BY t4 t19 t7 t22 t15 t30 t5~0 t20~0
t9~0 t24~0 t12~0 t27~0 t1~0
t16~0 t2~0 t17~0 t8~0 t23~0 t13~0 t28~0
t6~0 t21~0 t10~0
t25~0 t11~0 t26~0 t3~0 t14~0 t18~0 t29~0(*1);

FS3 BY t1 t16 t2 t17 t8 t23 t13 t28 t4~0
t19~0 t7~0 t22~0 t15~0 t30~0 t5~0
t20~0 t9~0 t24~0 t12~0 t27~0 t6~0 t21~0
t10~0 t25~0 t11~0 t26~0 t3~0 t14~0 t18~0 t29~0(*1);

FS4 BY t6 t21 t10 t25 t11 t26 t5~0 t20~0
t9~0 t24~0 t12~0 t27~0 t4~0
t19~0 t7~0 t22~0 t15~0 t30~0 t1~0 t16~0
t2~0 t17~0 t8~0 t23~0 t13~0 t28~0
t3~0 t14~0 t18~0 t29~0(*1);
```

Some examples from Trait EI research

```
INPUT READING TERMINATED NORMALLY



Multiple Group Configural Invariance Gender Confi, Metric and Scalar.

SUMMARY OF ANALYSIS

Number of groups                                                 2
Number of observations
   Group WOMAN                                                 280
   Group MAN                                                   248
   Total sample size                                           528

Number of dependent variables                                   30
Number of independent variables                                  0
Number of continuous latent variables                            5

Observed dependent variables

  Continuous
   T1          T2          T3          T4          T5          T6
   T7          T8          T9          T10         T11         T12
   T13         T14         T15         T16         T17         T18
   T19         T20         T21         T22         T23         T24
   T25         T26         T27         T28         T29         T30

Continuous latent variables

  EFA factors
  *1:   FG          FS1         FS2         FS3         FS4
```

```
Variables with special functions

  Grouping variable     GENDER

Estimator                                                      MLR
Rotation                                                    TARGET
Row standardization                                         Varies
Type of rotation                                        ORTHOGONAL
Information matrix                                        OBSERVED
Maximum number of iterations                                  1000
Convergence criterion                                    0.500D-04
Maximum number of steepest descent iterations                   20
Optimization Specifications for the Exploratory Factor Analysis
Rotation Algorithm
  Number of random starts                                       30
  Maximum number of iterations                             1000000
  Derivative convergence criterion                       0.100D-04

Input data file(s)
  C:\full_new_dataset_clinical.dat

Input data format  FREE
```

```
MODEL FIT INFORMATION FOR THE CONFIGURAL MODEL

Number of Free Parameters                      400

Loglikelihood

          H0 Value                      -29706.873
          H0 Scaling Correction Factor      1.3667
            for MLR
          H1 Value                      -29156.268
          H1 Scaling Correction Factor      1.1476
            for MLR

Information Criteria

          Akaike (AIC)                   60213.746
          Bayesian (BIC)                 61921.385
          Sample-Size Adjusted BIC       60651.675
            (n* = (n + 2) / 24)

Chi-Square Test of Model Fit

          Value                           1102.298*
          Degrees of Freedom                   590
          P-Value                           0.0000
          Scaling Correction Factor         0.9990
            for MLR

Chi-Square Contribution and P-Value From Each Group (degrees of freedom = 295)

          WOMAN                            512.679      0.000
          MAN                              589.618      0.000

*   The chi-square value for MLM, MLMV, MLR, ULSMV, WLSM and WLSMV cannot be used
    for chi-square difference testing in the regular way.  MLM, MLR and WLSM
    chi-square difference testing is described on the Mplus website.  MLMV, WLSMV,
    and ULSMV difference testing is done using the DIFFTEST option.

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                           0.057
          90 Percent C.I.                    0.052  0.063
          Probability RMSEA <= .05           0.011

CFI/TLI

          CFI                                0.885
          TLI                                0.830

Chi-Square Test of Model Fit for the Baseline Model

          Value                           5311.345
          Degrees of Freedom                   870
          P-Value                           0.0000

SRMR (Standardized Root Mean Square Residual)

          Value                              0.039
```

```
MODEL FIT INFORMATION FOR THE METRIC MODEL

Number of Free Parameters                      275

Loglikelihood

          H0 Value                      -29827.804
          H0 Scaling Correction Factor      1.2673
            for MLR
          H1 Value                      -29156.268
          H1 Scaling Correction Factor      1.1476
            for MLR

Information Criteria

          Akaike (AIC)                   60205.609
          Bayesian (BIC)                 61379.610
          Sample-Size Adjusted BIC       60506.685
            (n* = (n + 2) / 24)

Chi-Square Test of Model Fit

          Value                           1219.302*
          Degrees of Freedom                   715
          P-Value                           0.0000
          Scaling Correction Factor         1.1015
            for MLR

Chi-Square Contribution From Each Group

          WOMAN                            540.447
          MAN                              678.856

*   The chi-square value for MLM, MLMV, MLR, ULSMV, WLSM and WLSMV cannot be used
    for chi-square difference testing in the regular way.  MLM, MLR and WLSM
    chi-square difference testing is described on the Mplus website.  MLMV, WLSMV,
    and ULSMV difference testing is done using the DIFFTEST option.

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                           0.052
          90 Percent C.I.                    0.047  0.057
          Probability RMSEA <= .05           0.283

CFI/TLI

          CFI                                0.886
          TLI                                0.862

Chi-Square Test of Model Fit for the Baseline Model

          Value                           5311.345
          Degrees of Freedom                   870
          P-Value                           0.0000

SRMR (Standardized Root Mean Square Residual)

          Value                              0.052
```

```
MODEL FIT INFORMATION FOR THE SCALAR MODEL

Number of Free Parameters                      275

Loglikelihood

          H0 Value                      -29827.804
          H0 Scaling Correction Factor      1.2673
            for MLR
          H1 Value                      -29156.268
          H1 Scaling Correction Factor      1.1476
            for MLR

Information Criteria

          Akaike (AIC)                   60205.609
          Bayesian (BIC)                 61379.610
          Sample-Size Adjusted BIC       60506.685
            (n* = (n + 2) / 24)

Chi-Square Test of Model Fit

          Value                           1219.302*
          Degrees of Freedom                   715
          P-Value                           0.0000
          Scaling Correction Factor         1.1015
            for MLR

Chi-Square Contribution From Each Group

          WOMAN                            540.447
          MAN                              678.856

*   The chi-square value for MLM, MLMV, MLR, ULSMV, WLSM and WLSMV cannot be used
    for chi-square difference testing in the regular way.  MLM, MLR and WLSM
    chi-square difference testing is described on the Mplus website.  MLMV, WLSMV,
    and ULSMV difference testing is done using the DIFFTEST option.

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                           0.052
          90 Percent C.I.                    0.047  0.057
          Probability RMSEA <= .05           0.283

CFI/TLI

          CFI                                0.886
          TLI                                0.862

Chi-Square Test of Model Fit for the Baseline Model

          Value                           5311.345
          Degrees of Freedom                   870
          P-Value                           0.0000

SRMR (Standardized Root Mean Square Residual)

          Value                              0.052
```

Some examples from Trait EI research

TITLE: Multiple Group **Configural Measurement Invariance** Across Genders

DATA:

FILE IS "C:\full_new_dataset_clinical.dat";

VARIABLE:

names= education occupation civilstatus age gender

t1 t2 t3 t4 t5 t6 t7 t8 t9 t10 t11 t12 t13 t14 t15 t16 t17 t18 t19 t20 t21 t22 t23 t24 t25 t26 t27 t28 t29 t30;

usevar = t1 t2 t3 t4 t5 t6 t7 t8 t9 t10 t11 t12 t13 t14 t15 t16 t17 t18 t19 t20 t21 t22 t23 t24 t25 t26 t27 t28 t29 t30;

grouping is gender (1=Woman 2=Man);

ANALYSIS:

ESTIMATOR = MLR;

ROTATION = TARGET (orthogonal);

```
MODEL Man:
fg BY t1-t30 (*1);
FS1 BY t5 t20 t9 t24 t12 t27 t4~0 t19~0
t7~0 t22~0 t15~0 t30~0 t1~0
t16~0 t2~0 t17~0 t8~0 t23~0 t13~0
t28~0 t6~0 t21~0 t10~0
t25~0 t11~0 t26~0 t3~0 t14~0 t18~0 t29~0(*1);
FS2 BY t4 t19 t7 t22 t15 t30 t5~0 t20~0
t9~0 t24~0 t12~0 t27~0 t1~0
t16~0 t2~0 t17~0 t8~0 t23~0 t13~0 t28~0
t6~0 t21~0 t10~0
t25~0 t11~0 t26~0 t3~0 t14~0 t18~0 t29~0(*1);
FS3 BY t1 t16 t2 t17 t8 t23 t13 t28 t4~0
t19~0 t7~0 t22~0 t15~0 t30~0 t5~0
t20~0 t9~0 t24~0 t12~0 t27~0 t6~0 t21~0
t10~0 t25~0 t11~0 t26~0 t3~0 t14~0 t18~0 t29~0(*1);
FS4 BY t6 t21 t10 t25 t11 t26 t5~0 t20~0
t9~0 t24~0 t12~0 t27~0 t4~0
t19~0 t7~0 t22~0 t15~0 t30~0 t1~0 t16~0
t2~0 t17~0 t8~0 t23~0 t13~0 t28~0
t3~0 t14~0 t18~0 t29~0(*1);
```

MODEL:
fg BY t1-t30 (*1);
FS1 BY t5 t20 t9 t24 t12 t27 t4~0 t19~0 t7~0 t22~0 t15~0 t30~0 t1~0 t16~0 t2~0 t17~0 t8~0 t23~0 t13~0
t28~0 t6~0 t21~0 t10~0 t25~0 t11~0 t26~0 t3~0 t14~0 t18~0 t29~0(*1);
FS2 BY t4 t19 t7 t22 t15 t30 t5~0 t20~0 t9~0 t24~0 t12~0 t27~0 t1~0 t16~0 t2~0 t17~0 t8~0 t23~0 t13~0 t28~0 t6~0 t21~0 t10~0 t25~0 t11~0 t26~0 t3~0 t14~0 t18~0 t29~0(*1);
FS3 BY t1 t16 t2 t17 t8 t23 t13 t28 t4~0 t19~0 t7~0 t22~0 t15~0 t30~0 t5~0 t20~0 t9~0 t24~0 t12~0 t27~0 t6~0 t21~0 t10~0 t25~0 t11~0 t26~0 t3~0 t14~0 t18~0 t29~0(*1);
FS4 BY t6 t21 t10 t25 t11 t26 t5~0 t20~0 t9~0 t24~0 t12~0 t27~0 t4~0 t19~0 t7~0 t22~0 t15~0 t30~0 t1~0 t16~0 t2~0 t17~0 t8~0 t23~0 t13~0 t28~0 t3~0 t14~0 t18~0 t29~0(*1);
[t1-t30];
t1-t30;
[fg@0]; [FS1@0]; [FS2@0]; [FS3@0]; [FS4@0];
OUTPUT:
sampstat standardized SVALUES stdyx modindices(15);

Configural Measurement Invariance

```
THE MODEL ESTIMATION TERMINATED NORMALLY


MODEL FIT INFORMATION

Number of Free Parameters                        275

Loglikelihood

          H0 Value                        -29827.804
          H0 Scaling Correction Factor        1.2673
            for MLR
          H1 Value                        -29156.268
          H1 Scaling Correction Factor        1.1476
            for MLR

Information Criteria

          Akaike (AIC)                     60205.609
          Bayesian (BIC)                   61379.610
          Sample-Size Adjusted BIC         60506.685
            (n* = (n + 2) / 24)

Chi-Square Test of Model Fit

          Value                             1219.302*
          Degrees of Freedom                     715
          P-Value                             0.0000
          Scaling Correction Factor           1.1015
            for MLR
```

```
Chi-Square Contribution From Each Group

          WOMAN                              540.447
          MAN                                678.856

*   The chi-square value for MLM, MLMV, MLR, ULSMV, WLSM and WLSMV cannot be used
    for chi-square difference testing in the regular way.  MLM, MLR and WLSM
    chi-square difference testing is described on the Mplus website.  MLMV, WLSMV,
    and ULSMV difference testing is done using the DIFFTEST option.

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                             0.052
          90 Percent C.I.                      0.047  0.057
          Probability RMSEA <= .05             0.283

CFI/TLI

          CFI                                  0.886
          TLI                                  0.862

Chi-Square Test of Model Fit for the Baseline Model

          Value                             5311.345
          Degrees of Freedom                     870
          P-Value                             0.0000

SRMR (Standardized Root Mean Square Residual)

          Value                                0.052
```

Some examples from Trait EI research

TITLE: Multiple Group Metric Measurement Invariance Across Genders

```
[t1-t30];
t1-t30;
[fg@0]; [FS1@0]; [FS2@0]; [FS3@0]; [FS4@0];
```

Item intercepts (← [t1-t30];)

Item uniqueness (← t1-t30;)

Factor means (← [fg@0]; [FS1@0]; [FS2@0]; [FS3@0]; [FS4@0];)

Factor loadings are freed here so no need to include "Model Man" anymore

```
T18 WITH T3;
T19 WITH T4;
T24 WITH T9;
T30 WITH T7;
T17 WITH T2;
T25 WITH T10;
```

Correlated uniquenesses

Metric Measurement Invariance

```
THE MODEL ESTIMATION TERMINATED NORMALLY


MODEL FIT INFORMATION

Number of Free Parameters                      245

Loglikelihood

          H0 Value                      -29854.004
          H0 Scaling Correction Factor      1.3127
            for MLR
          H1 Value                      -29156.268
          H1 Scaling Correction Factor      1.1476
            for MLR

Information Criteria

          Akaike (AIC)                   60198.007
          Bayesian (BIC)                 61243.936
          Sample-Size Adjusted BIC       60466.239
            (n* = (n + 2) / 24)

Chi-Square Test of Model Fit

          Value                           1276.417*
          Degrees of Freedom                   745
          P-Value                           0.0000
          Scaling Correction Factor         1.0933
            for MLR
```

```
Chi-Square Contribution From Each Group

          WOMAN                            566.828
          MAN                              709.589

*   The chi-square value for MLM, MLMV, MLR, ULSMV, WLSM and WLSMV cannot be used
    for chi-square difference testing in the regular way.  MLM, MLR and WLSM
    chi-square difference testing is described on the Mplus website.  MLMV, WLSMV,
    and ULSMV difference testing is done using the DIFFTEST option.

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                           0.052
          90 Percent C.I.                    0.047  0.057
          Probability RMSEA <= .05           0.247

CFI/TLI

          CFI                                0.880
          TLI                                0.860

Chi-Square Test of Model Fit for the Baseline Model

          Value                           5311.345
          Degrees of Freedom                   870
          P-Value                           0.0000

SRMR (Standardized Root Mean Square Residual)

          Value                              0.054
```

```
MODEL MODIFICATION INDICES

NOTE:  Modification indices for direct effects of observed dependent variables
regressed on covariates may not be included.  To include these, request
MODINDICES (ALL).

Minimum M.I. value for printing the modification index     15.000

                                   M.I.     E.P.C.  Std E.P.C.  StdYX E.P.C.
Group WOMAN


WITH Statements

T18      WITH T3                 29.896     0.723      0.723      0.375
T19      WITH T4                 19.887     0.709      0.709      0.296
T24      WITH T9                 17.806     0.477      0.477      0.397
T28      WITH T6                 29.682     0.822      0.822      0.382
T30      WITH T7                 16.293     0.810      0.810      0.265

Group MAN


WITH Statements

T11      WITH T9                 15.109     0.430      0.430      0.390
T17      WITH T2                 17.364     0.712      0.712      0.296
T25      WITH T10                18.598     0.934      0.934      0.302
```

Some examples from Trait EI research

TITLE: Multiple Group Scalar Measurement Invariance Across Genders

[t1-t30]; ← Item intercepts are now invariant across groups

t1-t30; ← Item uniqueness (residuals)

[fg@0]; [FS1@0]; [FS2@0]; [FS3@0]; [FS4@0]; ← Factor means were set to be equal

[fg*]; [FS1*]; [FS2*]; [FS3*]; [FS4*]; ← Factor means set to be freely estimated across groups

Scalar Measurement Invariance

```
MODEL FIT INFORMATION

Number of Free Parameters                        250

Loglikelihood

          H0 Value                        -29845.373
          H0 Scaling Correction Factor        1.4101
            for MLR
          H1 Value                        -29156.268
          H1 Scaling Correction Factor        1.1476
            for MLR

Information Criteria

          Akaike (AIC)                     60190.747
          Bayesian (BIC)                   61258.021
          Sample-Size Adjusted BIC         60464.453
            (n* = (n + 2) / 24)

Chi-Square Test of Model Fit

          Value                             1301.574*
          Degrees of Freedom                     740
          P-Value                             0.0000
          Scaling Correction Factor           1.0589
            for MLR
```

```
Chi-Square Contribution From Each Group

          WOMAN                              578.240
          MEN                                723.334

*   The chi-square value for MLM, MLMV, MLR, ULSMV, WLSM and WL
    for chi-square difference testing in the regular way.  MLM,
    chi-square difference testing is described on the Mplus wet
    and ULSMV difference testing is done using the DIFFTEST opt

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                             0.054
          90 Percent C.I.                      0.049  0.058
          Probability RMSEA <= .05             0.107

CFI/TLI

          CFI                                  0.874
          TLI                                  0.851

Chi-Square Test of Model Fit for the Baseline Model

          Value                             5311.345
          Degrees of Freedom                     870
          P-Value                             0.0000

SRMR (Standardized Root Mean Square Residual)

          Value                                0.053
```

```
MODEL MODIFICATION INDICES

NOTE:  Modification indices for direct effects of observed dependent variables
regressed on covariates may not be included.  To include these, request
MODINDICES (ALL).

Minimum M.I. value for printing the modification index    15.000

                                   M.I.     E.P.C.  Std E.P.C.  StdYX E.P.C.
Group WOMAN


WITH Statements

T18      WITH T3                 30.985      0.724      0.724      0.375
T19      WITH T4                 19.749      0.694      0.694      0.293
T24      WITH T9                 18.840      0.479      0.479      0.398
T28      WITH T6                 29.846      0.809      0.809      0.381
T30      WITH T7                 16.704      0.807      0.807      0.264

Group MEN


WITH Statements

T11      WITH T9                 15.583      0.429      0.429      0.374
T17      WITH T2                 18.177      0.715      0.715      0.299
T25      WITH T10                18.983      0.928      0.928      0.300
```

Some examples from Trait EI research

TITLE: Multiple Group Strict Measurement Invariance Across Genders

t1-t30; ← Item uniqueness (residuals) are now invariant across groups

[fg*]; [FS1*]; [FS2*]; [FS3*]; [FS4*]; Factor means are freely estimated across groups, as when testing scalar invariance.

Reporting of Measurement Invariance

Pérez-Díaz & Petrides, 2021

Table 4. Multiple group measurement invariance model comparisons.

Models	χ^2	$\Delta\ \chi^2$	*df*	*CFI*	*Δ CFI*	*RMSEA*	*Δ RMSEA*	*RMSEALb*	*RMSEAUb*	*SRMR*	*Δ SRMR*
1											
Configural	1506.16	—	879	0.917	—	0.046	—	0.042	0.050	0.036	—
Metric	2031.69	525.53	1129	0.880	0.037	0.049	0.003	0.046	0.053	0.054	0.018
Scalar	2253.93	222.24	1179	0.857	0.023	0.053	0.004	0.049	0.056	0.061	0.007
2											
Configural	1121.93	—	586	0.927	—	0.043	—	0.039	0.047	0.032	—
Metric	1398.02	276.09	711	0.907	0.020	0.044	0.001	0.041	0.048	0.044	0.012
Scalar	1593.17	195.15	736	0.884	0.023	0.048	0.004	0.045	0.052	0.049	0.005
3											
Configural	783.80	—	584	0.946	—	0.039	—	0.031	0.046	0.037	—
Metric	1013.49	229.69	709	0.918	0.028	0.043	0.004	0.037	0.049	0.052	0.015
Scalar	1053.43	39.94	734	0.914	0.004	0.044	0.001	0.038	0.050	0.055	0.003
4											
Configural	1135.40	—	588	0.916	—	0.046	—	0.042	0.050	0.034	—
Metric	1414.86	279.46	713	0.892	0.024	0.048	0.002	0.044	0.051	0.047	0.013
Scalar	1576.47	161.61	738	0.871	0.021	0.051	0.003	0.048	0.055	0.053	0.006

Note. Model 1 = UK validation sample, N = 537; Chilean general population, N = 335; and Chilean clinical population, N = 120. Model 2 = UK validation sample and combined Chilean samples. Model 3 = Chilean general and clinical samples.Model 4 = UK validation sample and Chilean general population. χ^2 = Chi Squared, $\Delta\chi^2$ = Chi Square difference, df = degrees of freedom, CFI = Comparative Fit Index, ΔCFI = CFI difference, RMSEA = Root Mean Square Error of Approximation, Δ RMSEA = RMSEA difference, RMSEALb = RMSEA Lower bound, RMSEAUb = Upper bound. SRMR = Standardized root mean residual, Δ SRMR = SRMR difference.

Reporting of Measurement Invariance

Pérez-Díaz et al., 2021

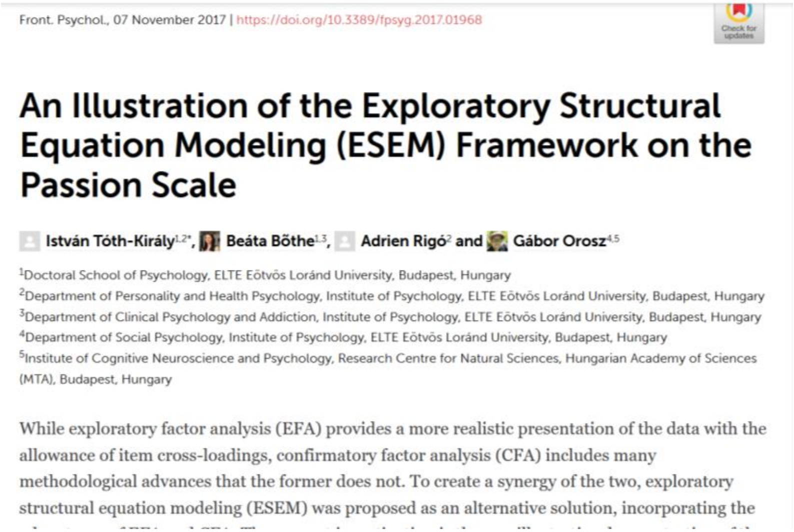
TABLE 1 | Multiple group measurement invariance comparisons by sociodemographic characteristics.

Models	χ^2	$\Delta\chi^2$	*df*	*CFI*	*Δ CFI*	*RMSEA*	*Δ RMSEA*	*RMSEALb*	*RMSEAUb*	*SRMR*	*Δ SRMR*
1. Gender											
Configural	1070.90	–	703	0.917	–	0.045	–	0.039	0.050	0.049	–
Metric	1120.81	49.91	733	0.913	0.004	0.045	0.000	0.039	0.050	0.052	0.003
Scalar	1099.95	20.86	728	0.916	0.003	0.044	0.001	0.039	0.049	0.051	0.001
2. Age											
Configural	1085.76	–	586	0.887	–	0.057	–	0.052	0.062	0.040	–
Metric	1164.16	78.40	737	0.904	0.017	0.047	0.010	0.042	0.052	0.051	0.011
Scalar	1323.80	159.64	732	0.866	0.028	0.055	0.008	0.051	0.060	0.051	0.000
3. Education											
Configural	1576.51	–	1114	0.901	–	0.049	–	0.043	0.054	0.061	–
Metric	1664.21	87.70	1174	0.896	0.005	0.049	0.000	0.043	0.054	0.065	0.004
Scalar	1646.01	18.20	1164	0.897	0.001	0.049	0.000	0.043	0.054	0.062	0.003
4. Civil status											
Configural	1642.57	–	1117	0.884	–	0.054	–	0.049	0.060	0.063	–
Metric	1861.72	122.09	1192	0.894	0.010	0.051	0.001	0.047	0.056	0.067	0.012
Scalar	1755.58	106.14	1180	0.873	0.019	0.055	0.004	0.050	0.061	0.069	0.002
5. Occupation											
Configural	1713.73	–	1123	0.861	–	0.060	–	0.054	0.066	0.067	–
Metric	1798.55	84.82	1183	0.855	0.006	0.060	0.000	0.054	0.065	0.072	0.005
Scalar	1792.44	6.11	1173	0.854	0.001	0.060	0.000	0.055	0.066	0.069	0.003

Model 1 = gender, N = 528, nWomen = 280, nMen = 248. Model 2 = age, N = 528, nYoung = 230, nSenior = 298. Model 3 = education, N = 528, nSecondary = 187, nUniversity = 257, nGraduate = 84. Model 4 = civil status, N = 479, nSingle = 273, nRelationship = 118, nMarried = 88. Model 5 = occupation, N = 438, nPrivate = 164, nPublic = 114, nStudent = 160. χ^2 = chi squared, $\Delta\chi^2$ = chi squared difference, df = degrees of freedom, CFI = comparative fit index, ΔCFI = CFI difference, RMSEA = root mean square error of approximation, Δ RMSEA = RMSEA difference, RMSEALb = RMSEA lower bound, RMSEAUb = RMSEA upper bound. SRMR = standardised root mean residual, Δ SRMR = SRMR difference.

Suggested resources

Go to the supplementary material!


Front. Psychol., 07 November 2017 | https://doi.org/10.3389/fpsyg.2017.01968

An Illustration of the Exploratory Structural Equation Modeling (ESEM) Framework on the Passion Scale

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While exploratory factor analysis (EFA) provides a more realistic presentation of the data with the allowance of item cross-loadings, confirmatory factor analysis (CFA) includes many methodological advances that the former does not. To create a synergy of the two, exploratory structural equation modeling (ESEM) was proposed as an alternative solution, incorporating the


Articles

The Spanish-Chilean Trait Emotional Intelligence Questionnaire-Short Form: The Adaptation and Validation of the TEIQue-SF in Chile

Pablo A. Pérez-Díaz & K. V. Petrides

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