

Testing Multiple-Group Measurement Invariance using WLSMV in Item Factor Models in Mplus version 7.4

Example data: 634 older adults (age 80-100) self-reporting on 7 items assessing the Instrumental Activities of Daily Living (IADL) as follows. We are examining differences between men ($N=214$) and women ($N=420$). Each item has four response options: 0 = can't do it, 1 = big problems doing it, 2 = some problems doing it, 3 = can do it. The items are: 1. Housework (cleaning and laundry), 2. Bedmaking, 3. Cooking, 4. Everyday shopping, 5. Getting to places outside of walking distance, 6. Handling banking and other business, and 7. Using the telephone.

Multiple Group IFA Model Syntax and Truncated Output:

```
TITLE: Assess polytomous IADL items
DATA: FILE IS ADL2.dat;
VARIABLE: NAMES = case female cial-cia7;
          USEVARIABLES = cial-cia7;
          CATEGORICAL = cial-cia7;
          GROUPING = female (0=Men 1=Women);
          IDVARIABLE = case;
          MISSING = .;

ANALYSIS: ESTIMATOR=WLSMV; PARAMETERIZATION=THETA;

PLOT: TYPE = PLOT1 PLOT2 PLOT3;

SAVEDATA: DIFFTEST=Configural.dat; ! Save configural info

OUTPUT: STDYX MODINDICES(3.84); ! Constraints to drop p<.05
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```
!!! CONFIGURAL MODEL FOR MEN REFERENCE GROUP
MODEL:
! Factor loadings all estimated, just labeled
  IADL BY cial-cia7* (I1-I7);
! Item thresholds all free, just labeled
  [cial$1-cia7$1*] (T1_1-T1_7);
  [cial$2-cia7$2*] (T2_1-T2_7);
  [cial$3-cia7$3*] (T3_1-T3_7);
! Item residual variances all fixed=1
  cial-cia7@1;
! Factor mean=0 and variance=1 for identification
  [IADL@0]; IADL@1;

!!! CONFIGURAL MODEL FOR WOMEN ALTERNATIVE GROUP
MODEL WOMEN:
! Factor loadings all estimated
  IADL BY cial-cia7*;
! Item thresholds all free
  [cial$1-cia7$1*];
  [cial$2-cia7$2*];
  [cial$3-cia7$3*];
! Item residual variances all fixed=1
  cial-cia7@1;
! Factor mean=0 and variance=1 for identification
  [IADL@0]; IADL@1;
```

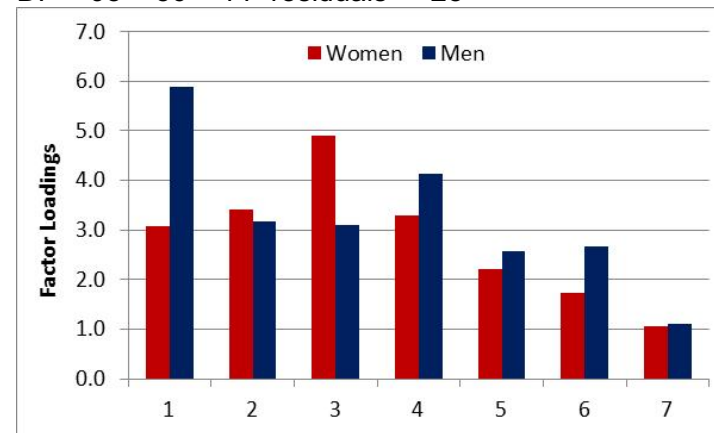
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MODEL FIT INFORMATION
Number of Free Parameters          56
Chi-Square Test of Model Fit
  Value                            72.921*
  Degrees of Freedom                28
  P-Value                          0.0000
Chi-Square Contributions From Each Group
  MEN                               24.975
  WOMEN                             47.946
RMSEA (Root Mean Square Error Of Approximation)
  Estimate                          0.071
  90 Percent C.I.                   0.051 0.091
  Probability RMSEA <= .05         0.040
CFI/TLI
  CFI                               0.999
  TLI                               0.998
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This will be our baseline configural model.

56 parameters estimated = $2 \times [7 \text{ loadings} + 21 \text{ thresholds}] = 56$

Possible parameters = $2 \times ([7 \times (7+1)] / 2) + 21 \text{ thresholds} = 98$

DF = $98 - 56 - 14 \text{ "residuals"} = 28$



Model 2a. Metric Invariance Model (IFA loadings held equal across groups – Mplus IRT discriminations still vary via factor variances)

<pre> ANALYSIS: ESTIMATOR IS WLSMV; PARAMETERIZATION=THETA; DIFFTEST=Configural.dat; ! Compare against configural SAVEDATA: DIFFTEST=MetricA.dat; ! Save full metric A info !!! MODEL FOR MEN REFERENCE GROUP (same as configural) MODEL: ! Factor loadings all estimated IADL BY cia1-cia7* (L1-L7); ! Item thresholds all free [cia1\$1-cia7\$1*] (T1_1-T1_7); [cia1\$2-cia7\$2*] (T2_1-T2_7); [cia1\$3-cia7\$3*] (T3_1-T3_7); ! Item residual variances all fixed=1 cial-cia7@1; ! Factor mean=0 and variance=1 for identification [IADL@0]; IADL@1; !!! 2 METRIC MODEL FOR WOMEN ALTERNATIVE GROUP MODEL WOMEN: ! Factor loadings NOW CONSTRAINED EQUAL TO MEN IADL BY cia1-cia7* (L1-L7); ! Item thresholds all free [cia1\$1-cia7\$1*]; [cia1\$2-cia7\$2*]; [cia1\$3-cia7\$3*]; ! Item residual variances all fixed=1 cial-cia7@1; ! Factor mean=0 for identification ! Factor variance NOW ESTIMATED [IADL@0]; IADL*; </pre>	<pre> Number of Free Parameters 50 Chi-Square Test of Model Fit Value 64.668* Degrees of Freedom 34 P-Value 0.0012 Chi-Square Contributions From Each Group MEN 30.856 WOMEN 33.813 THIS IS THE TEST OF CONFIGURAL VS. FULL METRIC A INVARIANCE Chi-Square Test for Difference Testing Value 9.395 Degrees of Freedom 6 P-Value 0.1525 RMSEA (Root Mean Square Error Of Approximation) Estimate 0.053 90 Percent C.I. 0.033 0.073 Probability RMSEA <= .05 0.367 CFI/TLI CFI 0.999 TLI 0.999 Although the DIFFTEST chi-square is nonsignificant, the modification indices suggest freeing the loading for cia3 between groups: MODEL MODIFICATION INDICES M.I. E.P.C. Std E.P.C. StdYX E.P.C. Group MEN BY Statements IADL BY CIA3 7.717 -2.375 -2.375 -0.487 IADL BY CIA6 5.858 0.338 0.338 0.136 Group WOMEN BY Statements IADL BY CIA3 7.674 1.524 1.269 0.310 IADL BY CIA6 5.858 -0.374 -0.311 -0.146 </pre>
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Model 2b. Metric Invariance Model (IFA loadings held equal across groups except cia3)

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ANALYSIS: ESTIMATOR IS WLSMV; PARAMETERIZATION=THETA;
              DIFFTEST=Configural.dat; ! Compare against configural

SAVEDATA: DIFFTEST=MetricB.dat; ! Save partial metric B info

!!! MODEL FOR MEN REFERENCE GROUP (same as configural)
MODEL:
! Factor loadings all estimated
  IADL BY cia1-cia7* (L1-L7);
! Item thresholds all free
  [cia1$1-cia7$1*] (T1_1-T1_7);
  [cia1$2-cia7$2*] (T2_1-T2_7);
  [cia1$3-cia7$3*] (T3_1-T3_7);
! Item residual variances all fixed=1
  cia1-cia7@1;
! Factor mean=0 and variance=1 for identification
  [IADL@0]; IADL@1;

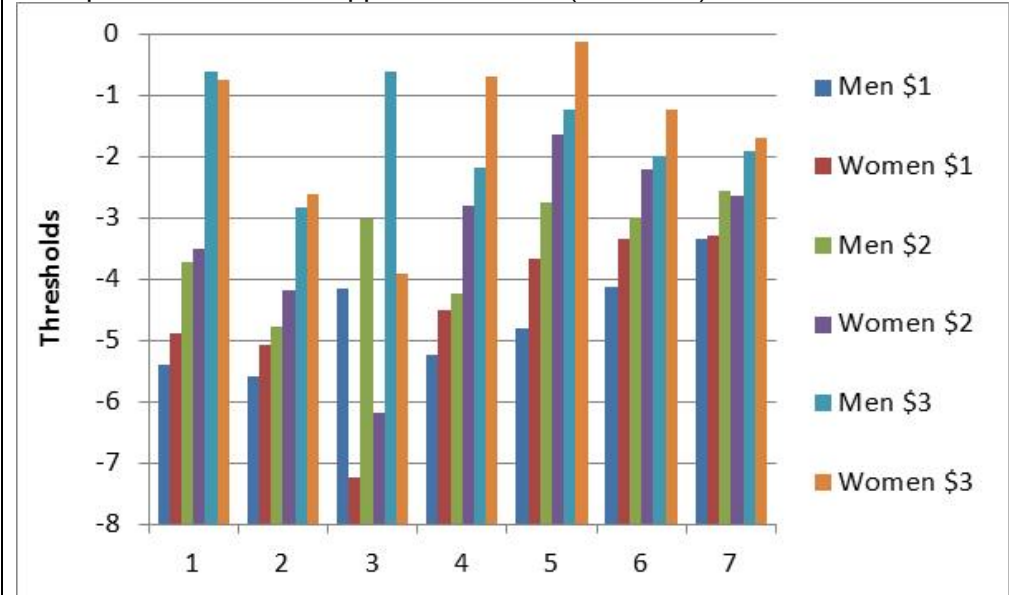
!!! 2 METRIC MODEL FOR WOMEN ALTERNATIVE GROUP
MODEL WOMEN:
! Factor loadings NOW CONSTRAINED EQUAL TO MEN EXCEPT 3
  IADL BY cia1-cia7* (L1-L2 L3a L4-L7);
! Item thresholds all free
  [cia1$1-cia7$1*];
  [cia1$2-cia7$2*];
  [cia1$3-cia7$3*];
! Item residual variances all fixed=1
  cia1-cia7@1;
! Factor mean=0 for identification
! Factor variance NOW ESTIMATED
  [IADL@0]; IADL*;
    
```

Here is the test comparing Metric B to Metric A.
Freeing cia3 helped:

Chi-Square Test for Difference Testing	
Value	5.559
Degrees of Freedom	1
P-Value	0.0184

Number of Free Parameters	51
Chi-Square Test of Model Fit	
Value	58.606*
Degrees of Freedom	33
P-Value	0.0039
Chi-Square Contribution From Each Group	
MEN	24.959
WOMEN	33.646
THIS IS THE TEST OF CONFIGURAL VS. PARTIAL METRIC B INVARIANCE	
Chi-Square Test for Difference Testing	
Value	5.521
Degrees of Freedom	5
P-Value	0.3556
RMSEA (Root Mean Square Error Of Approximation)	
Estimate	0.049
90 Percent C.I.	0.028 0.070
Probability RMSEA <= .05	0.490
CFI/TLI	
CFI	0.999
TLI	0.999

No new modification indices, so we are done with metric!
Let's preview what will happen with scalar (threshold) invariance:



Partial metric invariance solution (factor loadings constrained except cia3)

Group MEN					Group WOMEN				
	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value		Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
IADL BY - CHANGE IN PROBIT FOR ONE-UNIT CHANGE IN THETA					IADL BY				
CIA1	4.189	0.454	9.221	0.000	CIA1	4.189	0.454	9.221	0.000
CIA2	4.029	0.557	7.234	0.000	CIA2	4.029	0.557	7.234	0.000
CIA3	3.331	0.519	6.414	0.000	CIA3	6.223	1.252	4.972	0.000
CIA4	4.171	0.506	8.235	0.000	CIA4	4.171	0.506	8.235	0.000
CIA5	2.710	0.300	9.020	0.000	CIA5	2.710	0.300	9.020	0.000
CIA6	2.338	0.261	8.950	0.000	CIA6	2.338	0.261	8.950	0.000
CIA7	1.256	0.174	7.228	0.000	CIA7	1.256	0.174	7.228	0.000
Means MEAN OF THETA FIXED=0 FOR IDENTIFICATION					Means MEAN OF THETA FIXED=0 FOR IDENTIFICATION				
IADL	0.000	0.000	999.000	999.000	IADL	0.000	0.000	999.000	999.000
Thresholds - EXPECTED PROBIT OF Y=0 IF THETA=0					Thresholds				
CIA1\$1	-5.385	0.613	-8.779	0.000	CIA1\$1	-4.885	0.428	-11.407	0.000
CIA1\$2	-3.709	0.551	-6.733	0.000	CIA1\$2	-3.506	0.360	-9.746	0.000
CIA1\$3	-0.602	0.421	-1.430	0.153	CIA1\$3	-0.752	0.236	-3.186	0.001
CIA2\$1	-5.578	0.674	-8.279	0.000	CIA2\$1	-5.083	0.487	-10.446	0.000
CIA2\$2	-4.789	0.645	-7.428	0.000	CIA2\$2	-4.176	0.432	-9.678	0.000
CIA2\$3	-2.816	0.530	-5.311	0.000	CIA2\$3	-2.624	0.361	-7.268	0.000
CIA3\$1	-4.158	0.548	-7.583	0.000	CIA3\$1	-7.242	1.230	-5.890	0.000
CIA3\$2	-3.011	0.505	-5.964	0.000	CIA3\$2	-6.174	1.103	-5.600	0.000
CIA3\$3	-0.605	0.352	-1.718	0.086	CIA3\$3	-3.902	0.854	-4.570	0.000
CIA4\$1	-5.225	0.606	-8.621	0.000	CIA4\$1	-4.493	0.368	-12.197	0.000
CIA4\$2	-4.223	0.555	-7.607	0.000	CIA4\$2	-2.812	0.302	-9.324	0.000
CIA4\$3	-2.191	0.474	-4.620	0.000	CIA4\$3	-0.680	0.236	-2.881	0.004
CIA5\$1	-4.816	0.488	-9.860	0.000	CIA5\$1	-3.660	0.259	-14.134	0.000
CIA5\$2	-2.739	0.351	-7.803	0.000	CIA5\$2	-1.648	0.179	-9.202	0.000
CIA5\$3	-1.244	0.290	-4.285	0.000	CIA5\$3	-0.115	0.147	-0.780	0.435
CIA6\$1	-4.113	0.415	-9.906	0.000	CIA6\$1	-3.350	0.256	-13.091	0.000
CIA6\$2	-2.985	0.339	-8.809	0.000	CIA6\$2	-2.213	0.197	-11.206	0.000
CIA6\$3	-1.995	0.303	-6.595	0.000	CIA6\$3	-1.227	0.168	-7.321	0.000
CIA7\$1	-3.340	0.355	-9.397	0.000	CIA7\$1	-3.299	0.287	-11.504	0.000
CIA7\$2	-2.547	0.252	-10.086	0.000	CIA7\$2	-2.627	0.200	-13.110	0.000
CIA7\$3	-1.907	0.219	-8.717	0.000	CIA7\$3	-1.692	0.142	-11.899	0.000
Variances VARIANCE OF THETA FIXED=1 FOR IDENTIFICATION					Variances VARIANCE OF THETA NOW ESTIMATED				
IADL	1.000	0.000	999.000	999.000	IADL	0.624	0.139	4.473	0.000
Residual Variances ALL FIXED=1 FOR IDENTIFICATION					Residual Variances ALL FIXED=1 FOR IDENTIFICATION				
CIA1	1.000	0.000	999.000	999.000	CIA1	1.000	0.000	999.000	999.000
CIA2	1.000	0.000	999.000	999.000	CIA2	1.000	0.000	999.000	999.000
CIA3	1.000	0.000	999.000	999.000	CIA3	1.000	0.000	999.000	999.000
CIA4	1.000	0.000	999.000	999.000	CIA4	1.000	0.000	999.000	999.000
CIA5	1.000	0.000	999.000	999.000	CIA5	1.000	0.000	999.000	999.000
CIA6	1.000	0.000	999.000	999.000	CIA6	1.000	0.000	999.000	999.000
CIA7	1.000	0.000	999.000	999.000	CIA7	1.000	0.000	999.000	999.000

Model 3a. Full Threshold Invariance Model (all IFA thresholds held equal across groups – Mplus IRT difficulties can still vary)

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ANALYSIS: ESTIMATOR IS WLSMV; PARAMETERIZATION=THETA;
          DIFFTEST=MetricB.dat; ! Compare against partial metric B

SAVEDATA: DIFFTEST=ScalarA.dat; ! Save full scalar A info

!!! MODEL FOR MEN REFERENCE GROUP (same as configural)
MODEL:
! Factor loadings all estimated
  IADL BY cia1-cia7* (L1-L7);
! Item thresholds all free
  [cia1$1-cia7$1*] (T1_1-T1_7);
  [cia1$2-cia7$2*] (T2_1-T2_7);
  [cia1$3-cia7$3*] (T3_1-T3_7);
! Item residual variances all fixed=1
  cia1-cia7@1;
! Factor mean=0 and variance=1 for identification
  [IADL@0]; IADL@1;

!!! 3 SCALAR MODEL FOR WOMEN ALTERNATIVE GROUP
MODEL WOMEN:
! Factor loadings NOW CONSTRAINED EQUAL TO MEN EXCEPT 3
  IADL BY cia1-cia7* (L1-L2 L3a L4-L7);
! Item thresholds all CONSTRAINED EQUAL TO MEN BY OMISSION

! Item residual variances all fixed=1
  cia1-cia7@1;
! Factor mean NOW ESTIMATED
! Factor variance NOW ESTIMATED
  [IADL*]; IADL*;
    
```

The DIFFTEST chi-square is significant, and the modification indices suggest that cia3 threshold 3 is the biggest problem. This is not surprising given that its loading differed, too (but I thought I'd try to constrain cia3's thresholds anyway given that there are only seven items). Given the other mention of the "intercept" for cia3, let's see what happens when we free all the cia3 thresholds between groups.

MODEL FIT INFORMATION					
Number of Free Parameters					31
Chi-Square Test of Model Fit					
Value				134.476*	
Degrees of Freedom				53	
P-Value				0.0000	
Chi-Square Contributions From Each Group					
MEN				88.185	
WOMEN				46.291	
THIS IS THE TEST OF PARTIAL METRIC B VS. FULL SCALAR A INVARIANCE					
Chi-Square Test for Difference Testing					
Value				91.663	
Degrees of Freedom				20	
P-Value				0.0000	
RMSEA (Root Mean Square Error Of Approximation)					
Estimate				0.070	
90 Percent C.I.				0.055	0.084
Probability RMSEA <= .05				0.014	
CFI/TLI					
CFI				0.998	
TLI				0.998	
MODEL MODIFICATION INDICES					
	M.I.	E.P.C.	Std E.P.C.	StdYX	E.P.C.
Group MEN					
Means/Intercepts/Thresholds					
[CIA1]	10.619	-1.055	-1.055	-0.267	
[CIA2]	4.043	-0.703	-0.703	-0.170	
[CIA3]	40.682	-9.940	-9.940	-1.361	
[CIA4]	4.390	0.712	0.712	0.170	
[CIA5]	16.374	0.927	0.927	0.331	
[CIA6]	4.015	0.427	0.427	0.172	
[IADL]	40.339	-4.584	-4.584	-4.584	
[CIA1\$3]	6.828	0.628	0.628	0.159	
[CIA3\$1]	6.321	-2.568	-2.568	-0.352	
[CIA3\$3]	26.579	3.043	3.043	0.417	
[CIA4\$3]	4.568	-0.544	-0.544	-0.130	
[CIA5\$2]	4.494	-0.409	-0.409	-0.146	
[CIA5\$3]	8.185	-0.460	-0.460	-0.164	

Model 3b. Partial Threshold Invariance Model (freeing all cia3 thresholds between groups)

<pre> ANALYSIS: ESTIMATOR IS WLSMV; PARAMETERIZATION=THETA; DIFFTEST=MetricB.dat; ! Compare against partial metric B SAVEDATA: DIFFTEST=ScalarB.dat; ! Save partial scalar B info !!! MODEL FOR MEN REFERENCE GROUP (same as configural) MODEL: ! Factor loadings all estimated IADL BY cia1-cia7* (L1-L7); ! Item thresholds all free [cia1\$1-cia7\$1*] (T1_1-T1_7); [cia1\$2-cia7\$2*] (T2_1-T2_7); [cia1\$3-cia7\$3*] (T3_1-T3_7); ! Item residual variances all fixed=1 cial-cia7@1; ! Factor mean=0 and variance=1 for identification [IADL@0]; IADL@1; !!! 3 SCALAR MODEL FOR WOMEN ALTERNATIVE GROUP MODEL WOMEN: ! Factor loadings NOW CONSTRAINED EQUAL TO MEN EXCEPT 3 IADL BY cia1-cia7* (L1-L2 L3a L4-L7); ! Item thresholds otherwise CONSTRAINED EQUAL TO MEN BY OMISSION [cia3\$1* cia3\$2* cia3\$3*]; ! 3b ! Item residual variances all fixed=1 cial-cia7@1; ! Factor mean NOW ESTIMATED ! Factor variance NOW ESTIMATED [IADL*]; IADL*; Threshold for Men... CIA3\$1 -4.107 0.525 -7.820 0.000 CIA3\$2 -2.978 0.487 -6.119 0.000 CIA3\$3 -0.599 0.346 -1.729 0.084 Threshold for Women... CIA3\$1 -8.825 1.576 -5.600 0.000 CIA3\$2 -7.741 1.447 -5.350 0.000 CIA3\$3 -5.445 1.208 -4.509 0.000 </pre>	<pre> MODEL FIT INFORMATION Number of Free Parameters 34 Chi-Square Test of Model Fit Value 96.673* Degrees of Freedom 50 P-Value 0.0001 Chi-Square Contributions From Each Group MEN 53.397 WOMEN 43.276 THIS IS THE TEST OF PARTIAL METRIC B VS. PARTIAL SCALAR B INVARIANCE Chi-Square Test for Difference Testing Value 44.797 Degrees of Freedom 17 P-Value 0.0003 RMSEA (Root Mean Square Error Of Approximation) Estimate 0.054 90 Percent C.I. 0.038 0.070 Probability RMSEA <= .05 0.315 CFI/TLI CFI 0.999 TLI 0.999 MODEL MODIFICATION INDICES Group MEN Means/Intercepts/Thresholds [CIA1] 13.849 -1.287 -1.287 -0.295 [CIA2] 4.520 -0.730 -0.730 -0.173 [CIA5] 12.329 0.816 0.816 0.279 [CIA1\$3] 10.577 0.855 0.855 0.196 [CIA5\$3] 5.001 -0.373 -0.373 -0.127 </pre> <p>The DIFFTEST chi-square is still significant, and the modification indices suggest that cia1 threshold 3 is the next to go...</p>
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Model 3c. Partial Threshold Invariance Model (also freeing cia1 threshold 3 between groups)

<pre> ANALYSIS: ESTIMATOR IS WLSMV; PARAMETERIZATION=THETA; DIFFTEST=MetricB.dat; ! Compare against partial metric B SAVEDATA: DIFFTEST=ScalarC.dat; ! Save partial scalar C info !!! MODEL FOR MEN REFERENCE GROUP (same as configural) MODEL: ! Factor loadings all estimated IADL BY cia1-cia7* (L1-L7); ! Item thresholds all free [cia1\$1-cia7\$1*] (T1_1-T1_7); [cia1\$2-cia7\$2*] (T2_1-T2_7); [cia1\$3-cia7\$3*] (T3_1-T3_7); ! Item residual variances all fixed=1 cia1-cia7@1; ! Factor mean=0 and variance=1 for identification [IADL@0]; IADL@1; !!! 3 SCALAR MODEL FOR WOMEN ALTERNATIVE GROUP MODEL WOMEN: ! Factor loadings NOW CONSTRAINED EQUAL TO MEN EXCEPT 3 IADL BY cia1-cia7* (L1-L2 L3a L4-L7); ! Item thresholds otherwise CONSTRAINED EQUAL TO MEN BY OMISSION [cia3\$1* cia3\$2* cia3\$3*]; ! 3b [cia1\$3*]; ! 3c ! Item residual variances all fixed=1 cia1-cia7@1; ! Factor mean NOW ESTIMATED ! Factor variance NOW ESTIMATED [IADL*]; IADL*; Thresholds for Men... CIA1\$1 -5.909 0.584 -10.124 0.000 CIA1\$2 -4.469 0.531 -8.424 0.000 CIA1\$3 -0.620 0.434 -1.429 0.153 Thresholds for Women... CIA1\$1 -5.909 0.584 -10.124 0.000 CIA1\$2 -4.469 0.531 -8.424 0.000 CIA1\$3 -1.937 0.462 -4.193 0.000 </pre>	<pre> MODEL FIT INFORMATION Number of Free Parameters 35 Chi-Square Test of Model Fit Value 87.761* Degrees of Freedom 49 P-Value 0.0006 Chi-Square Contributions From Each Group MEN 46.376 WOMEN 41.385 THIS IS THE TEST OF PARTIAL METRIC B VS. PARTIAL SCALAR C INVARIANCE Chi-Square Test for Difference Testing Value 32.461 Degrees of Freedom 16 P-Value 0.0087 RMSEA (Root Mean Square Error Of Approximation) Estimate 0.050 90 Percent C.I. 0.033 0.067 Probability RMSEA <= .05 0.480 CFI/TLI CFI 0.999 TLI 0.999 MODEL MODIFICATION INDICES M.I. E.P.C. Std E.P.C. StdYX E.P.C. Group MEN Means/Intercepts/Thresholds [CIA1] 4.650 -0.956 -0.956 -0.215 [CIA2] 6.370 -0.884 -0.884 -0.205 [CIA5] 8.713 0.705 0.705 0.236 [CIA2\$3] 5.146 0.635 0.635 0.147 The DIFFTEST chi-square is still significant, and the modification indices suggest that cia2 threshold 3 is the next to go... </pre>
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Model 3d. Partial Threshold Invariance Model (also freeing cia2 threshold 3 between groups)

<pre> ANALYSIS: ESTIMATOR IS WLSMV; PARAMETERIZATION=THETA; DIFFTEST=MetricB.dat; ! Compare against partial metric B SAVEDATA: DIFFTEST=ScalarD.dat; ! Save partial scalar D info !!! MODEL FOR MEN REFERENCE GROUP (same as configural) MODEL: ! Factor loadings all estimated IADL BY cia1-cia7* (L1-L7); ! Item thresholds all free [cia1\$1-cia7\$1*] (T1_1-T1_7); [cia1\$2-cia7\$2*] (T2_1-T2_7); [cia1\$3-cia7\$3*] (T3_1-T3_7); ! Item residual variances all fixed=1 cia1-cia7@1; ! Factor mean=0 and variance=1 for identification [IADL@0]; IADL@1; !!! 3 SCALAR MODEL FOR WOMEN ALTERNATIVE GROUP MODEL WOMEN: ! Factor loadings NOW CONSTRAINED EQUAL TO MEN EXCEPT 3 IADL BY cia1-cia7* (L1-L2 L3a L4-L7); ! Item thresholds otherwise CONSTRAINED EQUAL TO MEN BY OMISSION [cia3\$1* cia3\$2* cia3\$3*]; ! 3b [cia1\$3*]; ! 3c [cia2\$3*]; ! 3d ! Item residual variances all fixed=1 cia1-cia7@1; ! Factor mean NOW ESTIMATED ! Factor variance NOW ESTIMATED [IADL*]; IADL*; Thresholds for Men... CIA2\$1 -6.161 0.682 -9.027 0.000 CIA2\$2 -5.289 0.640 -8.270 0.000 CIA2\$3 -2.929 0.554 -5.282 0.000 Thresholds for Women... CIA2\$1 -6.161 0.682 -9.027 0.000 CIA2\$2 -5.289 0.640 -8.270 0.000 CIA2\$3 -3.852 0.587 -6.567 0.000 </pre>	<pre> MODEL FIT INFORMATION Number of Free Parameters 36 Chi-Square Test of Model Fit Value 82.974* Degrees of Freedom 48 P-Value 0.0013 Chi-Square Contributions From Each Group MEN 42.539 WOMEN 40.435 THIS IS THE TEST OF PARTIAL METRIC B VS. PARTIAL SCALAR D INVARIANCE Chi-Square Test for Difference Testing Value 26.168 Degrees of Freedom 15 P-Value 0.0363 RMSEA (Root Mean Square Error Of Approximation) Estimate 0.048 90 Percent C.I. 0.030 0.065 Probability RMSEA <= .05 0.556 CFI/TLI CFI 0.999 TLI 0.999 MODEL MODIFICATION INDICES M.I. E.P.C. Std E.P.C. StdYX E.P.C. Group MEN Means/Intercepts/Thresholds [CIA1] 5.846 -1.082 -1.082 -0.243 [CIA5] 6.731 0.631 0.631 0.210 [IADL] 999.000 0.000 0.000 0.000 [CIA1\$2] 4.630 0.721 0.721 0.162 </pre> <p>So close... but the DIFFTEST chi-square is still significant, and the modification indices suggest that cia1 threshold 2 is the next to go...</p>
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Model 3e. Partial Threshold Invariance Model (also freeing cia1 threshold 2 between groups)

<pre> ANALYSIS: ESTIMATOR IS WLSMV; PARAMETERIZATION=THETA; DIFFTEST=MetricB.dat; ! Compare against partial metric B SAVEDATA: DIFFTEST=ScalarE.dat; ! Save partial scalar D info !!! MODEL FOR MEN REFERENCE GROUP (same as configural) MODEL: ! Factor loadings all estimated IADL BY cia1-cia7* (L1-L7); ! Item thresholds all free [cia1\$1-cia7\$1*] (T1_1-T1_7); [cia1\$2-cia7\$2*] (T2_1-T2_7); [cia1\$3-cia7\$3*] (T3_1-T3_7); ! Item residual variances all fixed=1 cia1-cia7@1; ! Factor mean=0 and variance=1 for identification [IADL@0]; IADL@1; !!! 3 SCALAR MODEL FOR WOMEN ALTERNATIVE GROUP MODEL WOMEN: ! Factor loadings NOW CONSTRAINED EQUAL TO MEN EXCEPT 3 IADL BY cia1-cia7* (L1-L2 L3a L4-L7); ! Item thresholds otherwise CONSTRAINED EQUAL TO MEN BY OMISSION [cia3\$1* cia3\$2* cia3\$3*]; ! 3b [cia1\$3*]; ! 3c [cia2\$3*]; ! 3d [cia1\$2*]; ! 3e ! Item residual variances all fixed=1 cia1-cia7@1; ! Factor mean NOW ESTIMATED ! Factor variance NOW ESTIMATED [IADL*]; IADL*; </pre>	<p>MODEL FIT INFORMATION</p> <table border="0"> <tr> <td>Number of Free Parameters</td> <td>37</td> </tr> <tr> <td>Chi-Square Test of Model Fit</td> <td></td> </tr> <tr> <td> Value</td> <td>78.437*</td> </tr> <tr> <td> Degrees of Freedom</td> <td>47</td> </tr> <tr> <td> P-Value</td> <td>0.0027</td> </tr> <tr> <td>Chi-Square Contributions From Each Group</td> <td></td> </tr> <tr> <td> MEN</td> <td>38.829</td> </tr> <tr> <td> WOMEN</td> <td>39.578</td> </tr> </table> <p>THIS IS THE TEST OF PARTIAL METRIC B VS. PARTIAL SCALAR E INVARIANCE</p> <table border="0"> <tr> <td>Chi-Square Test for Difference Testing</td> <td></td> </tr> <tr> <td> Value</td> <td>20.323</td> </tr> <tr> <td> Degrees of Freedom</td> <td>14</td> </tr> <tr> <td> P-Value</td> <td>0.1203</td> </tr> </table> <p>RMSEA (Root Mean Square Error Of Approximation)</p> <table border="0"> <tr> <td> Estimate</td> <td>0.046</td> <td></td> </tr> <tr> <td> 90 Percent C.I.</td> <td>0.027</td> <td>0.063</td> </tr> <tr> <td> Probability RMSEA <= .05</td> <td>0.627</td> <td></td> </tr> </table> <p>CFI/TLI</p> <table border="0"> <tr> <td> CFI</td> <td>0.999</td> </tr> <tr> <td> TLI</td> <td>0.999</td> </tr> </table> <p>No more modification indices! Scalar is finally done!</p> <p>The next step is to see if the “residual” variances need to be different between groups. This is only possible (i.e., the model with free residuals is only identified) given at least partial metric and scalar invariance per item.</p> <p>So far the residual variances have been fixed=1 in both groups for identification. We now proceed backwards: we estimated a “bigger” model, in which the residual variances are freed in the alternative women group for the items with at least partial scalar invariance (so all but cia3), and compare it back to our Scalar E model (in which they were fixed=1).</p>	Number of Free Parameters	37	Chi-Square Test of Model Fit		Value	78.437*	Degrees of Freedom	47	P-Value	0.0027	Chi-Square Contributions From Each Group		MEN	38.829	WOMEN	39.578	Chi-Square Test for Difference Testing		Value	20.323	Degrees of Freedom	14	P-Value	0.1203	Estimate	0.046		90 Percent C.I.	0.027	0.063	Probability RMSEA <= .05	0.627		CFI	0.999	TLI	0.999
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Thresholds for Men...				
CIA1\$1	-6.035	0.591	-10.215	0.000
CIA1\$2	-3.832	0.570	-6.728	0.000
CIA1\$3	-0.622	0.435	-1.431	0.152
Thresholds for Women...				
CIA1\$1	-6.035	0.591	-10.215	0.000
CIA1\$2	-4.823	0.544	-8.868	0.000
CIA1\$3	-2.103	0.468	-4.493	0.000

Partial Scalar E invariance solution

Group MEN					Group WOMEN				
	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value		Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
IADL BY - CHANGE IN PROBIT FOR ONE-UNIT CHANGE IN THETA					IADL BY				
CIA1	4.332	0.476	9.091	0.000	CIA1	4.332	0.476	9.091	0.000
CIA2	4.193	0.585	7.163	0.000	CIA2	4.193	0.585	7.163	0.000
CIA3	3.239	0.474	6.826	0.000	CIA3	6.717	1.374	4.889	0.000
CIA4	4.324	0.522	8.286	0.000	CIA4	4.324	0.522	8.286	0.000
CIA5	2.820	0.316	8.932	0.000	CIA5	2.820	0.316	8.932	0.000
CIA6	2.404	0.272	8.851	0.000	CIA6	2.404	0.272	8.851	0.000
CIA7	1.307	0.182	7.183	0.000	CIA7	1.307	0.182	7.183	0.000
Means MEAN OF THETA FIXED=0 FOR IDENTIFICATION					Means MEAN OF THETA NOW ESTIMATED				
IADL	0.000	0.000	999.000	999.000	IADL	-0.314	0.097	-3.239	0.001
Thresholds - EXPECTED PROBIT OF Y=0 IF THETA=0					Thresholds				
CIA1\$1	-6.035	0.591	-10.215	0.000	CIA1\$1	-6.035	0.591	-10.215	0.000
CIA1\$2	-3.832	0.570	-6.728	0.000	CIA1\$2	-4.823	0.544	-8.868	0.000
CIA1\$3	-0.622	0.435	-1.431	0.152	CIA1\$3	-2.103	0.468	-4.493	0.000
CIA2\$1	-6.215	0.686	-9.054	0.000	CIA2\$1	-6.215	0.686	-9.054	0.000
CIA2\$2	-5.343	0.643	-8.305	0.000	CIA2\$2	-5.343	0.643	-8.305	0.000
CIA2\$3	-2.926	0.554	-5.278	0.000	CIA2\$3	-3.925	0.591	-6.645	0.000
CIA3\$1	-4.052	0.508	-7.970	0.000	CIA3\$1	-9.550	1.785	-5.349	0.000
CIA3\$2	-2.933	0.472	-6.208	0.000	CIA3\$2	-8.458	1.649	-5.128	0.000
CIA3\$3	-0.589	0.341	-1.726	0.084	CIA3\$3	-6.121	1.389	-4.406	0.000
CIA4\$1	-5.705	0.561	-10.167	0.000	CIA4\$1	-5.705	0.561	-10.167	0.000
CIA4\$2	-4.188	0.504	-8.309	0.000	CIA4\$2	-4.188	0.504	-8.309	0.000
CIA4\$3	-2.081	0.458	-4.547	0.000	CIA4\$3	-2.081	0.458	-4.547	0.000
CIA5\$1	-4.622	0.368	-12.554	0.000	CIA5\$1	-4.622	0.368	-12.554	0.000
CIA5\$2	-2.590	0.314	-8.239	0.000	CIA5\$2	-2.590	0.314	-8.239	0.000
CIA5\$3	-1.066	0.285	-3.744	0.000	CIA5\$3	-1.066	0.285	-3.744	0.000
CIA6\$1	-4.092	0.337	-12.127	0.000	CIA6\$1	-4.092	0.337	-12.127	0.000
CIA6\$2	-2.962	0.298	-9.926	0.000	CIA6\$2	-2.962	0.298	-9.926	0.000
CIA6\$3	-1.982	0.277	-7.149	0.000	CIA6\$3	-1.982	0.277	-7.149	0.000
CIA7\$1	-3.594	0.295	-12.170	0.000	CIA7\$1	-3.594	0.295	-12.170	0.000
CIA7\$2	-2.880	0.234	-12.322	0.000	CIA7\$2	-2.880	0.234	-12.322	0.000
CIA7\$3	-2.058	0.194	-10.601	0.000	CIA7\$3	-2.058	0.194	-10.601	0.000
Variances VARIANCE OF THETA FIXED=1 FOR IDENTIFICATION					Variances VARIANCE OF THETA ESTIMATED				
IADL	1.000	0.000	999.000	999.000	IADL	0.567	0.125	4.530	0.000
Residual Variances ALL FIXED=1 FOR IDENTIFICATION					Residual Variances ALL FIXED=1 FOR IDENTIFICATION				
CIA1	1.000	0.000	999.000	999.000	CIA1	1.000	0.000	999.000	999.000
CIA2	1.000	0.000	999.000	999.000	CIA2	1.000	0.000	999.000	999.000
CIA3	1.000	0.000	999.000	999.000	CIA3	1.000	0.000	999.000	999.000
CIA4	1.000	0.000	999.000	999.000	CIA4	1.000	0.000	999.000	999.000
CIA5	1.000	0.000	999.000	999.000	CIA5	1.000	0.000	999.000	999.000
CIA6	1.000	0.000	999.000	999.000	CIA6	1.000	0.000	999.000	999.000
CIA7	1.000	0.000	999.000	999.000	CIA7	1.000	0.000	999.000	999.000

Model 4a. Partial Residual Variance Invariance Model (thresholds unconstrained between groups from Scalar E)
This last step for testing measurement invariance proceeds backwards.
Because freeing the residual variances is adding parameters, we must estimate this free residuals model first.

<pre> ANALYSIS: ESTIMATOR IS WLSMV; PARAMETERIZATION=THETA; SAVEDATA: DIFFTEST=ResidualFreeA.dat; ! Save free residual info !!! MODEL FOR MEN REFERENCE GROUP (same as configural) MODEL: ! Factor loadings all estimated IADL BY cia1-cia7* (L1-L7); ! Item thresholds all free [cia1\$1-cia7\$1*] (T1_1-T1_7); [cia1\$2-cia7\$2*] (T2_1-T2_7); [cia1\$3-cia7\$3*] (T3_1-T3_7); ! Item residual variances all fixed=1 cia1-cia7@1; ! Factor mean=0 and variance=1 for identification [IADL@0]; IADL@1; !!! 4 RESIDUAL VARIANCE MODEL FOR WOMEN ALTERNATIVE GROUP MODEL WOMEN: ! Factor loadings NOW CONSTRAINED EQUAL TO MEN EXCEPT 3 IADL BY cia1-cia7* (L1-L2 L3a L4-L7); ! Item thresholds otherwise CONSTRAINED EQUAL TO MEN BY OMISSION [cia3\$1* cia3\$2* cia3\$3*]; ! 3b [cia1\$3*]; ! 3c [cia2\$3*]; ! 3d [cia1\$2*]; ! 3e ! Item residual variances NOW FREE EXCEPT cia3 cia1-cia7*; cia3@1; ! Factor mean STILL ESTIMATED ! Factor variance STILL ESTIMATED [IADL*]; IADL*; </pre>	<pre> (Number of Free Parameters 43 Chi-Square Test of Model Fit Value 72.070* Degrees of Freedom 41 P-Value 0.0019 Chi-Square Contributions From Each Group MEN 29.084 WOMEN 42.986 RMSEA (Root Mean Square Error Of Approximation) Estimate 0.049 90 Percent C.I. 0.029 0.067 Probability RMSEA <= .05 0.515 CFI/TLI CFI 0.999 TLI 0.999 Residual Variances for Men... CIA1 1.000 0.000 999.000 999.000 CIA2 1.000 0.000 999.000 999.000 CIA3 1.000 0.000 999.000 999.000 CIA4 1.000 0.000 999.000 999.000 CIA5 1.000 0.000 999.000 999.000 CIA6 1.000 0.000 999.000 999.000 CIA7 1.000 0.000 999.000 999.000 Residual Variances for Women... CIA1 1.703 0.961 1.772 0.076 CIA2 0.387 0.142 2.720 0.007 CIA3 1.000 0.000 999.000 999.000 CIA4 0.718 0.308 2.334 0.020 CIA5 0.698 0.244 2.857 0.004 CIA6 1.113 0.390 2.856 0.004 CIA7 0.552 0.146 3.784 0.000 </pre>
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Model 4b. Residual Variance Invariance Model (testing all items except cia3)

We now constrain the residual variances to be equal between groups and test decrease in fit (left side is estimating Scalar E again).

```

ANALYSIS: ESTIMATOR IS WLSMV; PARAMETERIZATION=THETA;
              DIFFTEST=ResidualFreeA.dat; ! Compare to free residual

SAVEDATA: DIFFTEST=ResidualFixedB.dat; ! Save fixed B residual info

!!! 4B MODEL IS THE SAME AS SCALAR E

MODEL FIT INFORMATION
Number of Free Parameters          37

Chi-Square Test of Model Fit
  Value          78.437*
  Degrees of Freedom    47
  P-Value          0.0027

Chi-Square Contribution From Each Group
  MEN          38.859
  WOMEN        39.578

THIS IS THE TEST OF FULL RESIDUAL B VS. PARTIAL SCALAR E INVARIANCE
Chi-Square Test for Difference Testing
  Value          11.016
  Degrees of Freedom    6
  P-Value          0.0879

RMSEA (Root Mean Square Error Of Approximation)
  Estimate          0.046
  90 Percent C.I.    0.027  0.063
  Probability RMSEA <= .05    0.627

CFI/TLI
  CFI          0.999
  TLI          0.999

MODEL MODIFICATION INDICES
              M.I.      E.P.C.  Std E.P.C.  StdYX E.P.C.
Group MEN
Variances/Residual Variances
CIA2          5.009      1.006      1.006      0.054
CIA7          9.405      0.632      0.632      0.233

Although DIFFTEST is nonsignificant, it looks like the residual
variance for cia7 wants to be free, too...
    
```

```

ANALYSIS: ESTIMATOR IS WLSMV; PARAMETERIZATION=THETA;
              DIFFTEST=ResidualFreeA.dat; ! Compare to free residual

SAVEDATA: DIFFTEST=ResidualFixedC.dat; ! Save fixed C residual info

!!! 4C MODEL IS THE SAME AS RESIDUAL 4B=SCALAR E EXCEPT:
cia7*;

MODEL FIT INFORMATION for 4c
Number of Free Parameters          38

Chi-Square Test of Model Fit
  Value          74.739*
  Degrees of Freedom    46
  P-Value          0.0047

Chi-Square Contribution From Each Group
  MEN          35.044
  WOMEN        39.696

THIS IS THE TEST OF PARTIAL RESIDUAL C VS. PARTIAL SCALAR E INVARIANCE
Chi-Square Test for Difference Testing
  Value          6.854
  Degrees of Freedom    5
  P-Value          0.2317

RMSEA (Root Mean Square Error Of Approximation)
  Estimate          0.044
  90 Percent C.I.    0.025  0.062
  Probability RMSEA <= .05    0.676

CFI/TLI
  CFI          0.999
  TLI          0.999

No more modification indices! Residual variance is now done!
The last step is to test structural invariance to see if the factor variance
can be constrained across groups:

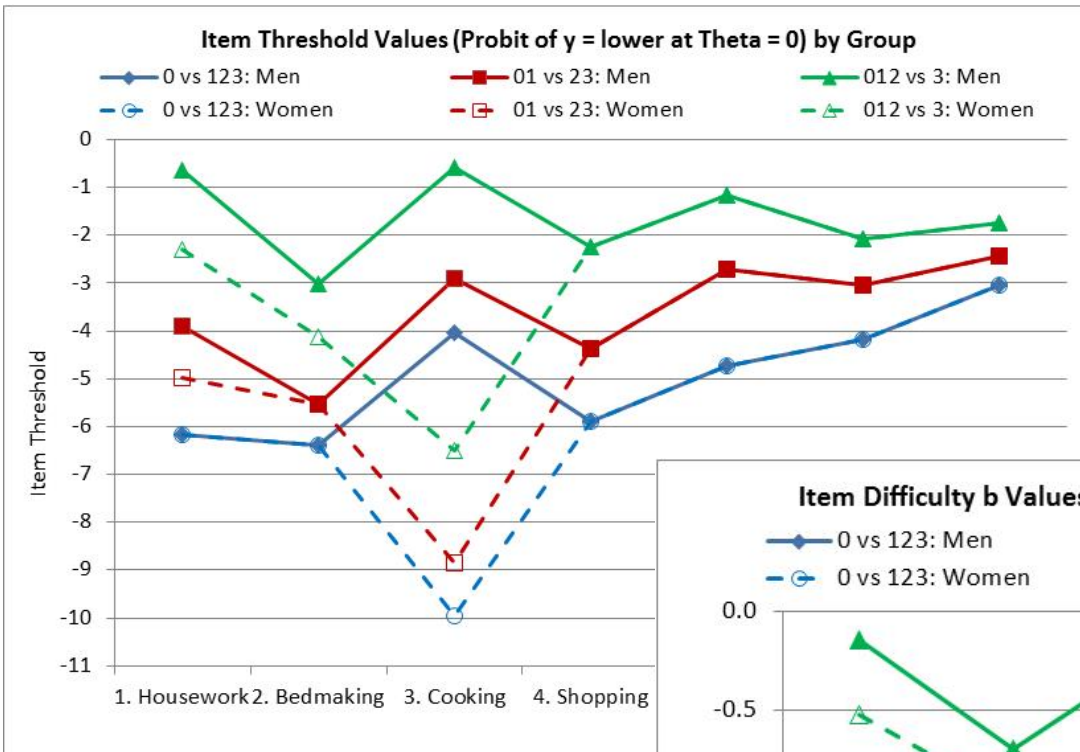
ANALYSIS: ESTIMATOR IS WLSMV; PARAMETERIZATION=THETA;
              DIFFTEST=ResidualFixedC.dat; ! Compare to fixed C residual

SAVEDATA: DIFFTEST=FactorVariance.dat; ! Save fixed variance info

!!! MODEL IS THE SAME AS RESIDUAL 4C EXCEPT:
IADL@1;

Chi-Square Test for Difference Testing: Keep the factor variance different!
  Value          8.818
  Degrees of Freedom    1
  P-Value          0.0030
    
```


Figures from Partial Measurement Invariance Model 4c:

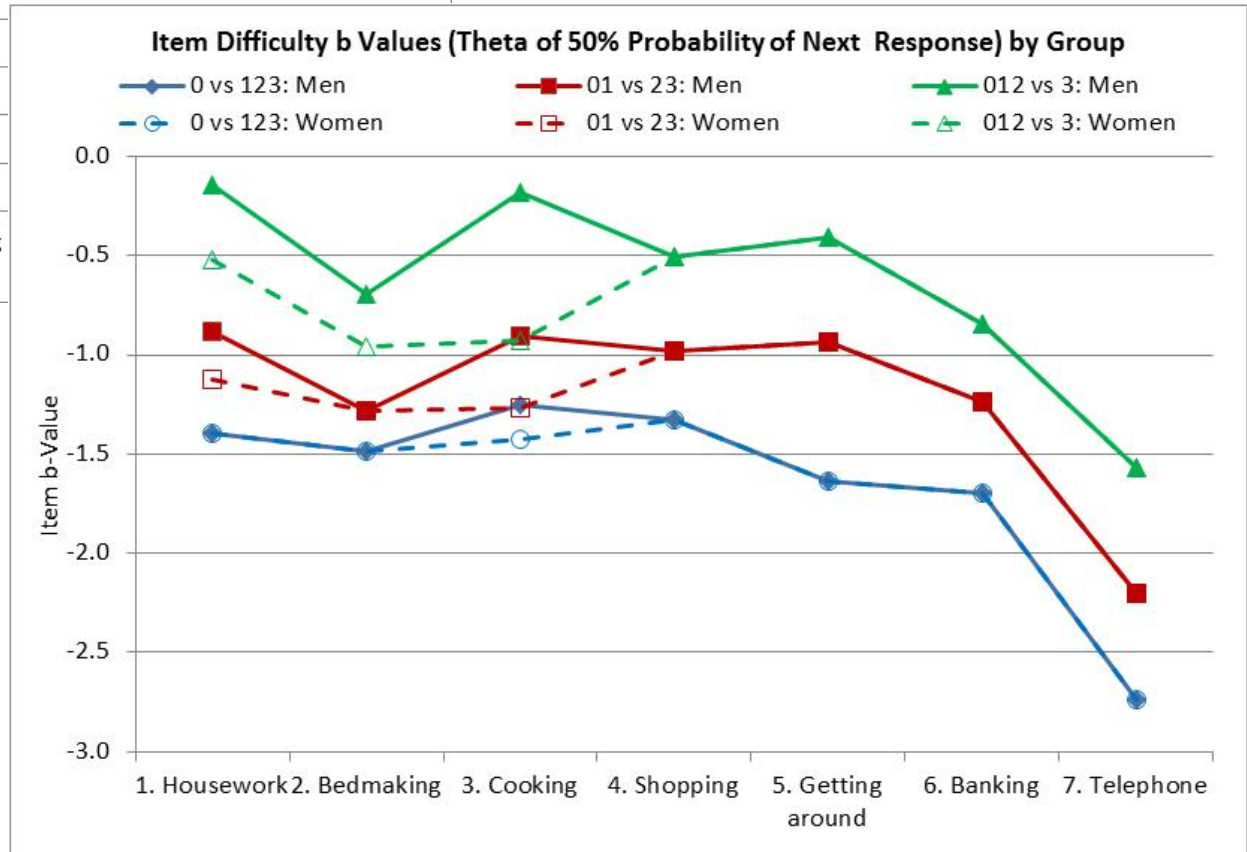


The **thresholds** predict the probit of y =lower response for someone with $\Theta=0$. At $\theta=0$, women have a *lower* probability than men of not being able to do housework, make the bed, or cook.

The **b-values (=threshold/loading)** predict the trait level at which the next response becomes 50%. So in women, it takes less latent trait to do these items.

In addition, women are less variable but less able to live independently than men (as given by the factor variance and factor mean differences, respectively.)

The difference in the loading for cia3 (not pictured) also indicates that cooking is less discriminating (lower a-value) in women than in men (i.e., it is less important for measuring ability to live independently).



Example write-up of these IFA analyses:

The extent to which an item factor model measuring independent daily living (with seven observed items) exhibited measurement invariance and structural invariance between men and women was examined using Mplus v. 7.4 (Muthén & Muthén, 1998-2015). WLSMV estimation including a probit link and the THETA parameterization was used to estimate all models. Thus, model fit statistics describe the fit of the item factor model to the polychoric correlation matrix among the items for each group. Nested model comparisons were conducted using the DIFFTEST procedure. A configural invariance model was initially specified in which a single factor was estimated simultaneously in each group. The factor variance was fixed to 1 and the factor mean was fixed to 0 in each group for identification, such that all item factor loadings (one per item) and thresholds (three per item given four response options) were then estimated. The residual variances are not uniquely identified in the configural invariance model and as such were all constrained to 1 in both groups. As shown in Table 1, the configural invariance model had good fit. The analysis proceeded by applying parameter constraints in successive models to examine potential decreases in fit resulting from measurement or structural non-invariance between men and women, with men as the reference group.

Equality of the unstandardized item factor loadings between groups was then examined in a metric invariance model. The factor variance was fixed to 1 in men for identification but was freely estimated in women; the factor mean was fixed to 0 in both groups for identification. All factor loadings were constrained equal across groups, all item thresholds were estimated, and all residual variances were constrained to 1 across groups. Although the metric invariance model did not fit significantly worse than the configural invariance model, DIFFTEST (6) = 9.40, $p = .15$, the modification indices suggested localized misfit for the constrained loading of item 3 (cooking). After freeing its loading between groups, the partial metric invariance model did not fit significantly worse than the configural invariance model, DIFFTEST (5) = 5.52, $p = .36$, and no loadings were indicated as problematic. The fact that partial metric invariance (i.e., “weak invariance”) held indicates that the items were related to the latent factor equivalently across groups, or more simply, that the same latent factor was being measured in each group. The exception is for the cooking item, which was less related to the trait of independent daily living in women.

Equality of the unstandardized item thresholds across groups was then examined in a scalar invariance model. The factor mean and variance were fixed to 0 and 1, respectively, in men for identification, but the factor mean and variance were then estimated for women. All factor loadings (except item 3) and all item thresholds were constrained equal across groups; all residual variances were still constrained equal to 1 in both groups. The full scalar invariance model A fit significantly worse than the partial metric invariance model, DIFFTEST (20) = 91.66, $p < .01$. Not surprisingly given its differential loading across groups, the modification indices suggested that item 3 was the largest source of the misfit. After freeing item 3’s thresholds, the partial scalar invariance model B still had significantly worse fit than the partial metric invariance model, DIFFTEST (17) = 44.80, $p < .01$. The modification indices suggested that threshold 3 of item 1 was the next largest remaining source of the misfit and should be freed. After doing so, the new partial scalar invariance model C (with all thresholds for item 3 and threshold 3 for item 1 freed) still fit significantly worse than the partial metric invariance model, DIFFTEST (16) = 32.46, $p < .01$. The modification indices suggested that threshold 3 of item 2 was the largest remaining source of the misfit and should be freed. After doing so, the new partial scalar invariance model D (with all thresholds for item 3 and threshold 3 for items 1 and 2 freed) still fit significantly worse than the partial metric invariance model, DIFFTEST (15) = 26.17, $p < .04$. The modification indices suggested that threshold 2 of item 1 was the largest remaining source of the misfit and should be freed. After doing so, the new partial scalar invariance model E (with all thresholds for items 3, thresholds 2 and 3 for item 1, and threshold 3 for item 2 freed) did not fit significantly worse than the partial metric invariance model, DIFFTEST (14) = 20.32, $p = .12$. The fact that partial scalar invariance (i.e., “strong invariance”) held indicates that items 4, 5, 6, and 7 have the same expected response at the same absolute level of the trait, or more simply, that the observed differences in the proportion of responses in each category for those items was due to factor mean differences only. However, at the same absolute level of the IADL factor, thresholds 2 and 3 for item 1, threshold 3 for item 2, and all thresholds for item 3 were more difficult for men, indicating that men have a greater probability of not being able to do housework, make the bed, or cook.

Equality of the unstandardized residual variances across groups was then examined in a residual variance invariance model. The model comparison at this step proceeded backwards, such that a model with all residual variances freely estimated in the women (except for item 3, which was non-invariant) was fitted first, and then compared with a model in which all residual variances were fixed to 1 in the women. The residual variances in the men were all fixed to 1 for identification in both models, and the rest of the model parameters were estimated as described for the last partial scalar invariance model E. Although the model with the residual variances constrained to 1 (to be equal to the men) fit nonsignificantly worse than the model with those residual variances freed, DIFFTEST (6) = 11.02, $p = .09$, the modification indices suggested that the residual variance for item 7 was a source of local misfit and should be freed. After doing so, the new partial residual variance invariance model B did not fit significantly worse than the model with free residual variances in the women group, DIFFTEST (5) = 6.85, $p = .23$, indicating that residual variance for item 7 was significantly smaller for women than men. The fact that partial residual variance invariance (i.e., “strict invariance”) held indicates that the amount of item variance not accounted for by the factor was the same across groups in all other items.

After achieving partial measurement invariance as was just described, structural invariance was then tested with one additional model. The factor variance in the women (which had been estimated freely) was constrained to 1 (i.e., to be equal to the factor variance in men), resulting in a significant decrease in fit relative to the last partial residual invariance model B, DIFFTEST (1) = 8.82, $p < .01$. Thus, women showed significantly less variability in ability to live independently (factor variance of 0.53) than did men (factor variance fixed = 1). The factor mean for women in the partial measurement invariance model was significantly different from 0 (difference = -0.35 , SE = 0.10, $p < .01$), indicating that women were marginally less able to live independently than men (factor mean fixed = 0).

In conclusion, these analyses showed that partial measurement invariance was obtained across men and women—that is, the relationships of the items to the latent factor of independent living were equivalent between men and women. However, items 1, 2, and 3 (housework, bedmaking, and cooking) were systematically more difficult for men than women at the same level of the latent trait. Structural invariance was not obtained, such that women were less variable and less able on average than men. Model parameters from the final model are given in Table 2.

(see excel worksheet for Table 1; Table 2 would have unstandardized and standardized estimates and their SEs)