

**Multiple Group CFA Invariance Example (data from Brown Chapter 7) using MLR Mplus 7.11:
Major Depression Criteria across Men and Women (n = 345 each)**

9 items rated by clinicians on a scale of 0 to 8 (0 = none, 8 = very severely disturbing/disabling)

1. Depressed mood
2. Loss of interest in usual activities
3. Weight/appetite change
4. Sleep disturbance
5. Psychomotor agitation/retardation
6. Fatigue/loss of energy
7. Feelings of worthless/guilt
8. Concentration difficulties
9. Thoughts of death/suicidality

Note: Mplus v. 7 now offers a simplified set of syntax commands to assess invariance. However, I will teach you the manual version so that you learn what you are doing first (then you can take their shortcuts on your own).

Mplus Code to Read in Data:

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TITLE:      Multiple Group Invariance
DATA:      FILE IS MDDALL.dat;           ! Don't need path if in same directory
              FORMAT IS free;             ! Default
              TYPE IS INDIVIDUAL;        ! Default

VARIABLE:  NAMES ARE SEX M1-M9;        ! Every variable in data set
              USEVARIABLES ARE M1-M9;     ! Every variable in MODEL, does not include grouping variable
              GROUPING IS SEX (0=F 1=M);  ! Specify grouping variable
              MISSING ARE ALL (99999);    ! Make sure to specify all missing values

ANALYSIS:  ESTIMATOR IS MLR;           ! For continuous items whose residuals may not be normal

MODEL:      (model syntax goes here, to be changed for each model)

OUTPUT:    SAMPSTAT                   ! Sample descriptives to verify data
              MODINDICES (4)             ! Voodoo to improve model (list if  $\chi^2 > 4$ )
              STDYX                       ! Requests fully standardized solution
              RESIDUAL;                   ! Requests standardized and normalized residuals

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In each case, the model for the reference group (women) is the same and what changes is how the men are allowed to differ. There are two ways to constrain parameters across groups. One is to leave it off the alternative group model, and the other is to use labeled constraints: () after the parameter, only one allowed before a semi-colon. We will use the latter because it is more general.

Model 1. Configural Invariance Model (Everything separate across groups)

<pre> ! REFERENCE GROUP CONFIGURAL MODEL; MODEL: ! Factor loadings (1=marker, rest free) DEPRESS BY M1@1 (L1) M2* (L2) M3* (L3) M4* (L4) M5* (L5) M6* (L6) M7* (L7) M8* (L8) M9* (L9); ! Item intercepts (all free) [M1*] (I1); [M2*] (I2); [M3*] (I3); [M4*] (I4); [M5*] (I5); [M6*] (I6); [M7*] (I7); [M8*] (I8); [M9*] (I9); ! Residual variances (all free) M1* (E1); M2* (E2); M3* (E3); M4* (E4); M5* (E5); M6* (E6); M7* (E7); M8* (E8); M9* (E9); ! Residual covariance (free for 1&2) M1 WITH M2* (ECOV12); ! Factor variance (FREE IN CONFIGURAL MODEL) DEPRESS*; ! Factor mean is 0 (required by Mplus) [DEPRESS@0]; </pre>	<pre> ! MODEL 1: CONFIGURAL MODEL FOR MEN MODEL M: ! Factor loadings (1=marker, rest free) DEPRESS BY M1@1 M2-M9*; ! Item intercepts (all free) [M1-M9*]; ! Residual variances (all free) M1-M9*; ! Residual covariance (free for 1&2) M1 WITH M2*; ! Factor variance (ALWAYS FREE) DEPRESS*; ! Factor mean is still 0 [DEPRESS@0]; </pre>
<pre> Number of Free Parameters 56 Loglikelihood H0 Value -13706.898 H0 Scaling Correction Factor 0.9808 for MLR H1 Value -13657.442 H1 Scaling Correction Factor 1.0143 for MLR Information Criteria Akaike (AIC) 27525.796 Bayesian (BIC) 27784.520 Sample-Size Adjusted BIC 27606.698 (n* = (n + 2) / 24) </pre>	<pre> Chi-Square Test of Model Fit Value 94.175* Degrees of Freedom 52 P-Value 0.0003 Scaling Correction Factor 1.0503 for MLR Chi-Square Contributions From Each Group W 50.418 M 43.756 RMSEA (Root Mean Square Error Of Approximation) Estimate 0.047 90 Percent C.I. 0.031 0.061 Probability RMSEA <= .05 0.632 CFI/TLI CFI 0.963 TLI 0.949 </pre>

UNSTANDARDIZED MODEL RESULTS – NOTE ALL PARAMETERS (EXCEPT MARKER LOADING AND FACTOR MEANS) DIFFER ACROSS GROUPS

Group W					Group M				
	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value		Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
DEPRESS BY (FACTOR LOADINGS)					DEPRESS BY				
M1	1.000	0.000	999.000	999.000	M1	1.000	0.000	999.000	999.000
M2	1.107	0.082	13.564	0.000	M2	1.236	0.102	12.147	0.000
M3	0.729	0.098	7.450	0.000	M3	0.786	0.142	5.543	0.000
M4	0.911	0.116	7.857	0.000	M4	1.165	0.167	6.982	0.000
M5	0.812	0.108	7.510	0.000	M5	0.958	0.144	6.641	0.000
M6	0.924	0.106	8.728	0.000	M6	1.131	0.160	7.090	0.000
M7	0.611	0.087	6.982	0.000	M7	0.766	0.131	5.865	0.000
M8	0.979	0.108	9.024	0.000	M8	1.019	0.145	7.029	0.000
M9	0.484	0.075	6.471	0.000	M9	0.632	0.100	6.299	0.000
M1 WITH (RESIDUAL COVARIANCE)					M1 WITH				
M2	0.393	0.166	2.364	0.018	M2	0.920	0.205	4.499	0.000
Means (FACTOR MEAN)					Means				
DEPRESS	0.000	0.000	999.000	999.000	DEPRESS	0.000	0.000	999.000	999.000
Intercepts (ITEM MEANS PER GROUP IN THIS SCALING)					Intercepts				
M1	4.184	0.089	47.258	0.000	M1	4.171	0.082	50.608	0.000
M2	3.725	0.104	35.848	0.000	M2	3.685	0.104	35.414	0.000
M3	1.952	0.108	18.058	0.000	M3	1.739	0.108	16.098	0.000
M4	3.589	0.114	31.458	0.000	M4	3.357	0.115	29.160	0.000
M5	2.256	0.110	20.522	0.000	M5	2.235	0.109	20.560	0.000
M6	3.955	0.103	38.237	0.000	M6	3.661	0.109	33.598	0.000
M7	3.869	0.106	36.382	0.000	M7	3.421	0.118	29.014	0.000
M8	3.595	0.111	32.331	0.000	M8	3.517	0.112	31.372	0.000
M9	1.205	0.092	13.053	0.000	M9	1.259	0.092	13.649	0.000
Variances (FACTOR VARIANCE)					Variances				
DEPRESS	1.564	0.238	6.576	0.000	DEPRESS	1.049	0.202	5.193	0.000
Residual Variances (ITEM ERROR VARIANCES)					Residual Variances				
M1	1.375	0.194	7.090	0.000	M1	1.498	0.216	6.932	0.000
M2	2.133	0.236	9.049	0.000	M2	2.459	0.274	8.989	0.000
M3	3.551	0.201	17.678	0.000	M3	3.727	0.205	18.167	0.000
M4	3.583	0.272	13.165	0.000	M4	3.547	0.291	12.191	0.000
M5	3.501	0.223	15.733	0.000	M5	3.467	0.236	14.717	0.000
M6	2.677	0.269	9.967	0.000	M6	3.111	0.296	10.521	0.000
M7	3.658	0.276	13.271	0.000	M7	4.599	0.279	16.457	0.000
M8	3.137	0.291	10.785	0.000	M8	3.625	0.296	12.268	0.000
M9	2.831	0.195	14.538	0.000	M9	2.770	0.208	13.291	0.000

Model 2a. Metric Invariance Model (loadings held equal across groups)

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! REFERENCE GROUP METRIC INVARIANCE MODEL;
MODEL:
! Factor loadings (NO MARKER -- ALL FREE NOW)
  DEPRESS BY
    M1* (L1)
    M2* (L2)
    M3* (L3)
    M4* (L4)
    M5* (L5)
    M6* (L6)
    M7* (L7)
    M8* (L8)
    M9* (L9);
! Item intercepts (all free)
  [M1*] (I1); [M2*] (I2); [M3*] (I3);
  [M4*] (I4); [M5*] (I5); [M6*] (I6);
  [M7*] (I7); [M8*] (I8); [M9*] (I9);
! Residual variances (all free)
  M1* (E1); M2* (E2); M3* (E3);
  M4* (E4); M5* (E5); M6* (E6);
  M7* (E7); M8* (E8); M9* (E9);
! Residual covariance (free for 1&2)
  M1 WITH M2* (ECOV12);
! Factor variance (NOW FIXED=1 IN METRIC MODEL)
  DEPRESS@1;
! Factor mean is 0 (required by Mplus)
  [DEPRESS@0];

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! MODEL 2a: METRIC ("WEAK") INVARIANCE MODEL FOR MEN
MODEL M:
! Factor loadings (ALL NOW EQUAL TO WOMEN)
  DEPRESS BY
    M1* (L1)
    M2* (L2)
    M3* (L3)
    M4* (L4)
    M5* (L5)
    M6* (L6)
    M7* (L7)
    M8* (L8)
    M9* (L9);
! Item intercepts (all free)
  [M1-M9*];
! Residual variances (all free)
  M1-M9*;
! Residual covariance (free for 1&2)
  M1 WITH M2*;
! Factor variance (STILL FREE)
  DEPRESS*;
! Factor mean is still 0
  [DEPRESS@0];

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Number of Free Parameters 48

Loglikelihood

H0 Value -13708.862
H0 Scaling Correction Factor 0.9906
for MLR
H1 Value -13657.442
H1 Scaling Correction Factor 1.0143
for MLR

Information Criteria

Akaike (AIC) 27513.724
Bayesian (BIC) 27735.488
Sample-Size Adjusted BIC 27583.069
(n* = (n + 2) / 24)

Did model fit get significantly worse?

Chi-Square Test of Model Fit

Value 99.532*
Degrees of Freedom 60
P-Value 0.0010
Scaling Correction Factor 1.0332
for MLR

Chi-Square Contributions From Each Group

W 52.985
M 46.547

RMSEA (Root Mean Square Error Of Approximation)

Estimate 0.042
90 Percent C.I. 0.027 0.056
Probability RMSEA <= .05 0.814

CFI/TLI

CFI 0.966
TLI 0.959

UNSTANDARDIZED MODEL RESULTS – NOTE NOW FACTOR LOADINGS ARE HELD EQUAL (but standardized loadings won't be yet)

Group W					Group M				
	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value		Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
DEPRESS BY					DEPRESS BY				
M1	1.180	0.082	14.455	0.000	M1	1.180	0.082	14.455	0.000
M2	1.386	0.088	15.667	0.000	M2	1.386	0.088	15.667	0.000
M3	0.888	0.084	10.542	0.000	M3	0.888	0.084	10.542	0.000
M4	1.202	0.091	13.153	0.000	M4	1.202	0.091	13.153	0.000
M5	1.035	0.084	12.301	0.000	M5	1.035	0.084	12.301	0.000
M6	1.191	0.084	14.198	0.000	M6	1.191	0.084	14.198	0.000
M7	0.793	0.092	8.643	0.000	M7	0.793	0.092	8.643	0.000
M8	1.186	0.094	12.595	0.000	M8	1.186	0.094	12.595	0.000
M9	0.647	0.073	8.813	0.000	M9	0.647	0.073	8.813	0.000
M1 WITH					M1 WITH				
M2	0.439	0.158	2.777	0.005	M2	0.862	0.187	4.609	0.000
Means					Means				
DEPRESS	0.000	0.000	999.000	999.000	DEPRESS	0.000	0.000	999.000	999.000
Intercepts					Intercepts				
M1	4.184	0.089	47.258	0.000	M1	4.171	0.082	50.608	0.000
M2	3.725	0.104	35.848	0.000	M2	3.685	0.104	35.414	0.000
M3	1.952	0.108	18.058	0.000	M3	1.739	0.108	16.098	0.000
M4	3.589	0.114	31.458	0.000	M4	3.357	0.115	29.160	0.000
M5	2.256	0.110	20.522	0.000	M5	2.235	0.109	20.560	0.000
M6	3.955	0.103	38.237	0.000	M6	3.661	0.109	33.598	0.000
M7	3.869	0.106	36.382	0.000	M7	3.421	0.118	29.014	0.000
M8	3.595	0.111	32.331	0.000	M8	3.517	0.112	31.372	0.000
M9	1.205	0.092	13.053	0.000	M9	1.259	0.092	13.649	0.000
Variances					Variances				
DEPRESS	1.000	0.000	999.000	999.000	DEPRESS	0.863	0.112	7.727	0.000
Residual Variances					Residual Variances				
M1	1.444	0.189	7.645	0.000	M1	1.435	0.203	7.060	0.000
M2	2.151	0.220	9.794	0.000	M2	2.412	0.245	9.854	0.000
M3	3.556	0.190	18.738	0.000	M3	3.731	0.196	19.064	0.000
M4	3.540	0.261	13.543	0.000	M4	3.617	0.258	14.028	0.000
M5	3.479	0.206	16.850	0.000	M5	3.488	0.216	16.177	0.000
M6	2.648	0.261	10.140	0.000	M6	3.161	0.270	11.689	0.000
M7	3.656	0.271	13.482	0.000	M7	4.619	0.260	17.797	0.000
M8	3.153	0.275	11.465	0.000	M8	3.587	0.276	12.998	0.000
M9	2.827	0.195	14.491	0.000	M9	2.781	0.208	13.395	0.000

Modification indices do not suggest that freeing any loadings between groups would help, so we proceed with loadings fully invariant.

Model 3a. Scalar Invariance Model (all loadings and intercepts held equal across groups)

<pre> ! REFERENCE GROUP SCALAR INVARIANCE MODEL (SAME); MODEL: ! Factor loadings (STILL ALL FREE) DEPRESS BY M1* (L1) M2* (L2) M3* (L3) M4* (L4) M5* (L5) M6* (L6) M7* (L7) M8* (L8) M9* (L9); ! Item intercepts (all free) [M1*] (I1); [M2*] (I2); [M3*] (I3); [M4*] (I4); [M5*] (I5); [M6*] (I6); [M7*] (I7); [M8*] (I8); [M9*] (I9); ! Residual variances (all free) M1* (E1); M2* (E2); M3* (E3); M4* (E4); M5* (E5); M6* (E6); M7* (E7); M8* (E8); M9* (E9); ! Residual covariance (free for 1&2) M1 WITH M2* (ECOV12); ! Factor variance (STILL FIXED=1) DEPRESS@1; ! Factor mean is 0 (required by Mplus) [DEPRESS@0]; </pre>	<pre> ! MODEL 3a: SCALAR ("STRONG") INVARIANCE MODEL FOR MEN MODEL M: ! Factor loadings (ALL STILL EQUAL TO WOMEN) DEPRESS BY M1* (L1) M2* (L2) M3* (L3) M4* (L4) M5* (L5) M6* (L6) M7* (L7) M8* (L8) M9* (L9); ! Item intercepts (ALL NOW EQUAL TO WOMEN NOW) [M1*] (I1); [M2*] (I2); [M3*] (I3); [M4*] (I4); [M5*] (I5); [M6*] (I6); [M7*] (I7); [M8*] (I8); [M9*] (I9); ! Residual variances (all free) M1-M9*; ! Residual covariance (free for 1&2) M1 WITH M2*; ! Factor variance (STILL FREE) DEPRESS*; ! Factor mean is NOW FREE [DEPRESS*]; </pre>
<pre> Number of Free Parameters 40 Loglikelihood H0 Value -13715.097 H0 Scaling Correction Factor 0.9875 for MLR H1 Value -13657.442 H1 Scaling Correction Factor 1.0143 for MLR Information Criteria Akaike (AIC) 27510.194 Bayesian (BIC) 27694.997 Sample-Size Adjusted BIC 27567.981 (n* = (n + 2) / 24) </pre> <p>Did model fit get significantly worse?</p>	<pre> Chi-Square Test of Model Fit Value 111.950* Degrees of Freedom 68 P-Value 0.0006 Scaling Correction Factor 1.0300 for MLR Chi-Square Contributions From Each Group W 58.945 M 53.006 RMSEA (Root Mean Square Error Of Approximation) Estimate 0.042 90 Percent C.I. 0.027 0.055 Probability RMSEA <= .05 0.842 CFI/TLI CFI 0.962 TLI 0.959 </pre>

UNSTANDARDIZED MODEL RESULTS – NOTE NOW FACTOR LOADINGS AND INTERCEPTS ARE HELD EQUAL

Group W					Group M				
	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value		Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
DEPRESS BY					DEPRESS BY				
M1	1.171	0.081	14.385	0.000	M1	1.171	0.081	14.385	0.000
M2	1.377	0.089	15.534	0.000	M2	1.377	0.089	15.534	0.000
M3	0.894	0.084	10.621	0.000	M3	0.894	0.084	10.621	0.000
M4	1.209	0.091	13.343	0.000	M4	1.209	0.091	13.343	0.000
M5	1.033	0.084	12.275	0.000	M5	1.033	0.084	12.275	0.000
M6	1.199	0.083	14.424	0.000	M6	1.199	0.083	14.424	0.000
M7	0.803	0.091	8.853	0.000	M7	0.803	0.091	8.853	0.000
M8	1.184	0.094	12.534	0.000	M8	1.184	0.094	12.534	0.000
M9	0.641	0.074	8.604	0.000	M9	0.641	0.074	8.604	0.000
M1 WITH					M1 WITH				
M2	0.454	0.159	2.852	0.004	M2	0.878	0.185	4.754	0.000
Means					Means (NOW REPRESENTS DIFFERENCE IN FACTOR MEANS)				
DEPRESS	0.000	0.000	999.000	999.000	DEPRESS	-0.112	0.083	-1.345	0.179
Intercepts					Intercepts				
M1	4.240	0.077	54.984	0.000	M1	4.240	0.077	54.984	0.000
M2	3.773	0.092	41.111	0.000	M2	3.773	0.092	41.111	0.000
M3	1.897	0.087	21.735	0.000	M3	1.897	0.087	21.735	0.000
M4	3.541	0.096	37.067	0.000	M4	3.541	0.096	37.067	0.000
M5	2.303	0.090	25.622	0.000	M5	2.303	0.090	25.622	0.000
M6	3.882	0.091	42.556	0.000	M6	3.882	0.091	42.556	0.000
M7	3.711	0.087	42.428	0.000	M7	3.711	0.087	42.428	0.000
M8	3.620	0.094	38.567	0.000	M8	3.620	0.094	38.567	0.000
M9	1.268	0.072	17.592	0.000	M9	1.268	0.072	17.592	0.000
Variances					Variances				
DEPRESS	1.000	0.000	999.000	999.000	DEPRESS	0.864	0.112	7.720	0.000
Residual Variances					Residual Variances				
M1	1.460	0.193	7.576	0.000	M1	1.451	0.200	7.258	0.000
M2	2.166	0.223	9.726	0.000	M2	2.431	0.240	10.124	0.000
M3	3.555	0.191	18.619	0.000	M3	3.730	0.196	19.058	0.000
M4	3.535	0.261	13.520	0.000	M4	3.611	0.258	13.975	0.000
M5	3.478	0.206	16.880	0.000	M5	3.489	0.216	16.166	0.000
M6	2.648	0.260	10.183	0.000	M6	3.161	0.276	11.468	0.000
M7	3.683	0.268	13.766	0.000	M7	4.657	0.277	16.832	0.000
M8	3.155	0.277	11.376	0.000	M8	3.588	0.274	13.119	0.000
M9	2.834	0.192	14.790	0.000	M9	2.788	0.213	13.106	0.000

Model 3b: Although the overall test of scalar invariance holds, the modification indices suggest that freeing the intercept for item 7 between groups would help significantly:

MODEL MODIFICATION INDICES
 Minimum M.I. value for printing the modification index 4.000

	M.I.	E.P.C.	Std E.P.C.	StdYX E.P.C.
Group W				
Means/Intercepts/Thresholds				
[M7]	5.896	0.158	0.158	0.076
Group M				
Means/Intercepts/Thresholds				
[M7]	5.894	-0.219	-0.219	-0.096

Old Intercept 7: 3.711
 New Women Intercept 7: 3.869 ($\approx 3.711 + .158$)
 New Men Intercept 7: 3.493 ($\approx 3.711 + -.219$)

Now re-test for scalar invariance:

! Item intercepts (all free)					! Item intercepts (NOW ALL EQUAL TO WOMEN EXCEPT 7)																																																																																																																																																
[M1*] (I1); [M2*] (I2); [M3*] (I3); [M4*] (I4); [M5*] (I5); [M6*] (I6); [M7*] (I7); [M8*] (I8); [M9*] (I9);					[M1*] (I1); [M2*] (I2); [M3*] (I3); [M4*] (I4); [M5*] (I5); [M6*] (I6); [M7*]; [M8*] (I8); [M9*] (I9);																																																																																																																																																
Number of Free Parameters 41					Chi-Square Test of Model Fit																																																																																																																																																
Loglikelihood					Value 106.031*																																																																																																																																																
H0 Value -13712.050					Degrees of Freedom 67																																																																																																																																																
H0 Scaling Correction Factor for MLR 0.9885					P-Value 0.0017																																																																																																																																																
H1 Value -13657.442					Scaling Correction Factor for MLR 1.0300																																																																																																																																																
H1 Scaling Correction Factor for MLR 1.0143					Chi-Square Contributions From Each Group																																																																																																																																																
Information Criteria					W 56.210																																																																																																																																																
Akaike (AIC) 27506.100					M 49.821																																																																																																																																																
Bayesian (BIC) 27695.523					RMSEA (Root Mean Square Error Of Approximation)																																																																																																																																																
Sample-Size Adjusted BIC 27565.332					Estimate 0.039																																																																																																																																																
(n* = (n + 2) / 24)					90 Percent C.I. 0.024 0.053																																																																																																																																																
					Probability RMSEA <= .05 0.892																																																																																																																																																
					CFI/TLI																																																																																																																																																
					CFI 0.966																																																																																																																																																
					TLI 0.963																																																																																																																																																
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Model 4a. Residual Variance Invariance Model (error variances held equal for all except item 7 because it didn't pass scalar)

<pre> ! REFERENCE GROUP RESIDUAL INVARIANCE MODEL (SAME); MODEL: ! Factor loadings (STILL ALL FREE) DEPRESS BY M1* (L1) M2* (L2) M3* (L3) M4* (L4) M5* (L5) M6* (L6) M7* (L7) M8* (L8) M9* (L9); ! Item intercepts (all free) [M1*] (I1); [M2*] (I2); [M3*] (I3); [M4*] (I4); [M5*] (I5); [M6*] (I6); [M7*] (I7); [M8*] (I8); [M9*] (I9); ! Residual variances (all free) M1* (E1); M2* (E2); M3* (E3); M4* (E4); M5* (E5); M6* (E6); M7* (E7); M8* (E8); M9* (E9); ! Residual covariance (free for 1&2) M1 WITH M2* (ECOV12); ! Factor variance (FIXED=1 IN METRIC MODEL) DEPRESS@1; ! Factor mean is 0 (required by Mplus) [DEPRESS@0]; </pre>	<pre> ! MODEL 4a: RESIDUAL ("STRICT") INVARIANCE MODEL FOR MEN MODEL M: ! Factor loadings (ALL STILL EQUAL TO WOMEN) DEPRESS BY M1* (L1) M2* (L2) M3* (L3) M4* (L4) M5* (L5) M6* (L6) M7* (L7) M8* (L8) M9* (L9); ! Item intercepts (ALL STILL EQUAL TO WOMEN EXCEPT FOR 7) [M1*] (I1); [M2*] (I2); [M3*] (I3); [M4*] (I4); [M5*] (I5); [M6*] (I6); [M7*]; [M8*] (I8); [M9*] (I9); ! Residual variances (ALL EQUAL TO WOMEN NOW EXCEPT 7) M1* (E1); M2* (E2); M3* (E3); M4* (E4); M5* (E5); M6* (E6); M7*; M8* (E8); M9* (E9); ! Residual covariance (free for 1&2) M1 WITH M2*; ! Factor variance (STILL FREE) DEPRESS*; ! Factor mean is STILL FREE [DEPRESS*]; </pre>
<pre> Number of Free Parameters 33 Loglikelihood H0 Value -13714.472 H0 Scaling Correction Factor 1.0053 for MLR H1 Value -13657.442 H1 Scaling Correction Factor 1.0143 for MLR Information Criteria Akaike (AIC) 27494.944 Bayesian (BIC) 27647.406 Sample-Size Adjusted BIC 27542.618 (n* = (n + 2) / 24) </pre> <p>Did model fit get significantly worse?</p>	<pre> Chi-Square Test of Model Fit Value 112.019* Degrees of Freedom 75 P-Value 0.0036 Scaling Correction Factor 1.0182 for MLR Chi-Square Contributions From Each Group W 59.668 M 52.350 RMSEA (Root Mean Square Error Of Approximation) Estimate 0.036 90 Percent C.I. 0.021 0.050 Probability RMSEA <= .05 0.954 CFI/TLI CFI 0.968 TLI 0.969 </pre>

UNSTANDARDIZED MODEL RESULTS - NOTE NOW FACTOR LOADINGS, INTERCEPTS (except 7), AND RESIDUAL VARIANCES (except 7) ARE HELD EQUAL

Group W					Group M				
	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value		Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
DEPRESS BY					DEPRESS BY				
M1	1.167	0.082	14.179	0.000	M1	1.167	0.082	14.179	0.000
M2	1.372	0.089	15.356	0.000	M2	1.372	0.089	15.356	0.000
M3	0.888	0.083	10.657	0.000	M3	0.888	0.083	10.657	0.000
M4	1.204	0.090	13.343	0.000	M4	1.204	0.090	13.343	0.000
M5	1.031	0.084	12.317	0.000	M5	1.031	0.084	12.317	0.000
M6	1.197	0.083	14.495	0.000	M6	1.197	0.083	14.495	0.000
M7	0.787	0.092	8.594	0.000	M7	0.787	0.092	8.594	0.000
M8	1.178	0.093	12.608	0.000	M8	1.178	0.093	12.608	0.000
M9	0.639	0.074	8.600	0.000	M9	0.639	0.074	8.600	0.000
M1 WITH (= to correlation of .27)					M1 WITH (= to correlation of .46)				
M2	0.485	0.160	3.034	0.002	M2	0.833	0.151	5.501	0.000
Means					Means				
DEPRESS	0.000	0.000	999.000	999.000	DEPRESS	-0.091	0.084	-1.084	0.278
Intercepts					Intercepts				
M1	4.228	0.078	53.947	0.000	M1	4.228	0.078	53.947	0.000
M2	3.763	0.093	40.537	0.000	M2	3.763	0.093	40.537	0.000
M3	1.886	0.087	21.609	0.000	M3	1.886	0.087	21.609	0.000
M4	3.528	0.096	36.878	0.000	M4	3.528	0.096	36.878	0.000
M5	2.292	0.090	25.454	0.000	M5	2.292	0.090	25.454	0.000
M6	3.862	0.091	42.537	0.000	M6	3.862	0.091	42.537	0.000
M7	3.869	0.106	36.382	0.000	M7	3.493	0.123	28.380	0.000
M8	3.609	0.094	38.326	0.000	M8	3.609	0.094	38.326	0.000
M9	1.261	0.071	17.668	0.000	M9	1.261	0.071	17.668	0.000
Variances					Variances				
DEPRESS	1.000	0.000	999.000	999.000	DEPRESS	0.883	0.111	7.936	0.000
Residual Variances					Residual Variances				
M1	1.448	0.145	9.955	0.000	M1	1.448	0.145	9.955	0.000
M2	2.301	0.177	12.967	0.000	M2	2.301	0.177	12.967	0.000
M3	3.646	0.143	25.449	0.000	M3	3.646	0.143	25.449	0.000
M4	3.574	0.197	18.123	0.000	M4	3.574	0.197	18.123	0.000
M5	3.479	0.161	21.646	0.000	M5	3.479	0.161	21.646	0.000
M6	2.903	0.199	14.558	0.000	M6	2.903	0.199	14.558	0.000
M7	3.653	0.271	13.464	0.000	M7	4.630	0.260	17.812	0.000
M8	3.367	0.207	16.292	0.000	M8	3.367	0.207	16.292	0.000
M9	2.809	0.143	19.650	0.000	M9	2.809	0.143	19.650	0.000

Modification indices do not suggest that freeing any residual variances between groups would help, so we proceed with them fully invariant.

Model 5a. Residual Covariance Invariance Model (error covariance for 1-2 now held equal)

<pre>! REFERENCE GROUP RES COVARIANCE INVARIANCE MODEL (SAME); MODEL: ! Factor loadings (STILL ALL FREE) DEPRESS BY M1* (L1) M2* (L2) M3* (L3) M4* (L4) M5* (L5) M6* (L6) M7* (L7) M8* (L8) M9* (L9); ! Item intercepts (all free) [M1*] (I1); [M2*] (I2); [M3*] (I3); [M4*] (I4); [M5*] (I5); [M6*] (I6); [M7*] (I7); [M8*] (I8); [M9*] (I9); ! Residual variances (all free) M1* (E1); M2* (E2); M3* (E3); M4* (E4); M5* (E5); M6* (E6); M7* (E7); M8* (E8); M9* (E9); ! Residual covariance (free for 1&2) M1 WITH M2* (ECOV12); ! Factor variance (FIXED=1 IN METRIC MODEL) DEPRESS@1; ! Factor mean is 0 (required by Mplus) [DEPRESS@0];</pre>	<pre>! MODEL 5a: RES COVARIANCE INVARIANCE MODEL FOR MEN MODEL M: ! Factor loadings (ALL STILL EQUAL TO WOMEN) DEPRESS BY M1* (L1) M2* (L2) M3* (L3) M4* (L4) M5* (L5) M6* (L6) M7* (L7) M8* (L8) M9* (L9); ! Item intercepts (ALL STILL EQUAL TO WOMEN EXCEPT FOR 7) [M1*] (I1); [M2*] (I2); [M3*] (I3); [M4*] (I4); [M5*] (I5); [M6*] (I6); [M7*]; [M8*] (I8); [M9*] (I9); ! Residual variances (ALL EQUAL TO WOMEN NOW EXCEPT 7) M1* (E1); M2* (E2); M3* (E3); M4* (E4); M5* (E5); M6* (E6); M7*; M8* (E8); M9* (E9); ! Residual covariance (NOW EQUAL TO WOMEN) M1 WITH M2* (ECOV12); ! Factor variance (STILL FREE) DEPRESS*; ! Factor mean is STILL FREE [DEPRESS*];</pre>
<pre>Number of Free Parameters 32 Loglikelihood H0 Value -13719.118 H0 Scaling Correction Factor 0.9672 for MLR H1 Value -13657.442 H1 Scaling Correction Factor 1.0143 for MLR Information Criteria Akaike (AIC) 27502.235 Bayesian (BIC) 27650.078 Sample-Size Adjusted BIC 27548.465 (n* = (n + 2) / 24)</pre>	<pre>Chi-Square Test of Model Fit Value 119.281* Degrees of Freedom 76 P-Value 0.0011 Scaling Correction Factor 1.0341 for MLR Chi-Square Contributions From Each Group W 62.953 M 56.328 RMSEA (Root Mean Square Error Of Approximation) Estimate 0.039 90 Percent C.I. 0.025 0.052 Probability RMSEA <= .05 0.916 CFI/TLI CFI 0.962 TLI 0.964</pre>

Model fit got significantly worse, so we'll leave it separate.

M1	WITH								
	M2	0.671	0.132	5.075	0.000				→ constrained residual covariance estimate

STRUCTURAL INVARIANCE TESTS
Model 6a. Factor Variance Invariance Model

<pre> ! REFERENCE GROUP FACTOR VARIANCE INVARIANCE MODEL; MODEL: ! Factor loadings (STILL ALL FREE) DEPRESS BY M1* (L1) M2* (L2) M3* (L3) M4* (L4) M5* (L5) M6* (L6) M7* (L7) M8* (L8) M9* (L9); ! Item intercepts (all free) [M1*] (I1); [M2*] (I2); [M3*] (I3); [M4*] (I4); [M5*] (I5); [M6*] (I6); [M7*] (I7); [M8*] (I8); [M9*] (I9); ! Residual variances (all free) M1* (E1); M2* (E2); M3* (E3); M4* (E4); M5* (E5); M6* (E6); M7* (E7); M8* (E8); M9* (E9); ! Residual covariance (free for 1&2) M1 WITH M2* (ECOV12); ! Factor variance (FIXED=1 IN METRIC MODEL) DEPRESS@1; ! Factor mean is 0 (required by Mplus) [DEPRESS@0]; </pre>	<pre> ! MODEL 6a: FACTOR VARIANCE INVARIANCE MODEL FOR MEN MODEL M: ! Factor loadings (ALL STILL EQUAL TO WOMEN) DEPRESS BY M1* (L1) M2* (L2) M3* (L3) M4* (L4) M5* (L5) M6* (L6) M7* (L7) M8* (L8) M9* (L9); ! Item intercepts (ALL STILL EQUAL TO WOMEN EXCEPT FOR 7) [M1*] (I1); [M2*] (I2); [M3*] (I3); [M4*] (I4); [M5*] (I5); [M6*] (I6); [M7*]; [M8*] (I8); [M9*] (I9); ! Residual variances (ALL EQUAL TO WOMEN NOW EXCEPT 7) M1* (E1); M2* (E2); M3* (E3); M4* (E4); M5* (E5); M6* (E6); M7*; M8* (E8); M9* (E9); ! Residual covariance (NOW BACK TO FREE) M1 WITH M2*; ! Factor variance (NOW FIXED TO 1 ALSO) DEPRESS@1; ! Factor mean is STILL FREE [DEPRESS*]; </pre>
<pre> Number of Free Parameters 32 Loglikelihood H0 Value -13714.894 H0 Scaling Correction Factor 1.0106 for MLR H1 Value -13657.442 H1 Scaling Correction Factor 1.0143 for MLR Information Criteria Akaike (AIC) 27493.789 Bayesian (BIC) 27641.631 Sample-Size Adjusted BIC 27540.019 (n* = (n + 2) / 24) </pre> <p>Did model fit get significantly worse?</p>	<pre> Chi-Square Test of Model Fit Value 113.113* Degrees of Freedom 76 P-Value 0.0037 Scaling Correction Factor 1.0158 for MLR Chi-Square Contributions From Each Group W 60.260 M 52.853 RMSEA (Root Mean Square Error Of Approximation) Estimate 0.036 90 Percent C.I. 0.021 0.049 Probability RMSEA <= .05 0.957 CFI/TLI CFI 0.968 TLI 0.969 </pre>

STRUCTURAL INVARIANCE TESTS
Model 7a. Factor Mean Invariance Model

<pre>! REFERENCE GROUP FACTOR VARIANCE INVARIANCE MODEL; MODEL: ! Factor loadings (STILL ALL FREE) DEPRESS BY M1* (L1) M2* (L2) M3* (L3) M4* (L4) M5* (L5) M6* (L6) M7* (L7) M8* (L8) M9* (L9); ! Item intercepts (all free) [M1*] (I1); [M2*] (I2); [M3*] (I3); [M4*] (I4); [M5*] (I5); [M6*] (I6); [M7*] (I7); [M8*] (I8); [M9*] (I9); ! Residual variances (all free) M1* (E1); M2* (E2); M3* (E3); M4* (E4); M5* (E5); M6* (E6); M7* (E7); M8* (E8); M9* (E9); ! Residual covariance (free for 1&2) M1 WITH M2* (ECOV12); ! Factor variance (FIXED=1 IN METRIC MODEL) DEPRESS@1; ! Factor mean is 0 (required by Mplus) [DEPRESS@0];</pre>	<pre>! MODEL 7a: FACTOR MEAN INVARIANCE MODEL FOR MEN MODEL M: ! Factor loadings (ALL STILL EQUAL TO WOMEN) DEPRESS BY M1* (L1) M2* (L2) M3* (L3) M4* (L4) M5* (L5) M6* (L6) M7* (L7) M8* (L8) M9* (L9); ! Item intercepts (ALL STILL EQUAL TO WOMEN EXCEPT FOR 7) [M1*] (I1); [M2*] (I2); [M3*] (I3); [M4*] (I4); [M5*] (I5); [M6*] (I6); [M7*]; [M8*] (I8); [M9*] (I9); ! Residual variances (ALL EQUAL TO WOMEN NOW EXCEPT 7) M1* (E1); M2* (E2); M3* (E3); M4* (E4); M5* (E5); M6* (E6); M7*; M8* (E8); M9* (E9); ! Residual covariance (NOW BACK TO FREE) M1 WITH M2*; ! Factor variance (NOW FIXED TO 1 ALSO) DEPRESS@1; ! Factor mean is NOW FIXED TO 0 TOO [DEPRESS@0];</pre>
<pre>Number of Free Parameters 31 Loglikelihood H0 Value -13715.514 H0 Scaling Correction Factor 1.0106 for MLR H1 Value -13657.442 H1 Scaling Correction Factor 1.0143 for MLR Information Criteria Akaike (AIC) 27493.027 Bayesian (BIC) 27636.250 Sample-Size Adjusted BIC 27537.813 (n* = (n + 2) / 24)</pre>	<pre>Chi-Square Test of Model Fit Value 114.340* Degrees of Freedom 77 P-Value 0.0037 Scaling Correction Factor 1.0158 for MLR Chi-Square Contributions From Each Group W 60.831 M 53.509 RMSEA (Root Mean Square Error Of Approximation) Estimate 0.036 90 Percent C.I. 0.021 0.049 Probability RMSEA <= .05 0.960 CFI/TLI CFI 0.967 TLI 0.970</pre>

Means
 DEPRESS -0.094 0.085 -1.098 0.272 → mean difference from PREVIOUS model 6 WAS NOT SIGNIFICANT

OUR FINAL INVARIANCE MODEL – PARTIAL MEASUREMENT INVARIANCE, FULL STRUCTURAL INVARIANCE

Group W					Group M				
	Estimate	S.E.	Est./S.E.	Two-Tailed P-Value		Estimate	S.E.	Est./S.E.	Two-Tailed P-Value
DEPRESS BY					DEPRESS BY				
M1	1.135	0.068	16.637	0.000	M1	1.135	0.068	16.637	0.000
M2	1.336	0.075	17.802	0.000	M2	1.336	0.075	17.802	0.000
M3	0.860	0.077	11.228	0.000	M3	0.860	0.077	11.228	0.000
M4	1.168	0.083	14.063	0.000	M4	1.168	0.083	14.063	0.000
M5	1.001	0.076	13.194	0.000	M5	1.001	0.076	13.194	0.000
M6	1.161	0.077	15.096	0.000	M6	1.161	0.077	15.096	0.000
M7	0.766	0.086	8.914	0.000	M7	0.766	0.086	8.914	0.000
M8	1.144	0.082	13.946	0.000	M8	1.144	0.082	13.946	0.000
M9	0.622	0.069	9.000	0.000	M9	0.622	0.069	9.000	0.000
M1 WITH (= to correlation of .27)					M1 WITH (= to correlation of .46)				
M2	0.485	0.159	3.047	0.002	M2	0.829	0.152	5.448	0.000
Means					Means				
DEPRESS	0.000	0.000	999.000	999.000	DEPRESS	0.000	0.000	999.000	999.000
Intercepts					Intercepts				
M1	4.176	0.060	69.283	0.000	M1	4.176	0.060	69.283	0.000
M2	3.702	0.074	50.291	0.000	M2	3.702	0.074	50.291	0.000
M3	1.845	0.077	24.121	0.000	M3	1.845	0.077	24.121	0.000
M4	3.473	0.081	42.797	0.000	M4	3.473	0.081	42.797	0.000
M5	2.245	0.077	29.048	0.000	M5	2.245	0.077	29.048	0.000
M6	3.808	0.075	50.564	0.000	M6	3.808	0.075	50.564	0.000
M7	3.842	0.104	37.048	0.000	M7	3.448	0.116	29.819	0.000
M8	3.556	0.079	45.035	0.000	M8	3.556	0.079	45.035	0.000
M9	1.232	0.065	18.878	0.000	M9	1.232	0.065	18.878	0.000
Variances					Variances				
DEPRESS	1.000	0.000	999.000	999.000	DEPRESS	1.000	0.000	999.000	999.000
Residual Variances					Residual Variances				
M1	1.447	0.145	9.949	0.000	M1	1.447	0.145	9.949	0.000
M2	2.295	0.178	12.893	0.000	M2	2.295	0.178	12.893	0.000
M3	3.649	0.143	25.557	0.000	M3	3.649	0.143	25.557	0.000
M4	3.576	0.197	18.171	0.000	M4	3.576	0.197	18.171	0.000
M5	3.478	0.161	21.617	0.000	M5	3.478	0.161	21.617	0.000
M6	2.906	0.199	14.596	0.000	M6	2.906	0.199	14.596	0.000
M7	3.654	0.271	13.478	0.000	M7	4.625	0.260	17.769	0.000
M8	3.368	0.207	16.275	0.000	M8	3.368	0.207	16.275	0.000
M9	2.807	0.143	19.666	0.000	M9	2.807	0.143	19.666	0.000

Write-up of CFA with MLR Multiple Group Invariance Model Comparisons (Table 1 for model fit in Excel workbook):

The extent to which a confirmatory factor model measuring depression (with nine items each on a 9-point response scale) exhibited measurement and structural invariance between women and men was examined using Mplus v. 7.11 (Muthén & Muthén, 1998-2012). Robust maximum likelihood (MLR) estimation was used for all analyses; accordingly, nested model comparisons were conducted using the $-2LL$ rescaled difference test. Women served as the reference group in all invariance models. A configural invariance model was initially specified in which single-factor models were estimated simultaneously within each group; the first item's loading was fixed to 1 and the factor mean was fixed to 0 for identification in each group. A residual covariance between items 1 and 2 was also estimated in each group as suggested by previous results. As shown in Table 1, the configural model had good fit, and thus a series of model constraints were then applied in successive models to examine potential decreases in fit resulting from measurement or structural non-invariance.

Equality of the unstandardized item factor loadings across groups was then examined in a metric invariance model in which the factor variance was fixed to 1 in women but was freely estimated in men; the factor means were fixed to 0 in both groups. All factor loadings were constrained to be equal across groups; all intercepts and residual variances (and the residual covariance between items 1 and 2) were still permitted to vary across groups. The metric invariance model fit well (see Table 1) and did not result in a significant decrease in fit relative to the configural model, $-2\Delta LL(8) = 4.26$, $p = .83$. The modification indices suggested no points of localized strain among the constrained loadings. The fact that 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.

Equality of the unstandardized item intercepts across groups was then examined in a scalar invariance model. The factor variance and mean were fixed to 1 and 0, respectively, for identification in the women, but the factor variance and mean were then estimated in the men. All factor loadings and item intercepts were constrained to be equal across groups; all residual variances (and the residual covariance between items 1 and 2) were still permitted to differ across groups. The scalar invariance model fit well (see Table 1) and did not result in a significant decrease in fit relative to the metric invariance model, $-2\Delta LL(8) = 12.39$, $p = .13$. However, examination of the modification indices suggested a point of localized strain such that model fit would be significantly improved by allowing the intercept for item 7 ("feelings of worthless or guilt") to differ between groups. A partial scalar invariance model was thus estimated in which the intercept for item 7 was allowed to differ between groups, resulting in a good-fitting model. The partial scalar invariance did not fit significantly worse than the metric invariance model, $-2\Delta LL(7) = 6.36$, $p = .50$, indicating that partial scalar invariance did hold. The factor that partial scalar invariance (i.e., "strong invariance") held indicates that both groups have the same expected item response at the same absolute level of the trait, or more simply, that the observed differences in item means between groups is due to factor mean differences only. The exception to this is item 7, for which women are expected to have a higher item response than men at the same absolute trait level of depression.

Equality of the unstandardized residual variances across groups was then examined in a residual variance invariance model. As in the partial scalar invariance model, the factor variance and mean were fixed to 1 and 0, respectively, for identification in the women, but the factor variance and mean were still estimated in the men. All factor loadings, item intercepts (except for item 7), and all residual variances (except for item 7) were constrained to be equal across groups; the residual covariance between item 1 and 2 was still permitted to differ across groups. The residual variance invariance model fit well (see Table 1) and did not result in significant decrease in fit relative to the partial scalar invariance model, $-2\Delta LL(8) = 5.27$, $p = .73$. The modification indices suggested no points of localized strain among the constrained residual variances. The fact that 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. Finally, equality of the residual covariance between items 1 and 2 across groups was tested and resulted in a significant decrease in fit relative to the residual invariance model, $-2\Delta LL(1) = 4.18$, $p = .04$, indicating that the residual relationship between

items 1 and 2 differed significantly between men and women. The residual covariance between items 1 and 2 was thus permitted to vary across groups in further models.

After achieving partial measurement invariance as just described, structural invariance was then tested with two additional models. First, the factor variance in men (which had been estimated freely) was constrained to 1 (i.e., to be equal to the factor variance in the women), resulting in a nonsignificant decrease in fit relative to the residual invariance model, $-2\Delta LL(1) = 1.01$, $p = .31$. Thus, men and women had equivalent amounts of individual differences in depression. Second, the factor mean in men (which had been estimated freely) was constrained to 0 (i.e., to be equal to the factor mean in women), resulting in a nonsignificant decrease in fit relative to the factor variance invariance model, $-2\Delta LL(1) = 1.23$, $p = .27$, indicating that men and women had comparable amounts of depression on average. Thus, in conclusion, these analyses showed that partial measurement invariance was obtained between men and women – that is, the relationships of the items to the latent factor of depression were equivalent in both groups (except for the intercept and residual variance for item 7). These analyses also showed that full structural invariance was obtained between men and women, such that both groups had the same amount of depression and interindividual variation in depression as measured by these nine items. The fact that both the factor variances and item residual variances could be constrained equal across groups also indicates equal reliability of the items (i.e., equal standardized factor loadings) across groups, with the exception of item 7. Model parameters from the final invariance model are given in Table 2.

Table 1

Model fit statistics for tests of multiple group measurement and structural invariance

Model	# Free Parms	Chi-Square Value	Chi-Square Scale Factor	Chi-Square DF	Chi-Square p-value	CFI	RMSEA Estimate	RMSEA Lower CI	RMSEA Higher CI	RMSEA p-value
1. Configural Model	56	94.175	1.0503	52	0.0003	0.963	0.047	0.031	0.061	0.632
2a. Metric Model	48	99.532	1.0332	60	0.0010	0.966	0.042	0.027	0.056	0.814
3a. Scalar Model	40	111.950	1.0300	68	0.0006	0.962	0.042	0.027	0.055	0.842
3b. Partial Scalar (no Item 7)	41	106.031	1.0300	67	0.0017	0.966	0.039	0.024	0.053	0.892
4a. Residual (no Item 7)	33	112.019	1.0182	75	0.0036	0.968	0.036	0.021	0.050	0.954
5a. Residual Covariance	32	119.281	1.0341	76	0.0011	0.962	0.039	0.025	0.052	0.916
6a. Factor Variance	32	113.113	1.0158	76	0.0037	0.968	0.036	0.021	0.049	0.957
7a. Factor Mean	31	114.340	1.0158	77	0.0037	0.967	0.036	0.021	0.049	0.960

Table 2 would have actual model parameters.... (unstandardized and standardized estimates and their SEs, so 4 columns)