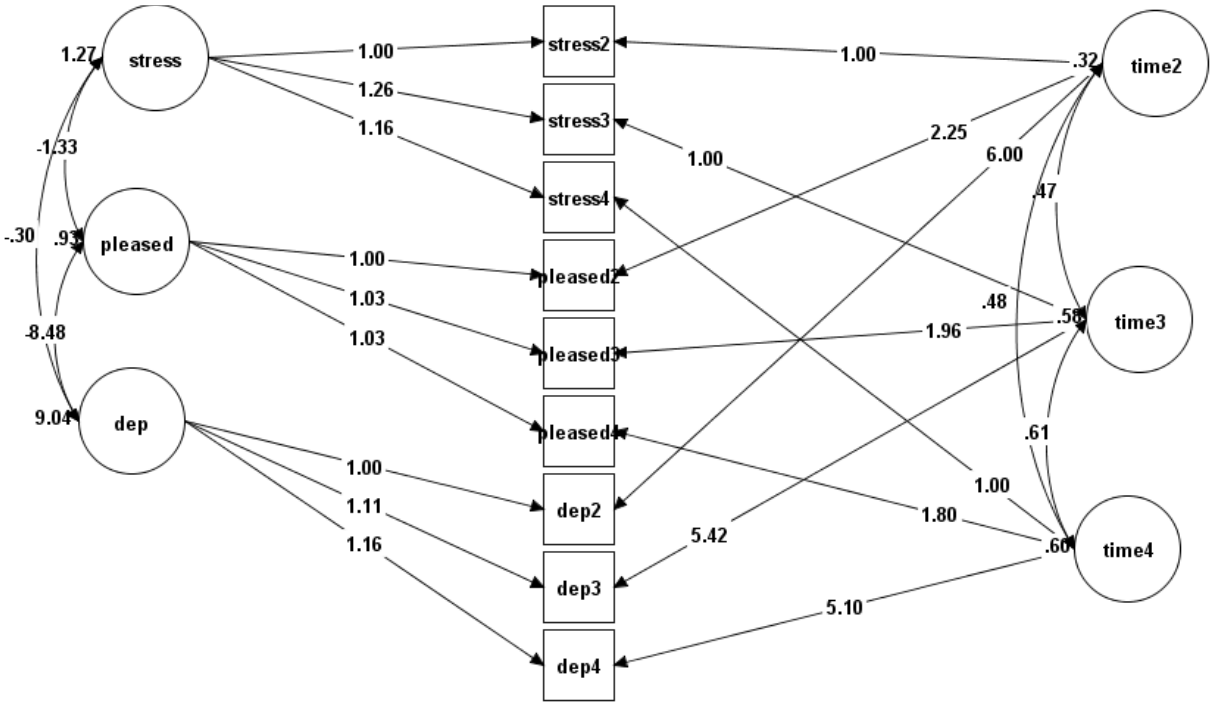
# PSY 9555A (Oct 16): CFA Extensions (Invariance and Means)
# Multi-Trait Multi-Method Model

```
model:
stress by stress2 stress3 stress4;!trait1
pleased by pleased2 pleased3 pleased4;!trait2
dep by dep2 dep3 dep4;!trait3
Time2 by stress2 pleased2 dep2;!method1 (not really a method but capturing variance associated with Time2)
Time3 by stress3 pleased3 dep3;!method2
Time4 by stress4 pleased4 dep4;!method3
stress with pleased dep;
pleased with dep;
time2 with time3 time4;
time3 with time4;
time2 - time4 with stress - dep @0;!fixing at 0 any correlations between the trait and method correlations
output: sampstat residual stdyx tech4; !note that tech4 outputs correlations among latent variables
```

This model did not converge

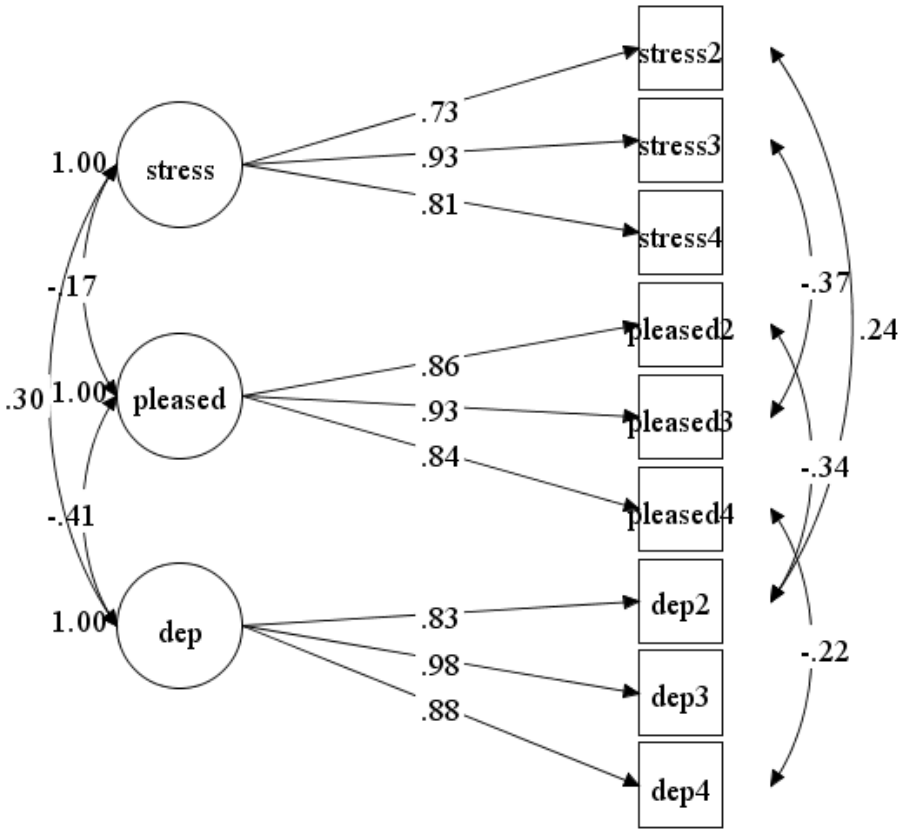


# Multi-Trait Multi-Method Model: Correlated Residuals

```
model:
stress by stress2 stress3 stress4;
pleased by pleased2 pleased3 pleased4;
dep by dep2 dep3 dep4;
stress with pleased dep;
stress2 with pleased2 dep2;
pleased2 with dep2;
stress3 with pleased3 dep3;
pleased3 with dep3;
stress4 with pleased4 dep4;
pleased4 with dep4;
output: sampstat residual stdyx tech4;
```

```
Chi-Square Test of Model Fit

          Value                             21.380*
          Degrees of Freedom                   15
          P-Value                          0.1251
          Scaling Correction Factor        1.0853
            for MLR

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                          0.033
          90 Percent C.I.                   0.000
          Probability RMSEA <= .05          0.796

CFI/TLI

          CFI                               0.995
          TLI                               0.988

SRMR (Standardized Root Mean Square Residual)

          Value                             0.025
```

Standardized solution
Non-significant coefficients/paths removed



# Reliability of Latent Variables

| | Estimate | S.E. | Est./S.E. | Two-Tailed P-Value |
|---|---|---|---|---|
| SEQUENT BY | | | | |
| HANDMOV | 1.000 | 0.000 | 999.000 | 999.000 |
| NUMBREC | 1.147 | 0.181 | 6.341 | 0.000 |
| WORDORD | 1.388 | 0.219 | 6.341 | 0.000 |
| SIMULT BY | | | | |
| GESCLOS | 1.000 | 0.000 | 999.000 | 999.000 |
| TRIANGLE | 1.445 | 0.227 | 6.353 | 0.000 |
| SPATMEM | 2.029 | 0.335 | 6.062 | 0.000 |
| MATANALG | 1.212 | 0.212 | 5.717 | 0.000 |
| PHOTSER | 1.727 | 0.265 | 6.521 | 0.000 |
| SIMULT WITH | | | | |
| SEQUENT | 1.271 | 0.324 | 3.918 | 0.000 |
| Variances | | | | |
| SEQUENT | 2.839 | 0.838 | 3.389 | 0.001 |
| SIMULT | 1.835 | 0.530 | 3.460 | 0.001 |
| Residual Variances | | | | |
| HANDMOV | 8.664 | 0.938 | 9.237 | 0.000 |
| NUMBREC | 1.998 | 0.414 | 4.830 | 0.000 |
| WORDORD | 2.902 | 0.604 | 4.801 | 0.000 |
| GESCLOS | 5.419 | 0.585 | 9.261 | 0.000 |
| TRIANGLE | 3.425 | 0.458 | 7.479 | 0.000 |
| SPATMEM | 9.998 | 1.202 | 8.320 | 0.000 |
| MATANALG | 5.104 | 0.578 | 8.837 | 0.000 |
| PHOTSER | 3.483 | 0.537 | 6.482 | 0.000 |

$$\hat{\rho}_{X_i X_i} = \frac{\left(\sum \hat{\lambda}_i\right)^2 \hat{\phi}}{\left(\sum \hat{\lambda}_i\right)^2 \hat{\phi} + \sum \hat{\theta}_{ii}}$$

In Kline (Raykov, 1997, 2004)
Use unstandardized solution

Reliability of SEQUENT

(1.00+1.147+1.388)^2 = 12.496
12.496 x 2.839 = 35.477
35.477 / 35.477 +(8.664+1.998+2.902) =.723

See Kline p. 242 for other equations
Involving correlated errors

## Modeling Means

- So far we have modeled the sample/observed  var-cov matrix
- It is also possible to model the means of the observed variables and latent variables
- Useful to compare groups, experimental conditions, and longitudinal data
- Advantage over t-tests, ANOVA, conventional repeated measures designs:
    - Possibility to first evaluate measurement invariance across groups or longitudinal waves
- Main caveat: having enough subjects in each condition
- Alternative procedure to compare groups in SEM – MIMIC model

## Understanding Means and Intercepts in SEM

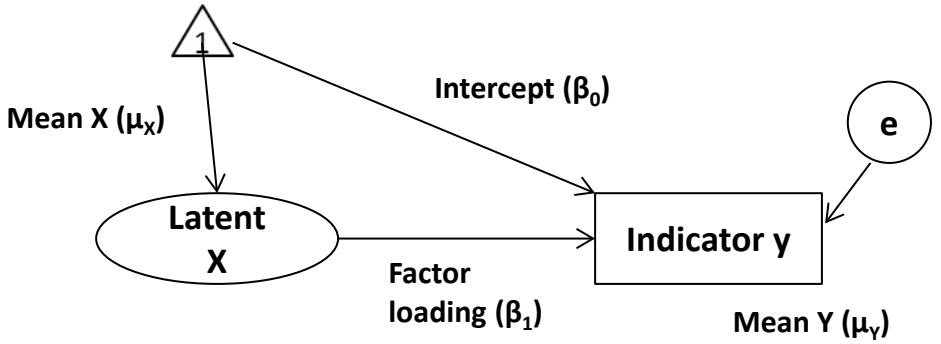
- Exogenous variables (X variables) have means
- Endogenous variables (Y variables) such as indicator variables have intercepts
  - Think of indicator variables in terms of regression equations

$$y_i = \beta_0 + \beta_1 X_{1i} + e_i$$

$$\mu_y = \beta_0 + \beta_1 \mu_{X_1}$$

$$if\ \mu_{X_1} = 0(\text{i.e., centered})$$

$$\mu_y = \beta_0$$



## Mean Structure: Multiple groups (gender)

```
usevariables are drink1b drink2b drink3b drink4b;
grouping is gender (1=male 2=female);  !multi-group statement
model: drink by drink1b drink2b drink3b drink4b;
```

In Mplus, in a multi-group analysis with a mean structure, both the intercepts and the factor loadings are held equal across groups as the default to specify measurement invariance.

Also means and intercepts of the latent variables of the first group are fixed at 0 while those in the other group(s) are free to vary.

Parameters and dfs
Elements:
(v (v+3))/2 = (4*7)/2 = 14 x 2 (groups) = 28

Parameters:
4 residuals x 2 = 8
4 intercepts
3 indicators (1 free)
1 latent variable variance x 2 = 2
1 mean (in one group)
Total parameters = 18
dfs = 28 – 18 = 10

# Mean Structure: Multiple groups (gender)

```
Chi-Square Test of Model Fit

          Value                             18.672
          Degrees of Freedom                   10
          P-Value                          0.0446

Chi-Square Contribution From Each Group

          MALE                              12.102
          FEMALE                             6.570

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                           0.065
          90 Percent C.I.                    0.010  0.110
          Probability RMSEA <= .05           0.261

CFI/TLI

          CFI                                0.994
          TLI                                0.993

Chi-Square Test of Model Fit for the Baseline Model

          Value                           1473.299
          Degrees of Freedom                   12
          P-Value                          0.0000

SRMR (Standardized Root Mean Square Residual)

          Value                              0.036
```

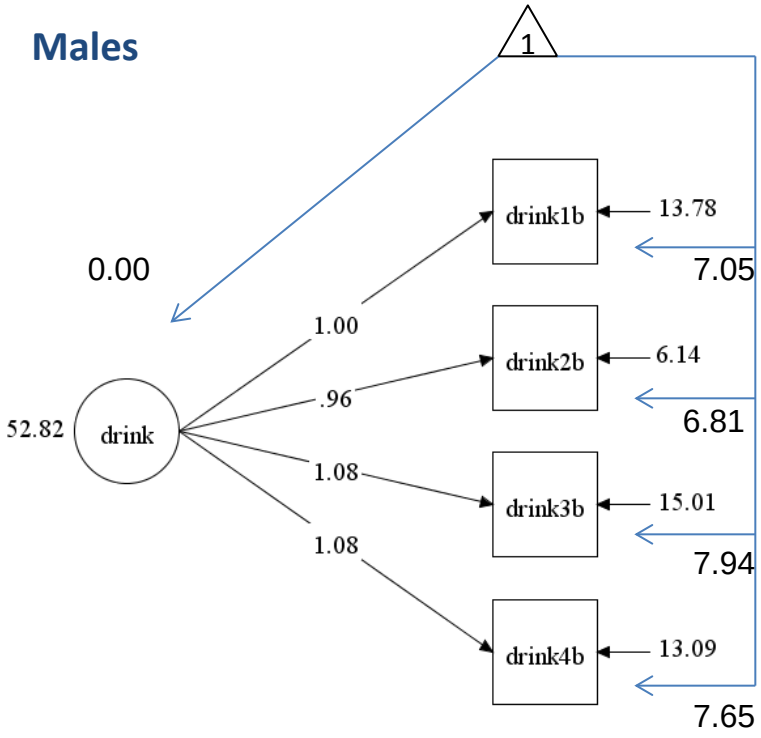
# Mean Structure: Multiple groups (gender)

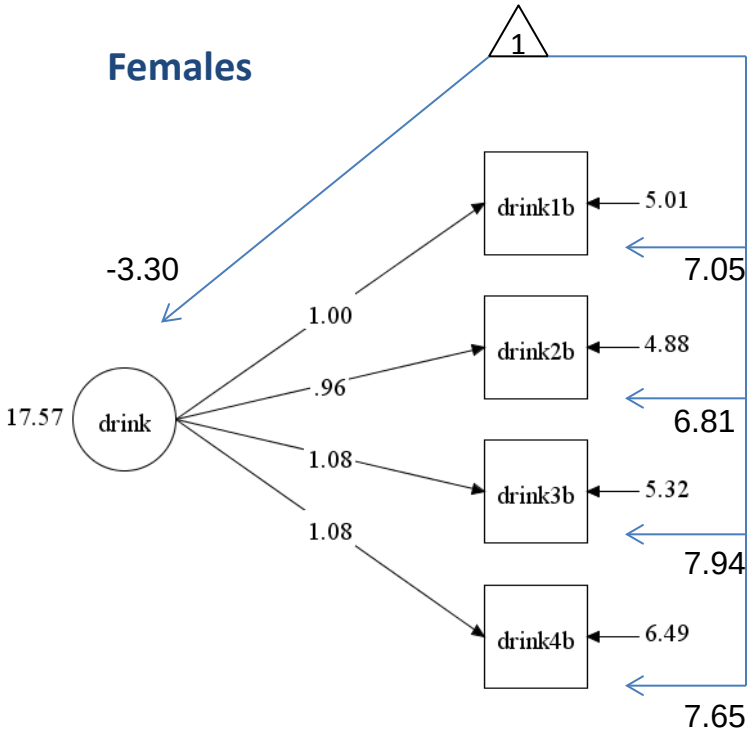
| | Estimate | S.E. | Est./S.E. | Two-Tailed P-Value |
|---|---|---|---|---|
| Group MALE | | | | |
| DRINK BY | | | | |
| DRINK1B | 1.000 | 0.000 | 999.000 | 999.000 |
| DRINK2B | 0.957 | 0.034 | 27.801 | 0.000 |
| DRINK3B | 1.085 | 0.040 | 26.790 | 0.000 |
| DRINK4B | 1.078 | 0.040 | 26.724 | 0.000 |
| Means | | | | |
| DRINK | 0.000 | 0.000 | 999.000 | 999.000 |
| Intercepts | | | | |
| DRINK1B | 7.054 | 0.627 | 11.250 | 0.000 |
| DRINK2B | 6.807 | 0.593 | 11.483 | 0.000 |
| DRINK3B | 7.940 | 0.679 | 11.701 | 0.000 |
| DRINK4B | 7.647 | 0.675 | 11.333 | 0.000 |
| Variances | | | | |
| DRINK | 52.818 | 6.946 | 7.604 | 0.000 |
| Residual Variances | | | | |
| DRINK1B | 13.782 | 2.005 | 6.874 | 0.000 |
| DRINK2B | 6.140 | 1.230 | 4.994 | 0.000 |
| DRINK3B | 15.007 | 2.211 | 6.787 | 0.000 |
| DRINK4B | 13.089 | 2.054 | 6.373 | 0.000 |

| | | | | |
|---|---|---|---|---|
| Group FEMALE | | | | |
| DRINK BY | | | | |
| DRINK1B | 1.000 | 0.000 | 999.000 | 999.000 |
| DRINK2B | 0.957 | 0.034 | 27.801 | 0.000 |
| DRINK3B | 1.085 | 0.040 | 26.790 | 0.000 |
| DRINK4B | 1.078 | 0.040 | 26.724 | 0.000 |
| Means | | | | |
| DRINK | -3.297 | 0.673 | -4.901 | 0.000 |
| Intercepts | | | | |
| DRINK1B | 7.054 | 0.627 | 11.250 | 0.000 |
| DRINK2B | 6.807 | 0.593 | 11.483 | 0.000 |
| DRINK3B | 7.940 | 0.679 | 11.701 | 0.000 |
| DRINK4B | 7.647 | 0.675 | 11.333 | 0.000 |
| Variances | | | | |
| DRINK | 17.574 | 1.841 | 9.545 | 0.000 |
| Residual Variances | | | | |
| DRINK1B | 5.010 | 0.599 | 8.358 | 0.000 |
| DRINK2B | 4.876 | 0.553 | 8.820 | 0.000 |
| DRINK3B | 5.325 | 0.649 | 8.203 | 0.000 |
| DRINK4B | 6.489 | 0.729 | 8.899 | 0.000 |

Significant difference between males and females
(but need to show invariance of intercepts first

# Mean Structure: Multiple groups (gender)




Note that the reproduced means for males are 7.05, 6.81, 7.94, and 7.65 are the same as their intercepts because their latent variable mean = 0. The reproduced means for females are 3.76, 3.65, 4.37, and 4.09. These can be reproduced as the mean of the latent variable (-3.30) x loading + intercept.

## CFA Measurement Invariance – Types of Invariance

- Dimensional invariance
- Configural invariance
- Metric (loadings) invariance
- Strong factorial (intercepts) invariance (also known as scalar invariance)
- Strict factorial invariance (indicator residual variances)

- Population heterogeneity
- Factor variances/covariances invariance
- Latent means invariance

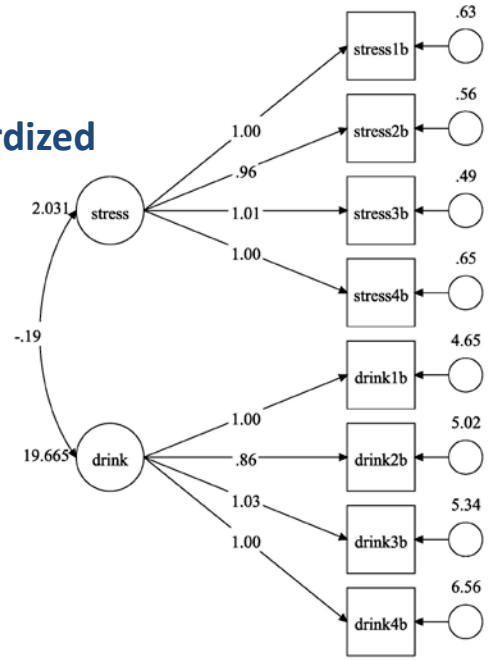
# Model 1: No constrained parameters (Unconstrained/Parent model)

```
usevariables are stress1b stress2b stress3b stress4b
drink1b drink2b drink3b drink4b;
grouping is gender (1=male 2=female);  !multi-group statement
model: stress by stress1b stress2b stress3b stress4b;
drink by drink1b drink2b drink3b drink4b;
[stress@0 drink@0]; !latent means in all groups fixed at zero
model female: !statements to indicate that parameters which are not constrained across groups
stress by stress2b stress3b stress4b; !to remove default loading equality constraints across groups
drink by drink2b drink3b drink4b; !do not include first indicator which was fixed
[stress1b stress2b stress3b stress4b]; !allowing all intercepts free with means at zero is like having no mean structure;
[drink1b drink2b drink3b drink4b];
output: sampstat stdyx residual modindices(5);
```

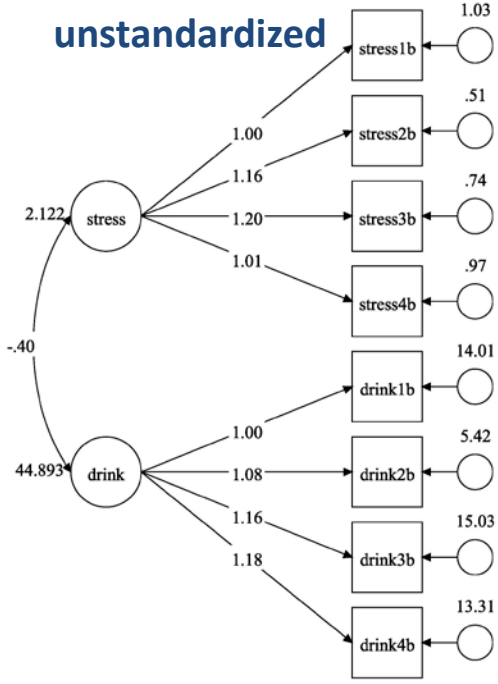
# Model 1: No constrained parameters (Unconstrained/Parent model)

```
MODEL FIT INFORMATION

Number of Free Parameters                       50

Loglikelihood

          H0 Value                       -7065.501
          H1 Value                       -7037.603

Information Criteria

          Akaike (AIC)                   14231.002
          Bayesian (BIC)                 14432.295
          Sample-Size Adjusted BIC       14273.633
            (n* = (n + 2) / 24)

Chi-Square Test of Model Fit

          Value                             55.797
          Degrees of Freedom                    38
          P-Value                           0.0312

Chi-Square Contributions From Each Group

          MALE                              29.443
          FEMALE                            26.354

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                           0.048
          90 Percent C.I.                    0.015  0.073
          Probability RMSEA <= .05           0.533

CFI/TLI

          CFI                                0.994
          TLI                                0.991

Chi-Square Test of Model Fit for the Baseline Model

          Value                           2851.951
          Degrees of Freedom                    56
          P-Value                           0.0000

SRMR (Standardized Root Mean Square Residual)

          Value                              0.023
```

**Females unstandardized**




**Males unstandardized**



# Model 1: No constrained parameters (Unconstrained/Parent model)

Group MALE

| | Estimate | S.E. | Est./S.E. | Two-Tailed P-Value |
|---|---|---|---|---|
| STRESS BY | | | | |
| STRESS1B | 1.000 | 0.000 | 999.000 | 999.000 |
| STRESS2B | 1.159 | 0.084 | 13.841 | 0.000 |
| STRESS3B | 1.205 | 0.090 | 13.329 | 0.000 |
| STRESS4B | 1.006 | 0.084 | 12.025 | 0.000 |
| DRINK BY | | | | |
| DRINK1B | 1.000 | 0.000 | 999.000 | 999.000 |
| DRINK2B | 1.081 | 0.061 | 17.781 | 0.000 |
| DRINK3B | 1.159 | 0.074 | 15.564 | 0.000 |
| DRINK4B | 1.183 | 0.073 | 16.317 | 0.000 |
| DRINK WITH | | | | |
| STRESS | -0.400 | 0.852 | -0.469 | 0.639 |
| Means | | | | |
| STRESS | 0.000 | 0.000 | 999.000 | 999.000 |
| DRINK | 0.000 | 0.000 | 999.000 | 999.000 |
| Intercepts | | | | |
| STRESS1B | 6.383 | 0.146 | 43.651 | 0.000 |
| STRESS2B | 6.627 | 0.151 | 43.959 | 0.000 |
| STRESS3B | 6.431 | 0.161 | 39.935 | 0.000 |
| STRESS4B | 6.351 | 0.145 | 43.690 | 0.000 |
| DRINK1B | 6.922 | 0.632 | 10.961 | 0.000 |
| DRINK2B | 6.727 | 0.626 | 10.751 | 0.000 |
| DRINK3B | 8.019 | 0.715 | 11.221 | 0.000 |
| DRINK4B | 7.853 | 0.718 | 10.940 | 0.000 |
| Variances | | | | |
| STRESS | 2.122 | 0.356 | 5.968 | 0.000 |
| DRINK | 44.893 | 6.742 | 6.659 | 0.000 |
| Residual Variances | | | | |
| STRESS1B | 1.033 | 0.144 | 7.165 | 0.000 |
| STRESS2B | 0.508 | 0.104 | 4.898 | 0.000 |
| STRESS3B | 0.742 | 0.127 | 5.841 | 0.000 |
| STRESS4B | 0.971 | 0.137 | 7.066 | 0.000 |
| DRINK1B | 14.006 | 1.963 | 7.135 | 0.000 |
| DRINK2B | 5.422 | 1.235 | 4.392 | 0.000 |
| DRINK3B | 15.027 | 2.183 | 6.885 | 0.000 |
| DRINK4B | 13.306 | 2.116 | 6.290 | 0.000 |

Group FEMALE

| | | | | |
|---|---|---|---|---|
| STRESS BY | | | | |
| STRESS1B | 1.000 | 0.000 | 999.000 | 999.000 |
| STRESS2B | 0.960 | 0.049 | 19.701 | 0.000 |
| STRESS3B | 1.014 | 0.049 | 20.505 | 0.000 |
| STRESS4B | 0.998 | 0.052 | 19.357 | 0.000 |
| DRINK BY | | | | |
| DRINK1B | 1.000 | 0.000 | 999.000 | 999.000 |
| DRINK2B | 0.865 | 0.043 | 19.960 | 0.000 |
| DRINK3B | 1.031 | 0.048 | 21.430 | 0.000 |
| DRINK4B | 0.995 | 0.049 | 20.245 | 0.000 |
| DRINK WITH | | | | |
| STRESS | -0.193 | 0.416 | -0.463 | 0.643 |
| Means | | | | |
| STRESS | 0.000 | 0.000 | 999.000 | 999.000 |
| DRINK | 0.000 | 0.000 | 999.000 | 999.000 |
| Intercepts | | | | |
| STRESS1B | 7.082 | 0.100 | 70.817 | 0.000 |
| STRESS2B | 7.286 | 0.096 | 76.290 | 0.000 |
| STRESS3B | 7.017 | 0.098 | 71.290 | 0.000 |
| STRESS4B | 6.900 | 0.100 | 68.870 | 0.000 |
| DRINK1B | 3.784 | 0.302 | 12.518 | 0.000 |
| DRINK2B | 3.688 | 0.272 | 13.540 | 0.000 |
| DRINK3B | 4.349 | 0.314 | 13.838 | 0.000 |
| DRINK4B | 4.037 | 0.313 | 12.905 | 0.000 |
| Variances | | | | |
| STRESS | 2.031 | 0.229 | 8.869 | 0.000 |
| DRINK | 19.665 | 2.114 | 9.301 | 0.000 |
| Residual Variances | | | | |
| STRESS1B | 0.629 | 0.072 | 8.715 | 0.000 |
| STRESS2B | 0.556 | 0.064 | 8.631 | 0.000 |
| STRESS3B | 0.486 | 0.062 | 7.786 | 0.000 |
| STRESS4B | 0.648 | 0.073 | 8.840 | 0.000 |
| DRINK1B | 4.646 | 0.593 | 7.838 | 0.000 |
| DRINK2B | 5.019 | 0.558 | 9.001 | 0.000 |
| DRINK3B | 5.342 | 0.659 | 8.101 | 0.000 |
| DRINK4B | 6.562 | 0.731 | 8.981 | 0.000 |

# Model 2: Constrained Loadings

```
usevariables are stress1b stress2b stress3b stress4b
drink1b drink2b drink3b drink4b;
grouping is gender (1=male 2=female);  !multi-group statement
model: stress by stress1b stress2b stress3b stress4b;
drink by drink1b drink2b drink3b drink4b;
[stress@0 drink@0]; !latent means in all groups fixed at zero
model female: !statements to indicate that parameters which are not constrained across groups
[stress1b stress2b stress3b stress4b]; !allowing all intercepts free with means at zero is like having no mean structure;
[drink1b drink2b drink3b drink4b];
output: sampstat stdyx residual modindices(5);
```

```
Chi-Square Test of Model Fit

          Value                             73.592
          Degrees of Freedom                   44
          P-Value                          0.0034

Chi-Square Contributions From Each Group

          MALE                              40.096
          FEMALE                            33.496

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                           0.057
          90 Percent C.I.                    0.033  0.079
          Probability RMSEA <= .05           0.289

CFI/TLI

          CFI                                0.989
          TLI                                0.987

Chi-Square Test of Model Fit for the Baseline Model

          Value                           2851.951
          Degrees of Freedom                   56
          P-Value                          0.0000

SRMR (Standardized Root Mean Square Residual)

          Value                              0.048
```

**Loadings Constrained (Nested Model):** $\chi^2_{(44)} = 73.59$, $p < .01$
(note also CFI = 0.989)

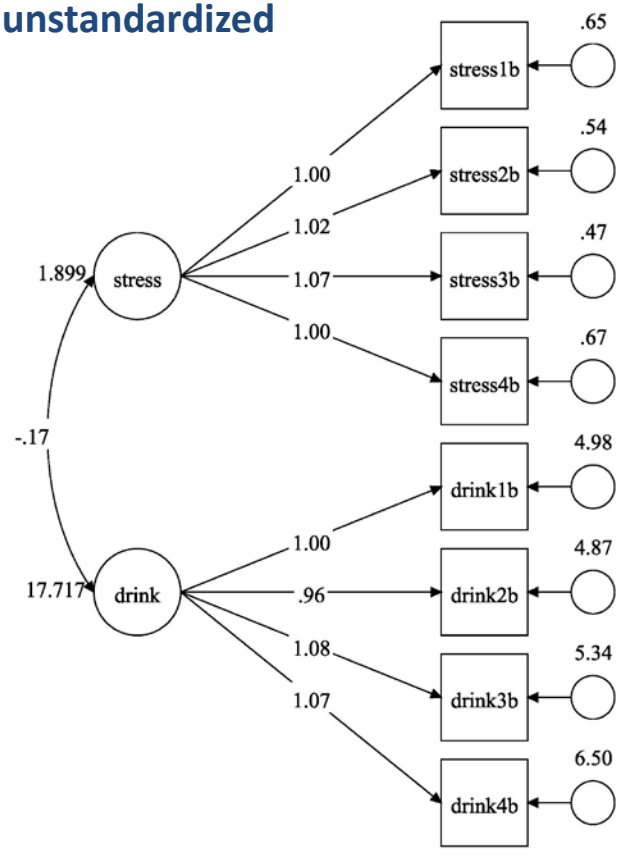
**Unconstrained (Parent Model)** : $\chi^2_{(38)} = 55.80$, $p < .05$
CFI = .994

**Chi-square Difference test:**

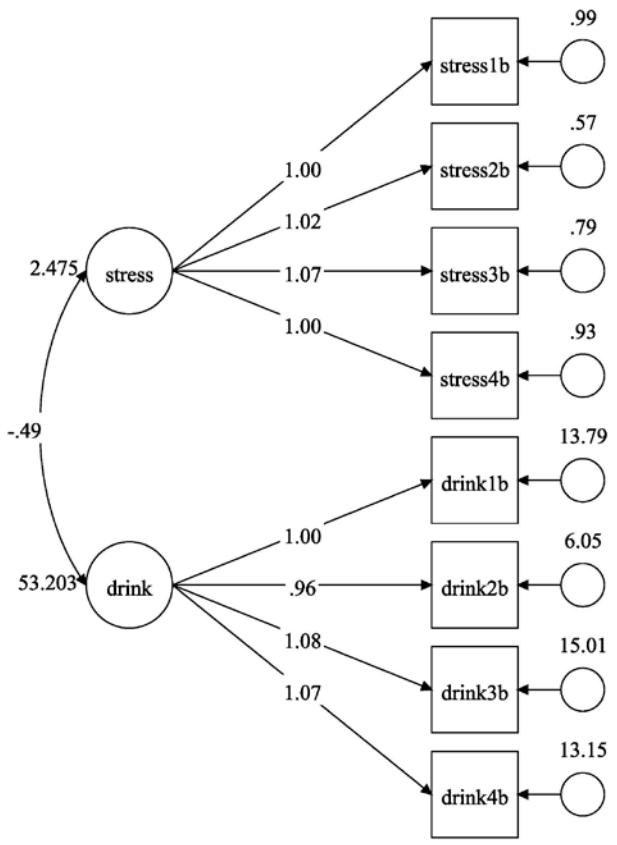
$\chi^2_{(44)} = 73.59 - \chi^2_{(38)} = 55.80 = \chi^2_{\text{diff }(6)} = 17.79$, $p < .01$
(crit $\chi^2_{(6)} = 12.59$ at $p = .05$ or 16.81 at $p = .01$)

# Model 2: Constrained Loadings

## Females unstandardized




## Males unstandardized



# Model 2: Constrained Loadings

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 5.000

| | | M.I. | E.P.C. | Std E.P.C. | StdYX E.P.C. |
|---|---|---|---|---|---|
| Group MALE | | | | | |
| BY Statements | | | | | |
| DRINK | BY DRINK1B | 7.515 | -0.174 | -1.266 | -0.155 |
| WITH Statements | | | | | |
| STRESS3B | WITH STRESS2B | 9.358 | 0.343 | 0.343 | 0.513 |
| DRINK1B | WITH STRESS2B | 5.180 | -0.705 | -0.705 | -0.252 |
| DRINK2B | WITH STRESS2B | 5.150 | 0.533 | 0.533 | 0.288 |
| DRINK3B | WITH DRINK1B | 5.046 | -3.801 | -3.801 | -0.264 |
| DRINK3B | WITH DRINK2B | 6.708 | 4.023 | 4.023 | 0.422 |
| DRINK4B | WITH STRESS3B | 5.210 | 0.793 | 0.793 | 0.246 |
| Group FEMALE | | | | | |
| BY Statements | | | | | |
| DRINK | BY DRINK1B | 7.500 | 0.173 | 0.730 | 0.153 |
| WITH Statements | | | | | |
| DRINK1B | WITH STRESS4B | 7.494 | -0.390 | -0.390 | -0.214 |
| DRINK2B | WITH STRESS2B | 5.285 | -0.300 | -0.300 | -0.184 |

# Model 3: Constrained Intercepts (and Loadings)

```
usevariables are stress1b stress2b stress3b stress4b
drink1b drink2b drink3b drink4b;
grouping is gender (1=male 2=female);  !multi-group statement
model: stress by stress1b stress2b stress3b stress4b;
drink by drink1b drink2b drink3b drink4b;
model female: !statements to indicate that parameters which are not constrained across groups
output: sampstat stdyx residual modindices(5);
```

**Model 3 Constrained Intercepts (Nested Model)**: $\chi^2_{(50)} = 76.82$, $p < .01$
CFI = 0.990

**Model 2 Constrained Loadings (Parent Model)** : $\chi^2_{(44)} = 73.59$, $p < .01$
CFI = 0.989

**Chi-square Difference test:**
$\chi^2_{(50)} = 76.82 - \chi^2_{(44)} = 73.59 = \chi^2_{\text{diff }(6)} = 3.23$, ns
(crit $\chi^2_{(6)} = 16.81$ at $p = .01$)

# Model 3: Constrained Intercepts (and Loadings)

| | Estimate | S.E. | Est./S.E. | Two-Tailed P-Value |
|---|---|---|---|---|
| **Group MALE** | | | | |
| STRESS BY | | | | |
| STRESS1B | 1.000 | 0.000 | 999.000 | 999.000 |
| STRESS2B | 1.020 | 0.041 | 24.648 | 0.000 |
| STRESS3B | 1.059 | 0.043 | 24.759 | 0.000 |
| STRESS4B | 0.989 | 0.043 | 22.956 | 0.000 |
| DRINK BY | | | | |
| DRINK1B | 1.000 | 0.000 | 999.000 | 999.000 |
| DRINK2B | 0.957 | 0.034 | 27.810 | 0.000 |
| DRINK3B | 1.084 | 0.040 | 26.788 | 0.000 |
| DRINK4B | 1.078 | 0.040 | 26.725 | 0.000 |
| DRINK WITH | | | | |
| STRESS | -0.486 | 1.006 | -0.483 | 0.629 |
| Means | | | | |
| STRESS | 0.000 | 0.000 | 999.000 | 999.000 |
| DRINK | 0.000 | 0.000 | 999.000 | 999.000 |
| Intercepts | | | | |
| STRESS1B | 6.447 | 0.141 | 45.728 | 0.000 |
| STRESS2B | 6.649 | 0.141 | 47.200 | 0.000 |
| STRESS3B | 6.384 | 0.147 | 43.458 | 0.000 |
| STRESS4B | 6.311 | 0.139 | 45.291 | 0.000 |
| DRINK1B | 7.054 | 0.627 | 11.249 | 0.000 |
| DRINK2B | 6.807 | 0.593 | 11.483 | 0.000 |
| DRINK3B | 7.940 | 0.679 | 11.701 | 0.000 |
| DRINK4B | 7.646 | 0.675 | 11.333 | 0.000 |
| Variances | | | | |
| STRESS | 2.502 | 0.342 | 7.316 | 0.000 |
| DRINK | 52.835 | 6.948 | 7.605 | 0.000 |
| Residual Variances | | | | |
| STRESS1B | 0.998 | 0.145 | 6.888 | 0.000 |
| STRESS2B | 0.564 | 0.104 | 5.424 | 0.000 |
| STRESS3B | 0.795 | 0.128 | 6.211 | 0.000 |
| STRESS4B | 0.933 | 0.137 | 6.832 | 0.000 |
| DRINK1B | 13.773 | 2.004 | 6.871 | 0.000 |
| DRINK2B | 6.134 | 1.229 | 4.990 | 0.000 |
| DRINK3B | 15.014 | 2.212 | 6.789 | 0.000 |
| DRINK4B | 13.104 | 2.055 | 6.376 | 0.000 |

| | | | | |
|---|---|---|---|---|
| **Group FEMALE** | | | | |
| STRESS BY | | | | |
| STRESS1B | 1.000 | 0.000 | 999.000 | 999.000 |
| STRESS2B | 1.020 | 0.041 | 24.648 | 0.000 |
| STRESS3B | 1.059 | 0.043 | 24.759 | 0.000 |
| STRESS4B | 0.989 | 0.043 | 22.956 | 0.000 |
| DRINK BY | | | | |
| DRINK1B | 1.000 | 0.000 | 999.000 | 999.000 |
| DRINK2B | 0.957 | 0.034 | 27.810 | 0.000 |
| DRINK3B | 1.084 | 0.040 | 26.788 | 0.000 |
| DRINK4B | 1.078 | 0.040 | 26.725 | 0.000 |
| DRINK WITH | | | | |
| STRESS | -0.171 | 0.383 | -0.448 | 0.654 |
| Means | | | | |
| STRESS | 0.612 | 0.162 | 3.777 | 0.000 |
| DRINK | -3.297 | 0.673 | -4.901 | 0.000 |
| Intercepts | | | | |
| STRESS1B | 6.447 | 0.141 | 45.728 | 0.000 |
| STRESS2B | 6.649 | 0.141 | 47.200 | 0.000 |
| STRESS3B | 6.384 | 0.147 | 43.458 | 0.000 |
| STRESS4B | 6.311 | 0.139 | 45.291 | 0.000 |
| DRINK1B | 7.054 | 0.627 | 11.249 | 0.000 |
| DRINK2B | 6.807 | 0.593 | 11.483 | 0.000 |
| DRINK3B | 7.940 | 0.679 | 11.701 | 0.000 |
| DRINK4B | 7.646 | 0.675 | 11.333 | 0.000 |
| Variances | | | | |
| STRESS | 1.921 | 0.208 | 9.237 | 0.000 |
| DRINK | 17.581 | 1.842 | 9.547 | 0.000 |
| Residual Variances | | | | |
| STRESS1B | 0.645 | 0.073 | 8.892 | 0.000 |
| STRESS2B | 0.542 | 0.064 | 8.484 | 0.000 |
| STRESS3B | 0.476 | 0.062 | 7.725 | 0.000 |
| STRESS4B | 0.669 | 0.074 | 9.060 | 0.000 |
| DRINK1B | 5.003 | 0.599 | 8.349 | 0.000 |
| DRINK2B | 4.876 | 0.553 | 8.820 | 0.000 |
| DRINK3B | 5.333 | 0.650 | 8.208 | 0.000 |
| DRINK4B | 6.489 | 0.729 | 8.900 | 0.000 |

# Model 4: Constrained Indicator Residual Variances (and Loadings and Intercepts)

```
usevariables are stress1b stress2b stress3b stress4b
drink1b drink2b drink3b drink4b;
grouping is gender (1=male 2=female);  !multi-group statement
model: stress by stress1b stress2b stress3b stress4b;
drink by drink1b drink2b drink3b drink4b;
stress1b (1)
stress2b (2)
stress3b (3)
stress4b (4)
drink1b (5)
drink2b (6)
drink3b (7)
drink4b (8); !constraining residuals
output: sampstat stdyx residual modindices(5);
```

**Model 4 Constrained Indicator Residuals (Nested Model):** $\chi^2_{(58)} = 190.62$, $p < .01$
CFI = 0.953

**Model 3 Constrained Intercepts (Parent Model)** :$\chi^2_{(50)} = 76.82$, $p < .01$
CFI = 0.990

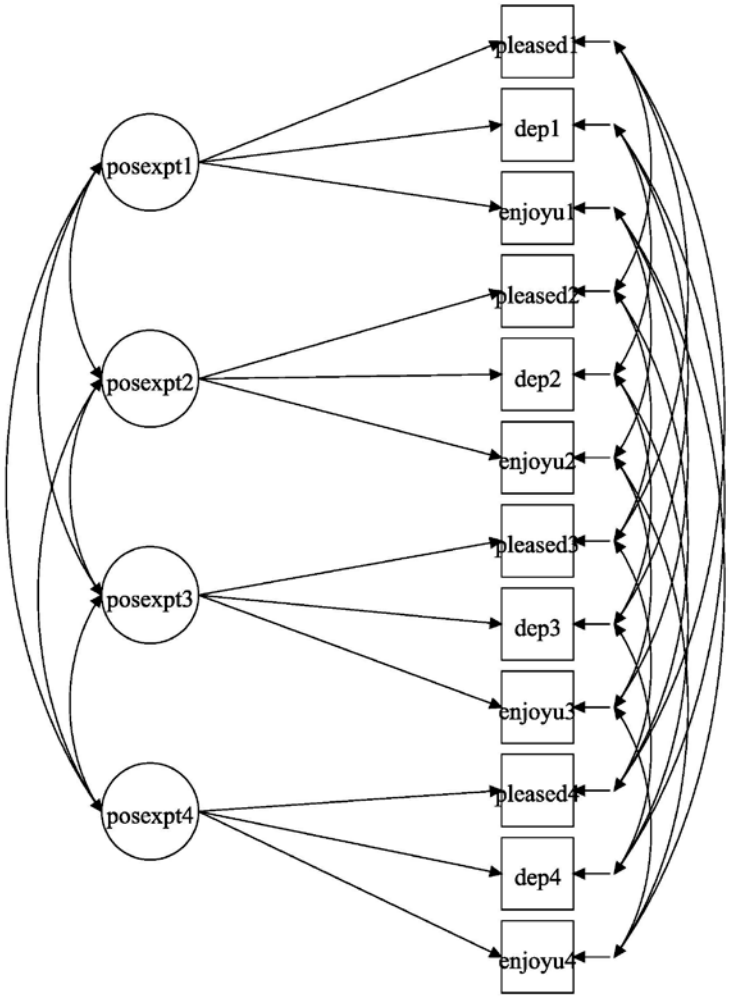
**Chi-square Difference test:**
$\chi^2_{(58)} = 190.62 - \chi^2_{(50)} = 76.82 = \chi^2_{\text{diff }(8)} = 113.80$, $p < .001$
(crit $\chi^2_{(8)} = 26.12$ at $p = .001$)

# Other Models of Invariance

```
usevariables are stress1b stress2b stress3b stress4b
drink1b drink2b drink3b drink4b;
grouping is gender (1=male 2=female);  !multi-group statement
model: stress by stress1b stress2b stress3b stress4b;
drink by drink1b drink2b drink3b drink4b;
stress1b (1)
stress2b (2)
stress3b (3)
stress4b (4)
drink1b (5)
drink2b (6)
drink3b (7)
drink4b (8); !constraining residuals
!stress (9); invariance of factor variance and covariance
!drink (10);
!stress with drink (11);
!model female: [stress@0 drink@0]; invariance of factor means;
output: sampstat stdyx residual modindices(5);
```

# Longitudinal Measurement Invariance: Unconstrained Model

```
usevariables are pleased1 pleased2 pleased3 pleased4
dep1 dep2 dep3 dep4
enjoyu1 enjoyu2 enjoyu3 enjoyu4;
model:
POSEXPt1 by pleased1 dep1 enjoyu1;
POSEXPt2 by pleased2 dep2 enjoyu2;
POSEXPt3 by pleased3 dep3 enjoyu3;
POSEXPt4 by pleased4 dep4 enjoyu4;
pleased1 with pleased2 pleased3 pleased4; ! allowing residu
pleased2 with pleased3 pleased4;
pleased3 with pleased4;
dep1 with dep2 dep3 dep4;
dep2 with dep3 dep4;
dep3 with dep4;
enjoyu1 with enjoyu2 enjoyu3 enjoyu4;
enjoyu2 with enjoyu3 enjoyu4;
enjoyu3 with enjoyu4;
output: sampstat residual stdyx modindices;
```



# Model 2: Constrained Loadings

```
usevariables are pleased1 pleased2 pleased3 pleased4
dep1 dep2 dep3 dep4
enjoyu1 enjoyu2 enjoyu3 enjoyu4;
model:
POSEXPt1 by pleased1 dep1 (1)
enjoyu1 (2);
POSEXPt2 by pleased2 dep2 (1)
enjoyu2 (2);
POSEXPt3 by pleased3 dep3 (1)
enjoyu3 (2);
POSEXPt4 by pleased4 dep4 (1)
enjoyu4 (2);
pleased1 with pleased2 pleased3 pleased4; ! allowing residuals to correlate ac
pleased2 with pleased3 pleased4;
pleased3 with pleased4;
dep1 with dep2 dep3 dep4;
dep2 with dep3 dep4;
dep3 with dep4;
enjoyu1 with enjoyu2 enjoyu3 enjoyu4;
enjoyu2 with enjoyu3 enjoyu4;
enjoyu3 with enjoyu4;
output: sampstat residual stdyx modindices;
```

```
Chi-Square Test of Model Fit

          Value                             95.680
          Degrees of Freedom                36
          P-Value                           0.0000

RMSEA (Root Mean Square Error Of Approximation)

          Estimate                          0.063
          90 Percent C.I.                   0.048  0.079
          Probability RMSEA <= .05          0.074

CFI/TLI

          CFI                               0.988
          TLI                               0.977

Chi-Square Test of Model Fit for the Baseline Model

          Value                          4880.751
          Degrees of Freedom                66
          P-Value                           0.0000

SRMR (Standardized Root Mean Square Residual)

          Value                             0.038
```

## Model 2 Constrained Loadings (Nested Model):

$\chi^2_{(36)} = 95.68$, $p < .01$ CFI = 0.988

## Model 1 Unconstrained (Parent Model) :

$\chi^2_{(30)} = 54.48$, $p < .01$ CFI = 0.995

## Chi-square Difference test:

$\chi^2_{(36)} = 95.68 - \chi^2_{(30)} = 54.48 = \chi^2_{\text{diff }(6)} = 41.20$, $p < .001$
(crit $\chi^2_{(6)} = 22.46$ at $p = .001$)

Conclusion:?

# Model 2: Constrained Loadings

## Unconstrained loadings (previous model)

MODEL RESULTS

| | Estimate | S.E. | Est./S.E. | Two-Tailed P-Value |
|---|---|---|---|---|
| POSEXPT1 BY | | | | |
| PLEASED1 | 1.000 | 0.000 | 999.000 | 999.000 |
| DEP1 | -2.908 | 0.252 | -11.532 | 0.000 |
| ENJOYU1 | 1.039 | 0.088 | 11.811 | 0.000 |
| POSEXPT2 BY | | | | |
| PLEASED2 | 1.000 | 0.000 | 999.000 | 999.000 |
| DEP2 | -2.056 | 0.194 | -10.582 | 0.000 |
| ENJOYU2 | 0.980 | 0.081 | 12.080 | 0.000 |
| POSEXPT3 BY | | | | |
| PLEASED3 | 1.000 | 0.000 | 999.000 | 999.000 |
| DEP3 | -1.743 | 0.176 | -9.907 | 0.000 |
| ENJOYU3 | 0.950 | 0.080 | 11.812 | 0.000 |
| POSEXPT4 BY | | | | |
| PLEASED4 | 1.000 | 0.000 | 999.000 | 999.000 |
| DEP4 | -2.155 | 0.217 | -9.947 | 0.000 |
| ENJOYU4 | 0.957 | 0.091 | 10.496 | 0.000 |

## Constrained Loadings

MODEL RESULTS

| | Estimate | S.E. | Est./S.E. | Two-Tailed P-Value |
|---|---|---|---|---|
| POSEXPT1 BY | | | | |
| PLEASED1 | 1.000 | 0.000 | 999.000 | 999.000 |
| DEP1 | -2.209 | 0.190 | -11.636 | 0.000 |
| ENJOYU1 | 0.982 | 0.078 | 12.577 | 0.000 |
| POSEXPT2 BY | | | | |
| PLEASED2 | 1.000 | 0.000 | 999.000 | 999.000 |
| DEP2 | -2.209 | 0.190 | -11.636 | 0.000 |
| ENJOYU2 | 0.982 | 0.078 | 12.577 | 0.000 |
| POSEXPT3 BY | | | | |
| PLEASED3 | 1.000 | 0.000 | 999.000 | 999.000 |
| DEP3 | -2.209 | 0.190 | -11.636 | 0.000 |
| ENJOYU3 | 0.982 | 0.078 | 12.577 | 0.000 |
| POSEXPT4 BY | | | | |
| PLEASED4 | 1.000 | 0.000 | 999.000 | 999.000 |
| DEP4 | -2.209 | 0.190 | -11.636 | 0.000 |
| ENJOYU4 | 0.982 | 0.078 | 12.577 | 0.000 |

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 10.000

| | M.I. | E.P.C. | Std E.P.C. | StdYX E.P.C. |
|---|---|---|---|---|
| BY Statements | | | | |
| POSEXPT1 BY DEP1 | 24.360 | -0.497 | -0.742 | -0.118 |
| POSEXPT2 BY DEP1 | 21.915 | -0.634 | -0.959 | -0.152 |
| POSEXPT2 BY DEP3 | 10.338 | 0.317 | 0.479 | 0.078 |
| POSEXPT3 BY DEP1 | 24.294 | -0.686 | -1.013 | -0.161 |
| POSEXPT3 BY DEP3 | 14.403 | 0.304 | 0.449 | 0.073 |
| POSEXPT4 BY DEP1 | 20.037 | -0.609 | -0.927 | -0.147 |
| POSEXPT4 BY DEP3 | 13.290 | 0.362 | 0.552 | 0.090 |
| WITH Statements | | | | |
| ENJOYU1 WITH DEP1 | 12.052 | -0.629 | -0.629 | -0.113 |

# Model 3: Constrained Intercept Model Syntax

```
usevariables are pleased1 pleased2 pleased3 pleased4
dep1 dep2 dep3 dep4
enjoyu1 enjoyu2 enjoyu3 enjoyu4;
model:
POSEXPt1 by pleased1 dep1 (1)
enjoyu1 (2);
POSEXPt2 by pleased2 dep2 (1)
enjoyu2 (2);
POSEXPt3 by pleased3 dep3 (1)
enjoyu3 (2);
POSEXPt4 by pleased4 dep4 (1)
enjoyu4 (2);
[pleased1 pleased2 pleased3 pleased4] (3);
[dep1 dep2 dep3 dep4] (4);
[enjoyu1 enjoyu2 enjoyu3 enjoyu4] (5);
pleased1 with pleased2 pleased3 pleased4; ! allowing residuals to correlate across time
pleased2 with pleased3 pleased4;
pleased3 with pleased4;
dep1 with dep2 dep3 dep4;
dep2 with dep3 dep4;
dep3 with dep4;
enjoyu1 with enjoyu2 enjoyu3 enjoyu4;
enjoyu2 with enjoyu3 enjoyu4;
enjoyu3 with enjoyu4;
[POSEXPt1@0];
[POSEXPt2 POSEXPt3 POSEXPt4];
output: sampstat residual stdyx modindices;
```