Assignment 1 SEM

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Simple linear regression for a continuous observed dependent variable with two covariates

Reading the ex3.1.dat file

```
## 'data.frame':    500 obs. of  3 variables:
##  $ V1: num  -0.355 0.562 0.316 3.347 -0.122 ...
##  $ V2: num  0.573 -0.368 -0.577 1.089 -0.694 ...
##  $ V3: num  -0.175 1.09 0.425 1.149 -0.767 ...
```

```
## [1] 500   3
```

```
##          V1        V2        V3
## 1 -0.354517  0.573051 -0.175230
## 2  0.561655 -0.368095  1.090042
## 3  0.315551 -0.577052  0.425472
## 4  3.347049  1.088520  1.149353
## 5 -0.122389 -0.694153 -0.766538
## 6 -0.251276 -0.017487 -1.367410
```

```
## [1] "V1" "V2" "V3"
```

Creating names for the variables present in the dataset

```
## [1] "y1" "x1" "x3"
```

Scaling the whole dataset

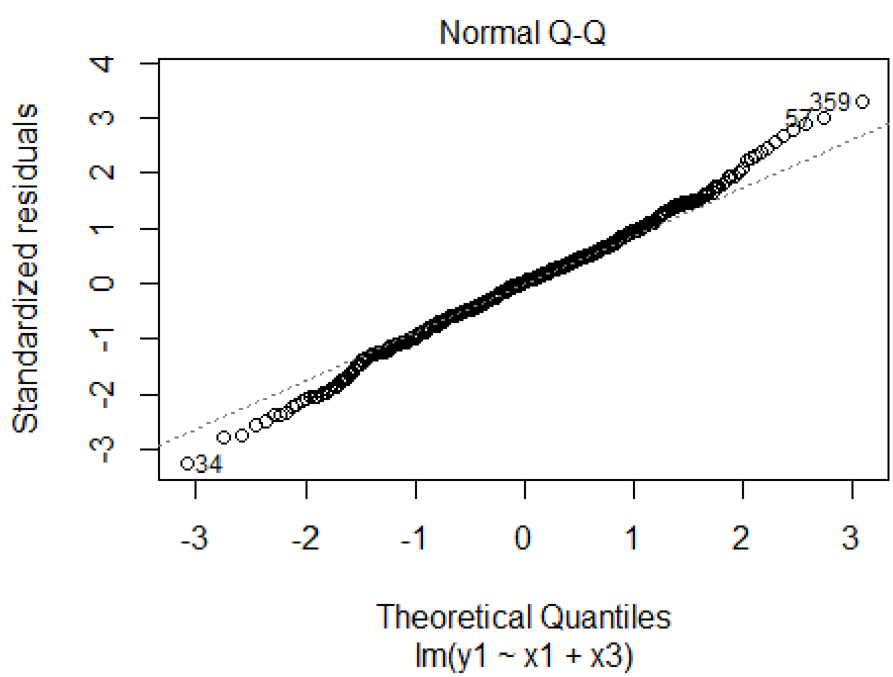
```
##        y1                 x1                 x3           
##  Min.   :-2.96235   Min.   :-3.00587   Min.   :-3.162585  
##  1st Qu.:-0.65139   1st Qu.:-0.71754   1st Qu.:-0.727682  
##  Median :-0.03607   Median : 0.02093   Median : 0.001914  
##  Mean   : 0.00000   Mean   : 0.00000   Mean   : 0.000000  
##  3rd Qu.: 0.70002   3rd Qu.: 0.72063   3rd Qu.: 0.777791  
##  Max.   : 2.97848   Max.   : 2.78874   Max.   : 2.979475
```

```
## [1] "matrix"
```

Regression model with diagnostic plot

```
## 
## Call:
## lm(formula = y1 ~ x1 + x3, data = data1_scaled)
```

```
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.02847 -0.37032  0.01512  0.36459  2.05378
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 1.752e-17  2.802e-02    0.00        1
## x1          6.534e-01  2.806e-02   23.29   <2e-16 ***
## x3          4.092e-01  2.806e-02   14.58   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.6265 on 497 degrees of freedom
## Multiple R-squared:  0.609,  Adjusted R-squared:  0.6075
## F-statistic: 387.1 on 2 and 497 DF,  p-value: < 2.2e-16
```

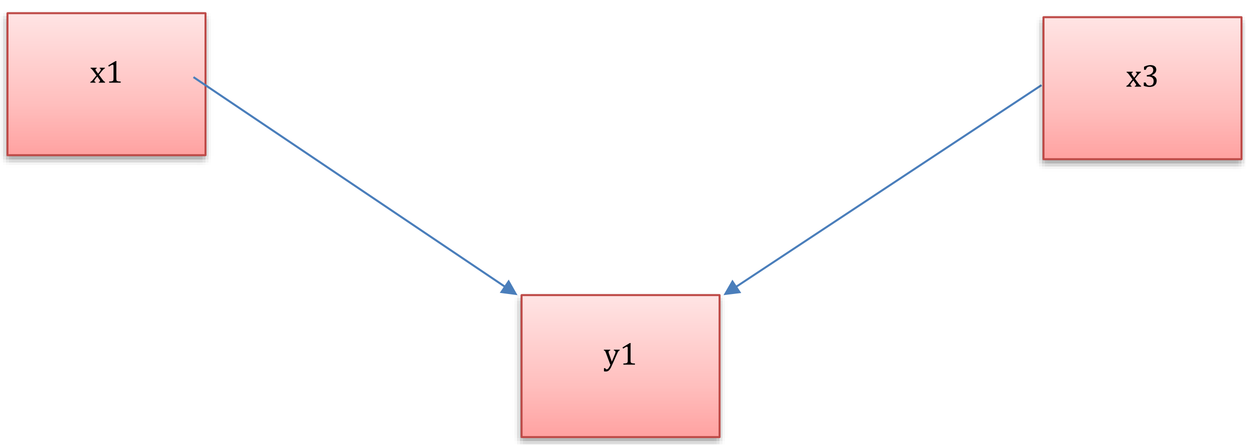


Interpretation

The higher the t-value, the better it is. The model shows t-value for x1 (23.2) and x3 (14.6) which should be more than 2, thus, fairly reliable coefficient as a predictor. The relation of y1 with x1 and x3 exists as p-value is less than the pre-determined statistical significance level (0.05). The standard error should be less than 2.5% to have the required precsion. In our model, the Standard Error is 2.806e-02 for x1 and x3. The R-square value is 0.60. The variation of dependent variable with two covariates seems to be 60 %.

The normal Q-Q plot is used to determine whether the residuals are normally distributed or not. The residuals in this plot were slightly deviated from the diagonal line in both the upper and lower tail. Points 34, 57 and 359 seems to be little off here. The residuals were approximately normally distributed.

Factor Mapping



Exploratory factor analysis with continuous factor indicators

Reading the dataset

```
## 'data.frame':    500 obs. of  12 variables:
##  $ V1 : num  -0.378 1.118 0.195 1.492 -0.442 ...
##  $ V2 : num  0.0759 1.7535 -0.6006 -0.2235 -0.4476 ...
##  $ V3 : num  -0.628 2.177 -1.482 -0.396 1.083 ...
##  $ V4 : num  -0.88 0.642 -0.312 0.94 -0.648 ...
##  $ V5 : num  -2.7 1.72 -2.04 0.6 0.67 ...
##  $ V6 : num  0.79 0.127 -1.114 2.825 0.577 ...
##  $ V7 : num  0.36942 -0.32402 -0.63162 -1.96677 0.00115 ...
##  $ V8 : num  0.678 0.634 -1.035 -0.725 -0.198 ...
##  $ V9 : num  1.85932 0.17849 -0.00555 0.21327 -0.79722 ...
##  $ V10: num  1.887 -0.761 -0.559 -0.647 0.281 ...
##  $ V11: num  0.447 -1.0819 1.1913 0.0502 -0.291 ...
##  $ V12: num  0.6782 -0.7933 0.1789 -1.059 -0.0991 ...
```

```
##          V1        V2        V3        V4        V5        V6        V7
## 1 -0.378137  0.075915 -0.628122 -0.880031 -2.703588  0.789544  0.369423
## 2  1.118025  1.753513  2.177335  0.642068  1.722000  0.127374 -0.324017
## 3  0.194822 -0.600631 -1.481951 -0.311791 -2.044864 -1.113668 -0.631615
## 4  1.491893 -0.223520 -0.395545  0.939834  0.600017  2.824590 -1.966773
## 5 -0.441761 -0.447650  1.082701 -0.647520  0.669891  0.576646  0.001154
## 6  1.138741  0.517782  0.134229  0.198726  1.479790  1.516361 -1.424818
##          V8        V9       V10       V11       V12
## 1  0.677649  1.859322  1.886903  0.447027  0.678236
## 2  0.634312  0.178495 -0.760867 -1.081870 -0.793253
## 3 -1.034981 -0.005553 -0.558788  1.191310  0.178950
## 4 -0.725317  0.213274 -0.646794  0.050215 -1.059023
## 5 -0.198322 -0.797221  0.280672 -0.290995 -0.099085
## 6  2.138852  1.618477 -1.519581 -0.792117  0.042684

## [1] 500  12

##  [1] "V1"  "V2"  "V3"  "V4"  "V5"  "V6"  "V7"  "V8"  "V9"  "V10" "V11"
## [12] "V12"
```

Creating names for variables

```
##  [1] "y1"  "y2"  "y3"  "y4"  "y5"  "y6"  "y7"  "y8"  "y9"  "y10" "y11"
## [12] "y12"

##          y1        y2        y3        y4        y5        y6        y7
## 1 -0.378137  0.075915 -0.628122 -0.880031 -2.703588  0.789544  0.369423
## 2  1.118025  1.753513  2.177335  0.642068  1.722000  0.127374 -0.324017
## 3  0.194822 -0.600631 -1.481951 -0.311791 -2.044864 -1.113668 -0.631615
## 4  1.491893 -0.223520 -0.395545  0.939834  0.600017  2.824590 -1.966773
## 5 -0.441761 -0.447650  1.082701 -0.647520  0.669891  0.576646  0.001154
## 6  1.138741  0.517782  0.134229  0.198726  1.479790  1.516361 -1.424818
##          y8        y9       y10       y11       y12
## 1  0.677649  1.859322  1.886903  0.447027  0.678236
## 2  0.634312  0.178495 -0.760867 -1.081870 -0.793253
## 3 -1.034981 -0.005553 -0.558788  1.191310  0.178950
## 4 -0.725317  0.213274 -0.646794  0.050215 -1.059023
## 5 -0.198322 -0.797221  0.280672 -0.290995 -0.099085
## 6  2.138852  1.618477 -1.519581 -0.792117  0.042684
```

The dataset has 500 obs. of 12 variables. The variables names are y1-y12.

Assessing the Factorability of the Data

- *Bartlett's Test of Sphericity*

```
## R was not square, finding R from data

## $chisq
## [1] 1420.056
##
```

```
## $p.value
## [1] 3.016298e-253
##
## $df
## [1] 66
```

Bartlett's test is statistically significant. It suggests that some of the variables are correlated with each other.

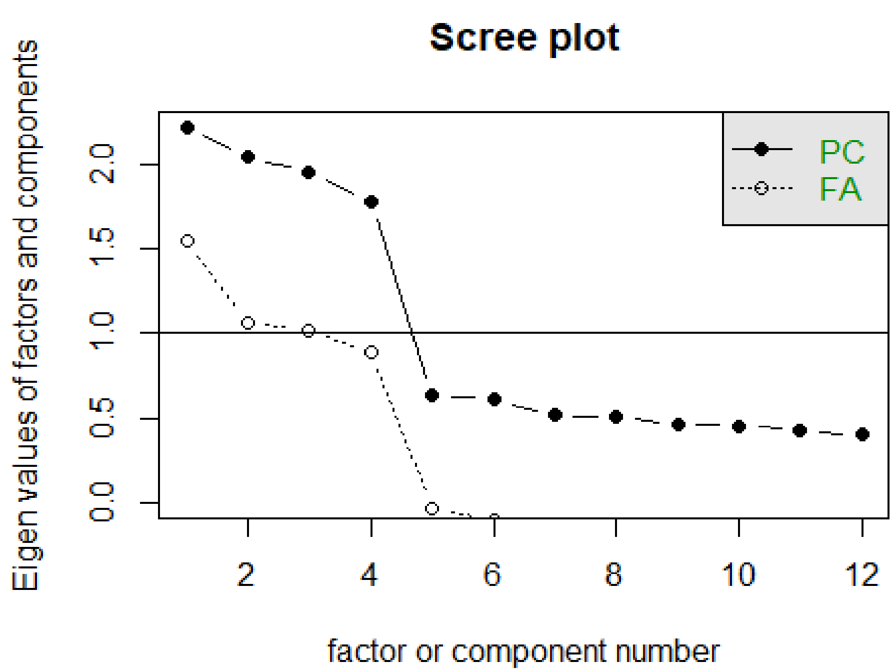
- *Kaiser-Meyer-Olkin (KMO)*

```
## Kaiser-Meyer-Olkin factor adequacy
## Call: KMO(r = data2)
## Overall MSA =  0.67
## MSA for each item =
##   y1   y2   y3   y4   y5   y6   y7   y8   y9  y10  y11  y12
## 0.67 0.63 0.67 0.70 0.64 0.68 0.69 0.69 0.69 0.69 0.65 0.72
```

The minimum acceptable value is 0.50, but the recommended value is 0.60 before undertaking a factor analysis. The overall KMO for this dataset is 0.67 suggests that the factor analysis can be performed.

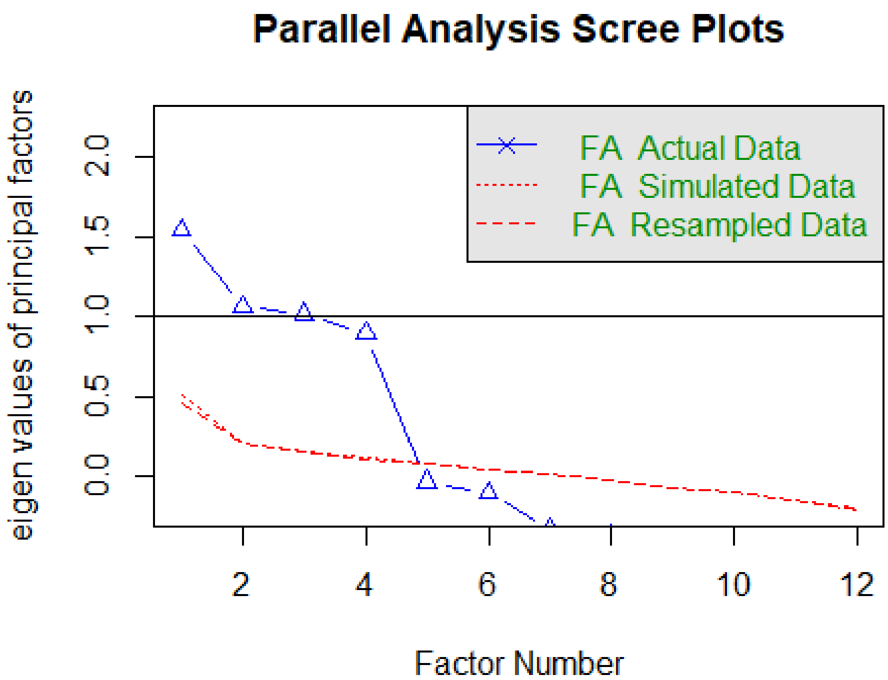
Determining the Number of Factors to Extract

- *Scree plot*



Eigenvalues are a measure of the amount of variance accounted for by a factor. The last point to fall on this line represents the last factor that can be extracted. As per the results of the scree plot, I would probably conclude that there are four factors in this dataset.

- *Parallel Analysis*




```
## Parallel analysis suggests that the number of factors = 4 and the number o
f components =  NA
```

The blue line in the parallel analysis shows the observed eigenvalues and the red dotted line show the random eigenvalues. Each point on the blue line that lies above the simulated data line (red line) is a factor that has to be extracted. Here 4 factors lie above the corresponding simulated data line. So, I will compare all the 4 factors to see the interpretability.

Factor Analysis

The aim of the factor analysis is to reduce the number of variables and to interpret the results.

- ***Factor analysis with 1 factor***

```
## Factor Analysis using method =  minres
## Call: fa(r = data2, nfactors = 1, rotate = "oblimin", fm = "minres")
## Standardized loadings (pattern matrix) based upon correlation matrix
##       MR1      h2   u2 com
## y1  -0.01 0.00012 1.00   1
## y2   0.04 0.00187 1.00   1
## y3   0.02 0.00037 1.00   1
## y4  -0.27 0.07120 0.93   1
## y5  -0.26 0.06679 0.93   1
## y6  -0.27 0.07445 0.93   1
## y7  -0.07 0.00552 0.99   1
## y8  -0.10 0.01039 0.99   1
## y9  -0.08 0.00627 0.99   1
## y10  0.64 0.40697 0.59   1
## y11  0.70 0.48620 0.51   1
## y12  0.64 0.41356 0.59   1
##
##                 MR1
## SS loadings    1.54
## Proportion Var 0.13
##
## Mean item complexity =  1
## Test of the hypothesis that 1 factor is sufficient.
##
## The degrees of freedom for the null model are  66  and the objective funct
ion was  2.87 with Chi Square of  1420.06
## The degrees of freedom for the model are 54  and the objective function wa
s  2.16
##
## The root mean square of the residuals (RMSR) is  0.18
## The df corrected root mean square of the residuals is  0.2
##
## The harmonic number of observations is  500 with the empirical chi square
2170.62  with prob <  0
## The total number of observations was  500  with Likelihood Chi Square =  1
064.4  with prob <  1.5e-187
##
## Tucker Lewis Index of factoring reliability =  0.087
## RMSEA index =  0.195  and the 90 % confidence intervals are  0.184 0.204
## BIC =  728.81
## Fit based upon off diagonal values = 0.29
## Measures of factor score adequacy
##                                                    MR1
## Correlation of (regression) scores with factors   0.85
## Multiple R square of scores with factors          0.72
## Minimum correlation of possible factor scores     0.44
```

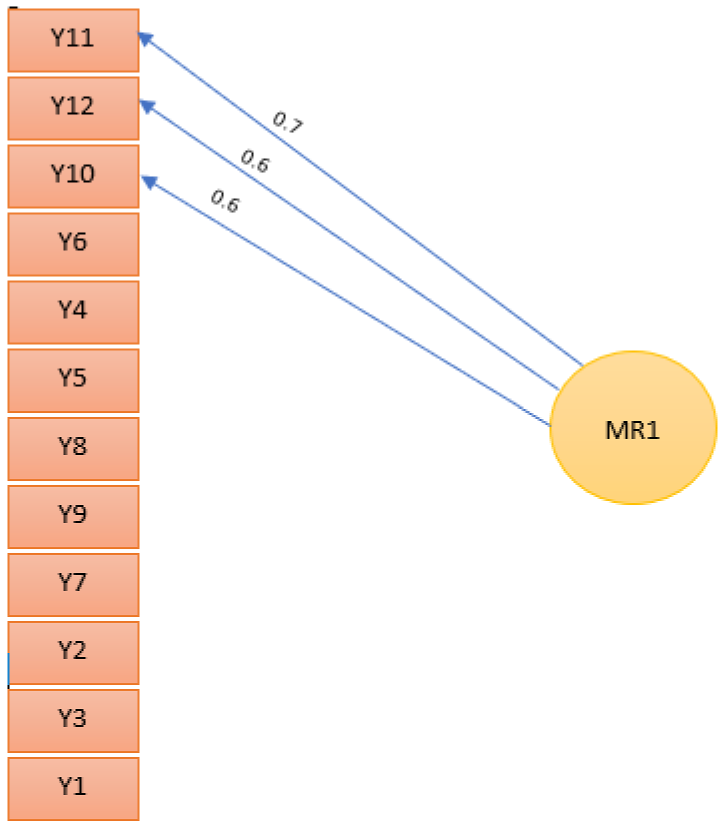
- *Applying cutoff (0.3) to improve visibility*

```
##
## Loadings:
##     MR1
## y1
## y2
## y3
## y4
## y5
## y6
## y7
## y8
## y9
## y10  0.638
## y11  0.697
## y12  0.643
##
##                  MR1
## SS loadings    1.544
## Proportion Var 0.129
```

- *Applying factanal function*

```
##
## Call:
## factanal(x = data2, factors = 1, rotation = "varimax")
##
## Uniquenesses:
##    y1    y2    y3    y4    y5    y6    y7    y8    y9   y10   y11   y12
## 0.999 0.999 1.000 0.983 0.986 0.983 1.000 0.998 0.999 0.524 0.392 0.556
##
## Loadings:
##     Factor1
## y1
## y2
## y3
## y4  -0.132
## y5  -0.116
## y6  -0.132
## y7
## y8
## y9
## y10  0.690
## y11  0.780
## y12  0.666
##
##                Factor1
## SS loadings      1.581
## Proportion Var   0.132
##
## Test of the hypothesis that 1 factor is sufficient.
```

```
## The chi square statistic is 1042.03 on 54 degrees of freedom.
## The p-value is 6.04e-183
```



Factor mapping

- *Adequacy test* (Validating the model with 1 factor analysis)

The root mean square of residuals (RMSR) is 0.18 and this value should be closer to 0. Next, the RMSEA (root mean square error of approximation) index is 0.195 and it should be below 0.05. Finally, the Tucker-Lewis Index (TLI) is 0.087, not an acceptable value, it should be over 0.9.

The significance level is very small indicating hypothesis of good model fit is rejected.

- ***Factor analysis with 2 factors***

```
## Factor Analysis using method =  minres
## Call: fa(r = data2, nfactors = 2, rotate = "oblimin", fm = "minres")
## Standardized loadings (pattern matrix) based upon correlation matrix
##       MR1   MR2     h2   u2 com
## y1   0.08  0.00 0.0062 0.99 1.0
```

```
## y2   0.02  0.05 0.0026 1.00 1.3
## y3  -0.03  0.02 0.0011 1.00 1.5
## y4   0.03 -0.26 0.0669 0.93 1.0
## y5   0.02 -0.25 0.0626 0.94 1.0
## y6   0.06 -0.26 0.0705 0.93 1.1
## y7   0.73  0.02 0.5394 0.46 1.0
## y8   0.72 -0.02 0.5222 0.48 1.0
## y9   0.71  0.01 0.5012 0.50 1.0
## y10 -0.01  0.64 0.4157 0.58 1.0
## y11  0.00  0.71 0.5056 0.49 1.0
## y12  0.01  0.66 0.4290 0.57 1.0
##
##                        MR1  MR2
## SS loadings           1.57 1.55
## Proportion Var        0.13 0.13
## Cumulative Var        0.13 0.26
## Proportion Explained  0.50 0.50
## Cumulative Proportion 0.50 1.00
##
##  With factor correlations of
##       MR1   MR2
## MR1  1.00 -0.02
## MR2 -0.02  1.00
##
## Mean item complexity =  1.1
## Test of the hypothesis that 2 factors are sufficient.
##
## The degrees of freedom for the null model are  66  and the objective funct
ion was  2.87 with Chi Square of  1420.06
## The degrees of freedom for the model are 43  and the objective function wa
s  1.38
##
## The root mean square of the residuals (RMSR) is  0.14
## The df corrected root mean square of the residuals is  0.18
##
## The harmonic number of observations is  500 with the empirical chi square
1346.53  with prob <  3.6e-254
## The total number of observations was  500  with Likelihood Chi Square =  6
80.22  with prob <  1.5e-115
##
## Tucker Lewis Index of factoring reliability =  0.276
## RMSEA index =  0.173  and the 90 % confidence intervals are  0.161 0.184
## BIC =  412.99
## Fit based upon off diagonal values = 0.56
## Measures of factor score adequacy
##                                                   MR1  MR2
## Correlation of (regression) scores with factors   0.88 0.85
## Multiple R square of scores with factors          0.77 0.73
## Minimum correlation of possible factor scores     0.53 0.45
```

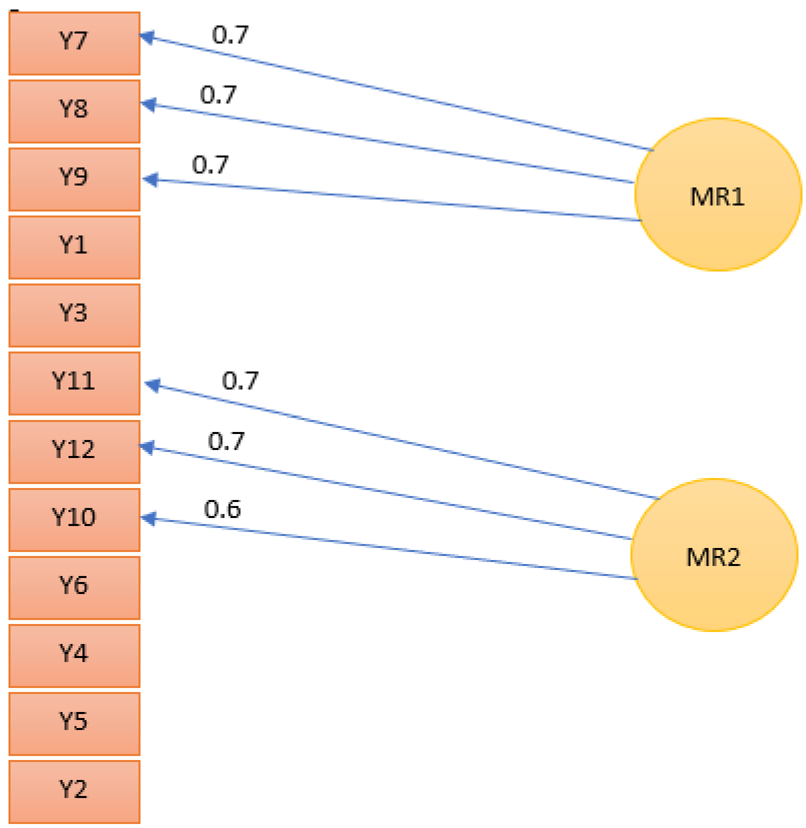
- *Applying cutoff (0.3) to improve visibility*

```
##
## Loadings:
##     MR1    MR2
## y1
## y2
## y3
## y4
## y5
## y6
## y7   0.735
## y8   0.722
## y9   0.708
## y10         0.645
## y11         0.711
## y12         0.655
##
##                  MR1   MR2
## SS loadings    1.574 1.548
## Proportion Var 0.131 0.129
## Cumulative Var 0.131 0.260
```

- *Applying factanal function*

```
##
## Call:
## factanal(x = data2, factors = 2, rotation = “varimax”)
##
## Uniquenesses:
##    y1    y2    y3    y4    y5    y6    y7    y8    y9   y10   y11   y12
## 0.994 0.999 0.998 0.982 0.987 0.980 0.460 0.473 0.502 0.524 0.392 0.555
##
## Loadings:
##     Factor1 Factor2
## y1
## y2
## y3
## y4  -0.132
## y5  -0.116
## y6  -0.131
## y7           0.735
## y8           0.724
## y9           0.705
## y10  0.690
## y11  0.780
## y12  0.667
##
##                Factor1 Factor2
## SS loadings      1.582   1.572
```

```
## Proportion Var   0.132   0.131
## Cumulative Var   0.132   0.263
##
## Test of the hypothesis that 2 factors are sufficient.
## The chi square statistic is 662.62 on 43 degrees of freedom.
## The p-value is 5.77e-112
```



Factor mapping

- *Adequacy test* (Validating the model with 2 factor analysis)

The root mean square of residuals (RMSR) is 0.14 and this value should be closer to 0. Next, the RMSEA (root mean square error of approximation) index is 0.173 and it should be below 0.05. Finally, the Tucker-Lewis Index (TLI) is 0.276, not an acceptable value considering it should be over 0.9.

The significance level again is very small indicating hypothesis of good model fit is rejected.

- ***Factor analysis with 3 factors***

```
## Factor Analysis using method =  minres
## Call: fa(r = data2, nfactors = 3, rotate = "oblimin", fm = "minres")
## Standardized loadings (pattern matrix) based upon correlation matrix
##       MR1   MR2   MR3    h2   u2 com
## y1   0.07 -0.03  0.64 0.417 0.58 1.0
## y2   0.00  0.02  0.78 0.612 0.39 1.0
## y3  -0.06 -0.02  0.64 0.416 0.58 1.0
## y4   0.03 -0.25 -0.06 0.067 0.93 1.1
## y5   0.02 -0.24 -0.11 0.070 0.93 1.4
## y6   0.06 -0.25 -0.07 0.072 0.93 1.3
## y7   0.73  0.02 -0.01 0.540 0.46 1.0
## y8   0.72 -0.02 -0.03 0.527 0.47 1.0
## y9   0.70  0.00  0.04 0.499 0.50 1.0
## y10 -0.01  0.65 -0.04 0.430 0.57 1.0
## y11  0.00  0.72  0.00 0.511 0.49 1.0
## y12  0.01  0.65  0.03 0.428 0.57 1.0
##
##                        MR1  MR2  MR3
## SS loadings           1.58 1.55 1.46
## Proportion Var        0.13 0.13 0.12
## Cumulative Var        0.13 0.26 0.38
## Proportion Explained  0.34 0.34 0.32
## Cumulative Proportion 0.34 0.68 1.00
##
##  With factor correlations of
##       MR1   MR2   MR3
## MR1  1.00 -0.02  0.01
## MR2 -0.02  1.00 -0.01
## MR3  0.01 -0.01  1.00
##
## Mean item complexity =  1.1
## Test of the hypothesis that 3 factors are sufficient.
##
## The degrees of freedom for the null model are  66  and the objective funct
ion was  2.87 with Chi Square of  1420.06
## The degrees of freedom for the model are 33  and the objective function wa
s  0.72
##
## The root mean square of the residuals (RMSR) is  0.1
## The df corrected root mean square of the residuals is  0.14
##
## The harmonic number of observations is  500 with the empirical chi square
641.61  with prob <  6.8e-114
## The total number of observations was  500  with Likelihood Chi Square =  3
53.78  with prob <  2.2e-55
##
## Tucker Lewis Index of factoring reliability =  0.524
## RMSEA index =  0.141  and the 90 % confidence intervals are  0.127 0.153
## BIC =  148.69
## Fit based upon off diagonal values = 0.79
```

```
## Measures of factor score adequacy
##                                                    MR1  MR2  MR3
## Correlation of (regression) scores with factors   0.88 0.85 0.87
## Multiple R square of scores with factors          0.77 0.73 0.75
## Minimum correlation of possible factor scores     0.53 0.46 0.50
```

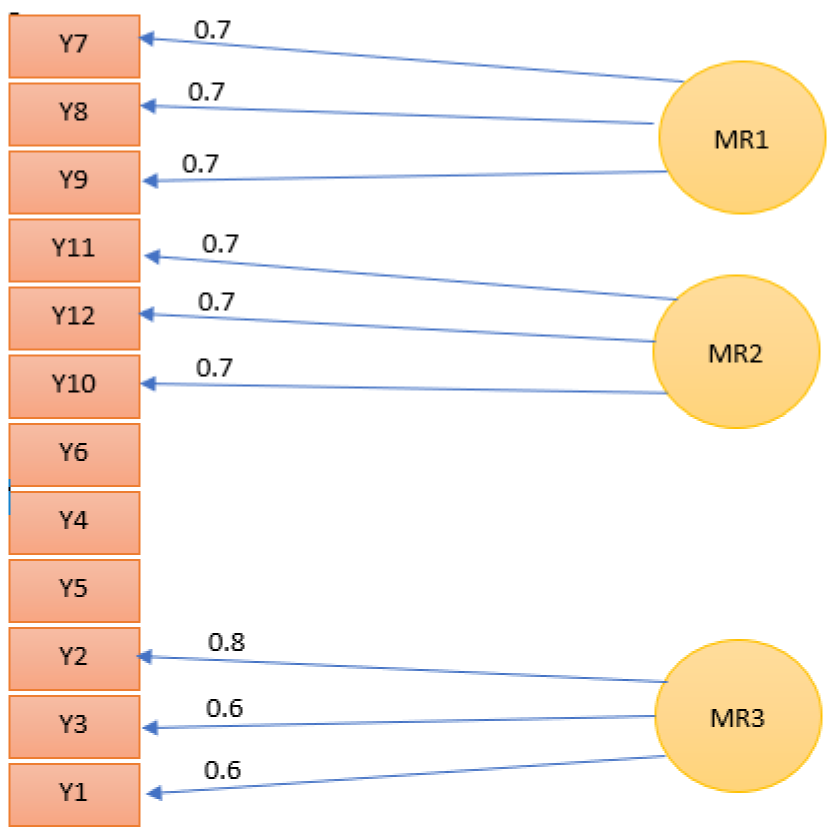
- *Applying cutoff (0.3) to improve visibility*

```
##
## Loadings:
##     MR1    MR2    MR3
## y1                 0.639
## y2                 0.782
## y3                 0.642
## y4
## y5
## y6
## y7   0.735
## y8   0.725
## y9   0.705
## y10         0.654
## y11         0.715
## y12         0.654
##
##                  MR1   MR2   MR3
## SS loadings    1.577 1.553 1.459
## Proportion Var 0.131 0.129 0.122
## Cumulative Var 0.131 0.261 0.382
```

- *Applying factanal function*

```
##
## Call:
## factanal(x = data2, factors = 3, rotation = “varimax”)
##
## Uniquenesses:
##    y1    y2    y3    y4    y5    y6    y7    y8    y9   y10   y11   y12
## 0.584 0.353 0.595 0.982 0.983 0.980 0.460 0.470 0.500 0.520 0.394 0.553
##
## Loadings:
##     Factor1 Factor2 Factor3
## y1                   0.640
## y2                   0.801
## y3                   0.633
## y4  -0.132
## y5  -0.118
## y6  -0.133
## y7           0.734
## y8           0.725
## y9           0.704
## y10  0.689
```

```
## y11  0.777
## y12  0.668
##
##                 Factor1 Factor2 Factor3
## SS loadings       1.586   1.573   1.466
## Proportion Var    0.132   0.131   0.122
## Cumulative Var    0.132   0.263   0.385
##
## Test of the hypothesis that 3 factors are sufficient.
## The chi square statistic is 335.92 on 33 degrees of freedom.
## The p-value is 7.46e-52
```



Factor mapping

- *Adequacy test* (Validating the model with 3 factor analysis)

The root mean square of residuals (RMSR) is 0.1 and this value should be closer to 0. Next, the RMSEA (root mean square error of approximation) index is 0.141 and it should be below 0.05. Finally, the Tucker-Lewis Index (TLI) is 0.524, again, not an acceptable value considering it's over 0.9.

The significance level using 3 factors is very small indicating hypothesis of good model fit is rejected.

- ***Factor analysis with 4 factors***

```
## Factor Analysis using method =  minres
## Call: fa(r = data2, nfactors = 4, rotate = "oblimin", fm = "minres")
## Standardized loadings (pattern matrix) based upon correlation matrix
##       MR2   MR1   MR3   MR4   h2   u2 com
## y1   0.07 -0.03  0.64  0.00 0.41 0.59   1
## y2  -0.01  0.03  0.81  0.02 0.65 0.35   1
## y3  -0.06 -0.03  0.63 -0.04 0.41 0.59   1
## y4   0.00 -0.02  0.03  0.65 0.42 0.58   1
## y5  -0.02  0.02 -0.03  0.76 0.57 0.43   1
## y6   0.03 -0.01  0.01  0.67 0.46 0.54   1
## y7   0.73  0.02 -0.01  0.00 0.54 0.46   1
## y8   0.73 -0.02 -0.03  0.00 0.53 0.47   1
## y9   0.71  0.00  0.04 -0.01 0.50 0.50   1
## y10 -0.01  0.69 -0.04  0.00 0.48 0.52   1
## y11  0.00  0.79  0.01  0.02 0.62 0.38   1
## y12  0.01  0.66  0.03 -0.04 0.44 0.56   1
##
##                        MR2  MR1  MR3  MR4
## SS loadings           1.58 1.54 1.47 1.45
## Proportion Var        0.13 0.13 0.12 0.12
## Cumulative Var        0.13 0.26 0.38 0.50
## Proportion Explained  0.26 0.26 0.24 0.24
## Cumulative Proportion 0.26 0.52 0.76 1.00
##
##  With factor correlations of
##       MR2   MR1   MR3   MR4
## MR2  1.00 -0.03  0.01  0.03
## MR1 -0.03  1.00  0.01 -0.12
## MR3  0.01  0.01  1.00 -0.04
## MR4  0.03 -0.12 -0.04  1.00
##
## Mean item complexity =  1
## Test of the hypothesis that 4 factors are sufficient.
##
## The degrees of freedom for the null model are  66  and the objective funct
ion was  2.87 with Chi Square of  1420.06
## The degrees of freedom for the model are 24  and the objective function wa
s  0.05
##
## The root mean square of the residuals (RMSR) is  0.01
## The df corrected root mean square of the residuals is  0.02
##
## The harmonic number of observations is  500 with the empirical chi square
13.63  with prob <  0.95
```

```
## The total number of observations was  500  with Likelihood Chi Square =  2
5.51  with prob <  0.38
##
## Tucker Lewis Index of factoring reliability =  0.997
## RMSEA index =  0.013  and the 90 % confidence intervals are  0 0.039
## BIC =  -123.64
## Fit based upon off diagonal values = 1
## Measures of factor score adequacy
##                                                    MR2  MR1  MR3  MR4
## Correlation of (regression) scores with factors   0.88 0.88 0.87 0.86
## Multiple R square of scores with factors          0.77 0.77 0.76 0.75
## Minimum correlation of possible factor scores     0.54 0.54 0.53 0.49
```

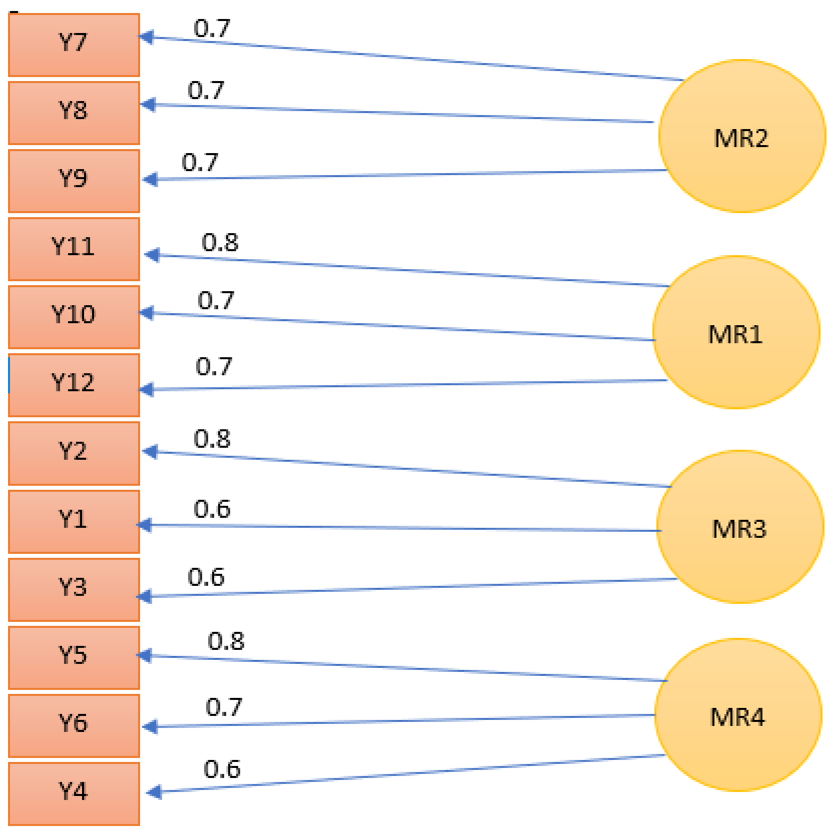
- *Applying cutoff (0.3) to improve visibility*

```
##
## Loadings:
##     MR2    MR1    MR3    MR4
## y1                 0.637
## y2                 0.807
## y3                 0.634
## y4                        0.647
## y5                        0.759
## y6                        0.675
## y7   0.735
## y8   0.726
## y9   0.706
## y10         0.692
## y11         0.792
## y12         0.658
##
##                  MR2   MR1   MR3   MR4
## SS loadings    1.576 1.543 1.465 1.452
## Proportion Var 0.131 0.129 0.122 0.121
## Cumulative Var 0.131 0.260 0.382 0.503
```

- *Applying factanal function*

```
##
## Call:
## factanal(x = data2, factors = 4, rotation = "varimax")
##
## Uniquenesses:
##    y1    y2    y3    y4    y5    y6    y7    y8    y9   y10   y11   y12
## 0.588 0.346 0.594 0.581 0.424 0.543 0.462 0.470 0.498 0.520 0.376 0.559
##
## Loadings:
##     Factor1 Factor2 Factor3 Factor4
## y1                  0.637
## y2                  0.807
## y3                  0.632
```

```
## y4                           0.645
## y5                           0.757
## y6                           0.673
## y7   0.733
## y8   0.727
## y9   0.706
## y10          0.691
## y11          0.789
## y12          0.659
##
##                Factor1 Factor2 Factor3 Factor4
## SS loadings      1.576   1.544   1.467   1.453
## Proportion Var   0.131   0.129   0.122   0.121
## Cumulative Var   0.131   0.260   0.382   0.503
##
## Test of the hypothesis that 4 factors are sufficient.
## The chi square statistic is 25.36 on 24 degrees of freedom.
## The p-value is 0.386
```



Factor mapping

All the four factors having 3 variables loaded.

- *Adequacy test* (Validating the model with 4 factor analysis)

The root mean square of residuals (RMSR) is 0.01 and this value should be closer to 0. Next, the RMSEA (root mean square error of approximation) index is 0.013 and it should be below 0.05. Finally, the Tucker-Lewis Index (TLI) is 0.997, an acceptable value considering it's over 0.9.

The significance level seems promising and has made a huge improvement as compared to the last three models. The p-value (0.386) suggests that the hypothesis of good model fit cannot be rejected.

Final Interpretation

The analysis including 4 factors seems to have perfect model fit for this dataset.

References:

Structural equation models, 2019, week 1 material

https://www.r-bloggers.com/exploratory-factor-analysis-in-r/

Assignment 2 SEM

Shweta Goswami

28-01-2019

Exercise 2.1

Draw the graphs, specify and test the hypothesis given on p. 1 of the lecture material. Draw conclusions based on the ??2 statistic and the CFI, TLI and RMSEA indices.

TITLE: CFA of Academic SC Structure for Grade 7 Adolescents (Byrne 2012, p. 56)

- Reading the ASC7INDM.DAT file

```
CFA <- read.fortran("ASC7INDM.DAT", format=c("40F1.0","X","6F2.0"))
str(CFA)
```

```
## 'data.frame':    265 obs. of  46 variables:
##  $ V1 : num  3 4 1 3 3 2 1 1 3 3 ...
##  $ V2 : num  4 4 4 3 4 3 1 4 3 3 ...
##  $ V3 : num  3 4 4 3 4 3 4 1 4 3 ...
##  $ V4 : num  3 4 4 2 4 2 2 1 3 3 ...
##  $ V5 : num  3 4 4 3 3 3 4 1 3 2 ...
##  $ V6 : num  3 4 1 3 4 2 3 1 2 3 ...
##  $ V7 : num  3 4 3 3 4 3 4 1 2 4 ...
##  $ V8 : num  4 4 4 4 3 3 4 1 3 4 ...
##  $ V9 : num  1 4 1 3 2 2 4 1 3 4 ...
##  $ V10: num  3 4 4 3 4 3 3 3 3 4 ...
##  $ V11: num  3 4 4 3 3 3 3 2 3 4 ...
##  $ V12: num  4 4 1 3 3 2 2 4 3 4 ...
##  $ V13: num  2 4 1 3 3 3 4 3 3 4 ...
##  $ V14: num  2 4 1 3 4 3 4 2 3 4 ...
##  $ V15: num  3 4 1 1 3 1 4 3 3 4 ...
##  $ V16: num  3 4 1 4 4 1 1 4 3 4 ...
##  $ V17: num  2 4 4 3 3 3 1 2 3 3 ...
##  $ V18: num  3 4 1 4 3 3 1 3 3 4 ...
##  $ V19: num  3 4 4 3 1 2 4 2 2 3 ...
##  $ V20: num  3 4 4 4 3 3 4 1 2 3 ...
##  $ V21: num  3 4 4 3 3 1 4 2 2 3 ...
##  $ V22: num  3 4 4 4 3 1 4 3 3 4 ...
##  $ V23: num  3 4 4 3 3 2 4 3 3 3 ...
##  $ V24: num  3 4 1 3 2 2 4 3 3 4 ...
##  $ V25: num  6 6 4 5 6 5 1 2 5 4 ...
##  $ V26: num  5 6 6 5 5 5 6 1 5 6 ...
##  $ V27: num  4 6 6 5 5 5 1 6 6 3 ...
##  $ V28: num  6 6 2 6 4 3 6 4 6 6 ...
##  $ V29: num  3 6 6 5 3 3 4 4 6 6 ...
##  $ V30: num  4 6 4 6 4 2 6 4 6 5 ...
##  $ V31: num  4 6 6 5 4 4 6 4 6 6 ...
##  $ V32: num  6 6 3 6 4 4 6 6 6 6 ...
##  $ V33: num  2 5 6 5 4 4 1 6 5 4 ...
##  $ V34: num  6 6 5 6 6 4 6 6 6 6 ...
```

```
##  $ V35: num  1 6 4 3 5 5 1 1 5 4 ...
##  $ V36: num  5 6 5 5 6 6 6 5 6 6 ...
##  $ V37: num  6 6 6 6 3 4 5 3 6 5 ...
##  $ V38: num  6 6 6 6 4 5 6 4 6 6 ...
##  $ V39: num  6 6 3 6 4 4 6 4 6 6 ...
##  $ V40: num  6 6 1 5 5 4 5 6 6 6 ...
##  $ V41: num  33 33 24 38 39 40 31 39 39 36 ...
##  $ V42: num  13 14 15 15 11 14 15 10 18 17 ...
##  $ V43: num  4 6 2 9 9 6 7 4 6 6 ...
##  $ V44: num  4 7 5 9 9 6 9 4 9 6 ...
##  $ V45: num  6 8 7 8 8 8 7 7 9 9 ...
##  $ V46: num  9 6 10 9 8 8 9 5 10 9 ...
```

```r
dim(CFA)
```

```
## [1] 265  46
```

```r
head(CFA)
```

```
##   V1 V2 V3 V4 V5 V6 V7 V8 V9 V10 V11 V12 V13 V14 V15 V16 V17 V18 V19 V20
## 1  3  4  3  3  3  3  3  4  1   3   3   4   2   2   3   3   2   3   3   3
## 2  4  4  4  4  4  4  4  4  4   4   4   4   4   4   4   4   4   4   4   4
## 3  1  4  4  4  4  1  3  4  1   4   4   1   1   1   1   1   4   1   4   4
## 4  3  3  3  2  3  3  3  4  3   3   3   3   3   3   1   4   3   4   3   4
## 5  3  4  4  4  3  4  4  3  2   4   3   3   3   4   3   4   3   3   1   3
## 6  2  3  3  2  3  2  3  3  2   3   3   2   3   3   1   1   3   3   2   3
##   V21 V22 V23 V24 V25 V26 V27 V28 V29 V30 V31 V32 V33 V34 V35 V36 V37 V38
## 1   3   3   3   3   6   5   4   6   3   4   4   6   2   6   1   5   6   6
## 2   4   4   4   4   6   6   6   6   6   6   6   6   5   6   6   6   6   6
## 3   4   4   4   1   4   6   6   2   6   4   6   3   6   5   4   5   6   6
## 4   3   4   3   3   5   5   5   6   5   6   5   6   5   6   3   5   6   6
## 5   3   3   3   2   6   5   5   4   3   4   4   4   4   6   5   6   3   4
## 6   1   1   2   2   5   5   5   3   3   2   4   4   4   4   5   6   4   5
##   V39 V40 V41 V42 V43 V44 V45 V46
## 1   6   6  33  13   4   4   6   9
## 2   6   6  33  14   6   7   8   6
## 3   3   1  24  15   2   5   7  10
## 4   6   5  38  15   9   9   8   9
## 5   4   5  39  11   9   9   8   8
## 6   4   4  40  14   6   6   8   8
```

- Creating names for all the variables

```r
names(CFA) = c("SPPCN08", "SPPCN18", "SPPCN28", "SPPCN38", "SPPCN48", "SPPCN58", "SPPCN01", "SPPCN11",

"SDQ2N01", "SDQ2N13", "SDQ2N25", "SDQ2N37", "SDQ2N04", "SDQ2N16", "SDQ2N28", "SDQ2N40", "SDQ2N10", "SDQ2

"MASTENG1", "MASTMAT1", "TENG1", "TMAT1", "SENG1", "SMAT1")

names(CFA)
```

```
##  [1] "SPPCN08"  "SPPCN18"  "SPPCN28"  "SPPCN38"  "SPPCN48"  "SPPCN58"
##  [7] "SPPCN01"  "SPPCN11"  "SPPCN21"  "SPPCN31"  "SPPCN41"  "SPPCN51"
## [13] "SPPCN06"  "SPPCN16"  "SPPCN26"  "SPPCN36"  "SPPCN46"  "SPPCN56"
## [19] "SPPCN03"  "SPPCN13"  "SPPCN23"  "SPPCN33"  "SPPCN43"  "SPPCN53"
## [25] "SDQ2N01"  "SDQ2N13"  "SDQ2N25"  "SDQ2N37"  "SDQ2N04"  "SDQ2N16"
## [31] "SDQ2N28"  "SDQ2N40"  "SDQ2N10"  "SDQ2N22"  "SDQ2N34"  "SDQ2N46"
```

```
## [37] "SDQ2N07"  "SDQ2N19"  "SDQ2N31"  "SDQ2N43"  "MASTENG1" "MASTMAT1"
## [43] "TENG1"    "TMAT1"    "SENG1"    "SMAT1"
```

- Specify the 4-factor model

```r
library(lavaan)
model <- '
F1 =~ SDQ2N01 + SDQ2N13 + SDQ2N25 + SDQ2N37
F2 =~ SDQ2N04 + SDQ2N16 + SDQ2N28 + SDQ2N40
F3 =~ SDQ2N10 + SDQ2N22 + SDQ2N34 + SDQ2N46
F4 =~ SDQ2N07 + SDQ2N19 + SDQ2N31 + SDQ2N43
'
```

- Fitting the model

```r
fit <- cfa(model, data=CFA,  control=list(iter.max=1000))
```

- Display summary output

```r
summary(fit, fit.measures=TRUE)
```

```
## lavaan 0.6-3 ended normally after 49 iterations
##
##   Optimization method                           NLMINB
##   Number of free parameters                         38
##
##   Number of observations                           265
##
##   Estimator                                         ML
##   Model Fit Test Statistic                     159.112
##   Degrees of freedom                                98
##   P-value (Chi-square)                           0.000
##
## Model test baseline model:
##
##   Minimum Function Test Statistic             1703.155
##   Degrees of freedom                               120
##   P-value                                        0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                    0.961
##   Tucker-Lewis Index (TLI)                       0.953
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)              -6562.678
##   Loglikelihood unrestricted model (H1)      -6483.122
##
##   Number of free parameters                         38
##   Akaike (AIC)                               13201.356
##   Bayesian (BIC)                             13337.386
##   Sample-size adjusted Bayesian (BIC)        13216.905
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.049
```

```
##   90 Percent Confidence Interval          0.034  0.062
##   P-value RMSEA <= 0.05                           0.556
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                            0.048
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard Errors                             Standard
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   F1 =~
##     SDQ2N01           1.000
##     SDQ2N13           1.083    0.154    7.044    0.000
##     SDQ2N25           0.851    0.132    6.455    0.000
##     SDQ2N37           0.934    0.131    7.131    0.000
##   F2 =~
##     SDQ2N04           1.000
##     SDQ2N16           1.279    0.150    8.520    0.000
##     SDQ2N28           1.247    0.154    8.097    0.000
##     SDQ2N40           1.259    0.156    8.048    0.000
##   F3 =~
##     SDQ2N10           1.000
##     SDQ2N22           0.889    0.103    8.658    0.000
##     SDQ2N34           0.670    0.148    4.539    0.000
##     SDQ2N46           0.843    0.117    7.225    0.000
##   F4 =~
##     SDQ2N07           1.000
##     SDQ2N19           0.841    0.058   14.495    0.000
##     SDQ2N31           0.952    0.049   19.516    0.000
##     SDQ2N43           0.655    0.049   13.298    0.000
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   F1 ~~
##     F2                0.415    0.078    5.292    0.000
##     F3                0.355    0.072    4.947    0.000
##     F4                0.635    0.118    5.387    0.000
##   F2 ~~
##     F3                0.464    0.078    5.921    0.000
##     F4                0.873    0.134    6.519    0.000
##   F3 ~~
##     F4                0.331    0.100    3.309    0.001
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .SDQ2N01           1.198    0.126    9.537    0.000
##    .SDQ2N13           1.119    0.124    9.019    0.000
##    .SDQ2N25           1.056    0.107    9.897    0.000
##    .SDQ2N37           0.771    0.087    8.821    0.000
```

```
##    .SDQ2N04           1.394    0.128   10.900    0.000
##    .SDQ2N16           0.616    0.068    9.020    0.000
##    .SDQ2N28           0.896    0.090    9.959    0.000
##    .SDQ2N40           0.952    0.095   10.029    0.000
##    .SDQ2N10           0.653    0.082    7.941    0.000
##    .SDQ2N22           0.657    0.075    8.735    0.000
##    .SDQ2N34           2.590    0.233   11.128    0.000
##    .SDQ2N46           1.201    0.118   10.183    0.000
##    .SDQ2N07           0.854    0.100    8.551    0.000
##    .SDQ2N19           1.228    0.121   10.153    0.000
##    .SDQ2N31           0.365    0.065    5.649    0.000
##    .SDQ2N43           0.964    0.092   10.473    0.000
##     F1                0.613    0.137    4.464    0.000
##     F2                0.561    0.126    4.453    0.000
##     F3                0.668    0.116    5.749    0.000
##     F4                2.307    0.273    8.460    0.000
```

- The estimator used is ML, the model seems to be converged normally, the number of observations is equal to the number of rows in the data.
- Chi-Square Test of Model Fit : Assess overall fit and the discrepancy between the sample and fitted covariance matrices. Here the x2 is 159.112, with 98 degrees of freedom (ideal value >2df). The p-value should be more than >0.05 to have a good model fit and here, the p-value is 0.000.
- Comparative fit index (CFI): The index tells whether the model fits the data better than a more baseline model. The higher the index, the better it is. The CFI (0.961) with 4-factor model seems to be fit okay i.e. > .9.
- TLI (Tucker-Lewis index): The index is similar to CFI but more conservative one.It also tells whether the model fits the data better than a more baseline model. The higher the index, the better it is. The TLI (0.953) appears to be fit okay i.e. > .9.
- The difference between AIC and BIC seems to be low. The lower the difference, the better it is.
- RMSEA (Root mean square error of approximation): It indicates residuals and meaures covariance among indicators. The lower, the better. Here, the RMSEA (0.049) is less than 0.05 (ideal value) with a 90%CI from .03 to .06.
- SRMR (Standardized Root Mean Square Residual) : The square-root of the difference between the residuals of the covariance matrix and the hypothesized model. The cut-off of good fit is <0.08. Here, the SRMR is 0.048.
- Obtaining confidence intervals for the estimated coefficients

```r
parameterEstimates(fit, ci = TRUE, level = 0.95)
```

```
##        lhs op     rhs   est    se      z pvalue ci.lower ci.upper
## 1       F1 =~ SDQ2N01 1.000 0.000     NA     NA    1.000    1.000
## 2       F1 =~ SDQ2N13 1.083 0.154  7.044  0.000    0.782    1.384
## 3       F1 =~ SDQ2N25 0.851 0.132  6.455  0.000    0.592    1.109
## 4       F1 =~ SDQ2N37 0.934 0.131  7.131  0.000    0.677    1.190
## 5       F2 =~ SDQ2N04 1.000 0.000     NA     NA    1.000    1.000
## 6       F2 =~ SDQ2N16 1.279 0.150  8.520  0.000    0.985    1.573
## 7       F2 =~ SDQ2N28 1.247 0.154  8.097  0.000    0.945    1.549
## 8       F2 =~ SDQ2N40 1.259 0.156  8.048  0.000    0.952    1.565
## 9       F3 =~ SDQ2N10 1.000 0.000     NA     NA    1.000    1.000
## 10      F3 =~ SDQ2N22 0.889 0.103  8.658  0.000    0.688    1.091
## 11      F3 =~ SDQ2N34 0.670 0.148  4.539  0.000    0.381    0.960
## 12      F3 =~ SDQ2N46 0.843 0.117  7.225  0.000    0.614    1.071
```

```
## 13       F4 =~ SDQ2N07 1.000 0.000     NA     NA    1.000    1.000
## 14       F4 =~ SDQ2N19 0.841 0.058 14.495  0.000    0.727    0.955
## 15       F4 =~ SDQ2N31 0.952 0.049 19.516  0.000    0.857    1.048
## 16       F4 =~ SDQ2N43 0.655 0.049 13.298  0.000    0.559    0.752
## 17 SDQ2N01 ~~ SDQ2N01 1.198 0.126  9.537  0.000    0.952    1.444
## 18 SDQ2N13 ~~ SDQ2N13 1.119 0.124  9.019  0.000    0.876    1.362
## 19 SDQ2N25 ~~ SDQ2N25 1.056 0.107  9.897  0.000    0.847    1.265
## 20 SDQ2N37 ~~ SDQ2N37 0.771 0.087  8.821  0.000    0.600    0.943
## 21 SDQ2N04 ~~ SDQ2N04 1.394 0.128 10.900  0.000    1.144    1.645
## 22 SDQ2N16 ~~ SDQ2N16 0.616 0.068  9.020  0.000    0.482    0.750
## 23 SDQ2N28 ~~ SDQ2N28 0.896 0.090  9.959  0.000    0.719    1.072
## 24 SDQ2N40 ~~ SDQ2N40 0.952 0.095 10.029  0.000    0.766    1.138
## 25 SDQ2N10 ~~ SDQ2N10 0.653 0.082  7.941  0.000    0.492    0.815
## 26 SDQ2N22 ~~ SDQ2N22 0.657 0.075  8.735  0.000    0.510    0.805
## 27 SDQ2N34 ~~ SDQ2N34 2.590 0.233 11.128  0.000    2.134    3.046
## 28 SDQ2N46 ~~ SDQ2N46 1.201 0.118 10.183  0.000    0.970    1.432
## 29 SDQ2N07 ~~ SDQ2N07 0.854 0.100  8.551  0.000    0.658    1.050
## 30 SDQ2N19 ~~ SDQ2N19 1.228 0.121 10.153  0.000    0.991    1.465
## 31 SDQ2N31 ~~ SDQ2N31 0.365 0.065  5.649  0.000    0.238    0.491
## 32 SDQ2N43 ~~ SDQ2N43 0.964 0.092 10.473  0.000    0.783    1.144
## 33       F1 ~~      F1 0.613 0.137  4.464  0.000    0.344    0.883
## 34       F2 ~~      F2 0.561 0.126  4.453  0.000    0.314    0.808
## 35       F3 ~~      F3 0.668 0.116  5.749  0.000    0.440    0.896
## 36       F4 ~~      F4 2.307 0.273  8.460  0.000    1.773    2.842
## 37       F1 ~~      F2 0.415 0.078  5.292  0.000    0.261    0.568
## 38       F1 ~~      F3 0.355 0.072  4.947  0.000    0.214    0.496
## 39       F1 ~~      F4 0.635 0.118  5.387  0.000    0.404    0.867
## 40       F2 ~~      F3 0.464 0.078  5.921  0.000    0.310    0.617
## 41       F2 ~~      F4 0.873 0.134  6.519  0.000    0.610    1.135
## 42       F3 ~~      F4 0.331 0.100  3.309  0.001    0.135    0.527
```

- Obtaining goodness of fit indicators of the model

```
fitMeasures(fit, c("chisq", "rmsea", "srmr", "gfi", "ecvi"))
```

```
##   chisq   rmsea    srmr     gfi    ecvi
## 159.112   0.049   0.048   0.933   0.887
```

- The GFI should be > 0.95. Here, it is 0.93.
- Obtaining reliability

```
reliability(fit)
```

```
##               F1        F2        F3        F4     total
## alpha  0.6925568 0.7594267 0.6075534 0.8847428 0.8646270
## omega  0.6888167 0.7690608 0.6025494 0.8894519 0.9011247
## omega2 0.6888167 0.7690608 0.6025494 0.8894519 0.9011247
## omega3 0.6829250 0.7789836 0.5952326 0.8848980 0.9178356
## avevar 0.3580256 0.4565463 0.2787087 0.6731031 0.4683085
```

- Inspecting the model

```
inspect(fit)
```

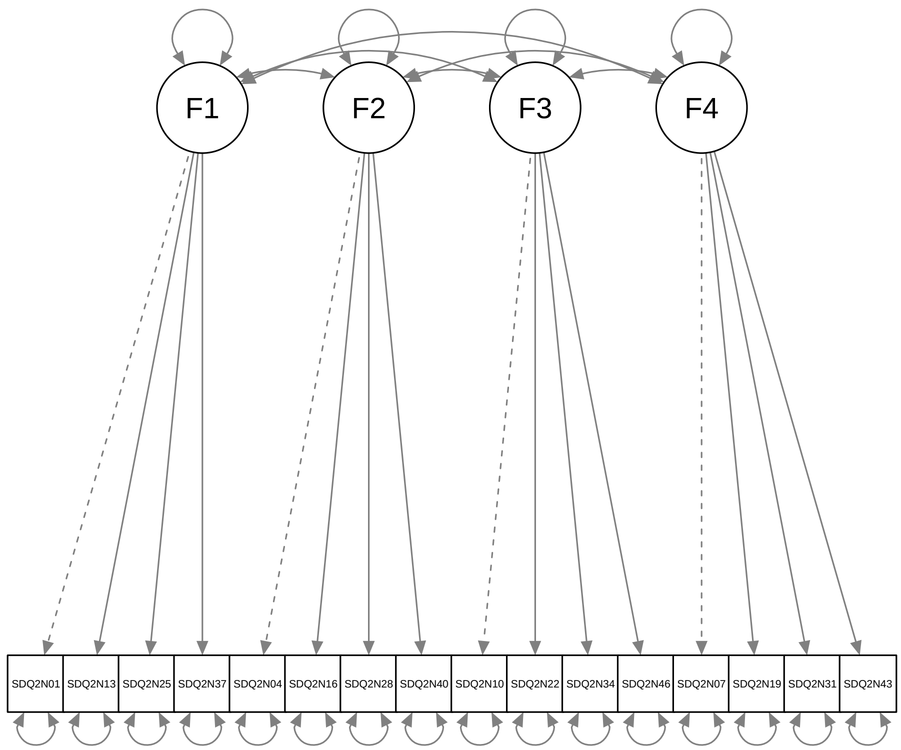
```
## $lambda
##         F1 F2 F3 F4
## SDQ2N01  0  0  0  0
```

```
## SDQ2N13  1  0  0  0
## SDQ2N25  2  0  0  0
## SDQ2N37  3  0  0  0
## SDQ2N04  0  0  0  0
## SDQ2N16  0  4  0  0
## SDQ2N28  0  5  0  0
## SDQ2N40  0  6  0  0
## SDQ2N10  0  0  0  0
## SDQ2N22  0  0  7  0
## SDQ2N34  0  0  8  0
## SDQ2N46  0  0  9  0
## SDQ2N07  0  0  0  0
## SDQ2N19  0  0  0 10
## SDQ2N31  0  0  0 11
## SDQ2N43  0  0  0 12
##
## $theta
##         SDQ2N01 SDQ2N13 SDQ2N25 SDQ2N37 SDQ2N04 SDQ2N16 SDQ2N28 SDQ2N40
## SDQ2N01 13
## SDQ2N13  0      14
## SDQ2N25  0       0      15
## SDQ2N37  0       0       0      16
## SDQ2N04  0       0       0       0      17
## SDQ2N16  0       0       0       0       0      18
## SDQ2N28  0       0       0       0       0       0      19
## SDQ2N40  0       0       0       0       0       0       0      20
## SDQ2N10  0       0       0       0       0       0       0       0
## SDQ2N22  0       0       0       0       0       0       0       0
## SDQ2N34  0       0       0       0       0       0       0       0
## SDQ2N46  0       0       0       0       0       0       0       0
## SDQ2N07  0       0       0       0       0       0       0       0
## SDQ2N19  0       0       0       0       0       0       0       0
## SDQ2N31  0       0       0       0       0       0       0       0
## SDQ2N43  0       0       0       0       0       0       0       0
##         SDQ2N10 SDQ2N22 SDQ2N34 SDQ2N46 SDQ2N07 SDQ2N19 SDQ2N31 SDQ2N43
## SDQ2N01
## SDQ2N13
## SDQ2N25
## SDQ2N37
## SDQ2N04
## SDQ2N16
## SDQ2N28
## SDQ2N40
## SDQ2N10 21
## SDQ2N22  0      22
## SDQ2N34  0       0      23
## SDQ2N46  0       0       0      24
## SDQ2N07  0       0       0       0      25
## SDQ2N19  0       0       0       0       0      26
## SDQ2N31  0       0       0       0       0       0      27
## SDQ2N43  0       0       0       0       0       0       0      28
##
## $psi
##    F1 F2 F3 F4
```

```
## F1 29
## F2 33 30
## F3 34 36 31
## F4 35 37 38 32
```

- Creating diagram

```r
semPaths(fit)
```



Exercise 2.2

Draw the graphs, specify and test these two additional hypotheses (again draw conclusions based on the ??2 statistic and the CFI, TLI and RMSEA indices):

1. Hypothesis 2: SC is a two-factor structure consisting of GSC and ASC (so that the four GSC measures load onto the GSC and all other onto the ASC).

- Specify the 2-factor model

```r
model1 <-  '
GSC =~ SDQ2N01 + SDQ2N13 + SDQ2N25 + SDQ2N37
ASC =~ SDQ2N04 + SDQ2N16 + SDQ2N28 + SDQ2N40 + SDQ2N10 + SDQ2N22 + SDQ2N34 + SDQ2N46 +
SDQ 2N07 + SDQ2N19 + SDQ2N31 + SDQ2N43
'
```

- Fitting the model

```r
fit1 <- cfa(model1, data=CFA,  control=list(iter.max=1000))
```

- Displaying summary output

```r
summary(fit1, fit.measures=TRUE)
```

```
## lavaan 0.6-3 ended normally after 38 iterations
##
##   Optimization method                           NLMINB
##   Number of free parameters                         33
##
##   Number of observations                           265
##
##   Estimator                                         ML
##   Model Fit Test Statistic                     457.653
##   Degrees of freedom                               103
##   P-value (Chi-square)                           0.000
##
## Model test baseline model:
##
##   Minimum Function Test Statistic             1703.155
##   Degrees of freedom                               120
##   P-value                                        0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                    0.776
##   Tucker-Lewis Index (TLI)                       0.739
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)              -6711.949
##   Loglikelihood unrestricted model (H1)      -6483.122
##
##   Number of free parameters                         33
##   Akaike (AIC)                               13489.897
##   Bayesian (BIC)                             13608.028
##   Sample-size adjusted Bayesian (BIC)        13503.401
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.114
##   90 Percent Confidence Interval          0.103  0.125
##   P-value RMSEA <= 0.05                          0.000
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.101
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard Errors                             Standard
```

```
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   GSC =~
##     SDQ2N01           1.000
##     SDQ2N13           1.048    0.151    6.930    0.000
##     SDQ2N25           0.860    0.131    6.542    0.000
##     SDQ2N37           0.890    0.128    6.957    0.000
##   ASC =~
##     SDQ2N04           1.000
##     SDQ2N16           1.263    0.170    7.440    0.000
##     SDQ2N28           1.276    0.177    7.221    0.000
##     SDQ2N40           1.235    0.176    7.026    0.000
##     SDQ2N10           0.581    0.123    4.736    0.000
##     SDQ2N22           0.558    0.117    4.786    0.000
##     SDQ2N34           0.065    0.161    0.406    0.685
##     SDQ2N46           0.514    0.132    3.885    0.000
##     SDQ2N07           2.069    0.262    7.885    0.000
##     SDQ2N19           1.871    0.242    7.721    0.000
##     SDQ2N31           2.021    0.247    8.192    0.000
##     SDQ2N43           1.442    0.193    7.481    0.000
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   GSC ~~
##     ASC               0.340    0.068    4.975    0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .SDQ2N01           1.170    0.127    9.216    0.000
##    .SDQ2N13           1.134    0.127    8.906    0.000
##    .SDQ2N25           1.026    0.107    9.582    0.000
##    .SDQ2N37           0.799    0.090    8.842    0.000
##    .SDQ2N04           1.495    0.134   11.171    0.000
##    .SDQ2N16           0.799    0.076   10.490    0.000
##    .SDQ2N28           1.018    0.095   10.695    0.000
##    .SDQ2N40           1.138    0.105   10.828    0.000
##    .SDQ2N10           1.166    0.103   11.364    0.000
##    .SDQ2N22           1.043    0.092   11.360    0.000
##    .SDQ2N34           2.888    0.251   11.510    0.000
##    .SDQ2N46           1.554    0.136   11.425    0.000
##    .SDQ2N07           1.191    0.123    9.654    0.000
##    .SDQ2N19           1.247    0.124   10.067    0.000
##    .SDQ2N31           0.575    0.073    7.852    0.000
##    .SDQ2N43           0.996    0.095   10.442    0.000
##     GSC               0.641    0.142    4.508    0.000
##     ASC               0.461    0.114    4.034    0.000
```

- The model seems to be converged normally, the number of observations is equal to the number of rows in the data.
- Chi-Square Test of Model Fit : Here the ??2 is 457.65, with 103 degrees of freedom (ideal value >2df). The p-value should be more than >0.05 to have a good model fit and here, the p-value is 0.000.
- Comparative fit index (CFI): The higher the index, the better it is. The CFI (0.776) value suggests

2-factor model seems to be not a good fit as it should be >.9.

- TLI (Tucker-Lewis index): The higher the index, the better it is. The TLI again should be more than > .9 and here, it is 0.739.
- The difference between AIC and BIC seems to be okay. The lower the difference, the better it is.
- RMSEA (Root mean square error of approximation): Here, the RMSEA (0.114) is more than 0.05 (ideal value) with a 90%CI from 0.103 to 0.125.
- SRMR (Standardized Root Mean Square Residual) : The cut-off of good fit is <0.08. Here, the SRMR is 0.101.
- Obtaining confidence intervals for the estimated coefficients

```
parameterEstimates(fit1, ci = TRUE, level = 0.95)
```

```
##         lhs op     rhs   est    se      z pvalue ci.lower ci.upper
## 1       GSC =~ SDQ2N01 1.000 0.000     NA     NA    1.000    1.000
## 2       GSC =~ SDQ2N13 1.048 0.151  6.930  0.000    0.751    1.344
## 3       GSC =~ SDQ2N25 0.860 0.131  6.542  0.000    0.602    1.117
## 4       GSC =~ SDQ2N37 0.890 0.128  6.957  0.000    0.639    1.140
## 5       ASC =~ SDQ2N04 1.000 0.000     NA     NA    1.000    1.000
## 6       ASC =~ SDQ2N16 1.263 0.170  7.440  0.000    0.930    1.596
## 7       ASC =~ SDQ2N28 1.276 0.177  7.221  0.000    0.930    1.623
## 8       ASC =~ SDQ2N40 1.235 0.176  7.026  0.000    0.891    1.580
## 9       ASC =~ SDQ2N10 0.581 0.123  4.736  0.000    0.340    0.821
## 10      ASC =~ SDQ2N22 0.558 0.117  4.786  0.000    0.329    0.786
## 11      ASC =~ SDQ2N34 0.065 0.161  0.406  0.685   -0.250    0.381
## 12      ASC =~ SDQ2N46 0.514 0.132  3.885  0.000    0.255    0.774
## 13      ASC =~ SDQ2N07 2.069 0.262  7.885  0.000    1.554    2.583
## 14      ASC =~ SDQ2N19 1.871 0.242  7.721  0.000    1.396    2.346
## 15      ASC =~ SDQ2N31 2.021 0.247  8.192  0.000    1.538    2.505
## 16      ASC =~ SDQ2N43 1.442 0.193  7.481  0.000    1.065    1.820
## 17 SDQ2N01 ~~ SDQ2N01 1.170 0.127  9.216  0.000    0.921    1.419
## 18 SDQ2N13 ~~ SDQ2N13 1.134 0.127  8.906  0.000    0.885    1.384
## 19 SDQ2N25 ~~ SDQ2N25 1.026 0.107  9.582  0.000    0.816    1.236
## 20 SDQ2N37 ~~ SDQ2N37 0.799 0.090  8.842  0.000    0.622    0.976
## 21 SDQ2N04 ~~ SDQ2N04 1.495 0.134 11.171  0.000    1.232    1.757
## 22 SDQ2N16 ~~ SDQ2N16 0.799 0.076 10.490  0.000    0.650    0.948
## 23 SDQ2N28 ~~ SDQ2N28 1.018 0.095 10.695  0.000    0.832    1.205
## 24 SDQ2N40 ~~ SDQ2N40 1.138 0.105 10.828  0.000    0.932    1.344
## 25 SDQ2N10 ~~ SDQ2N10 1.166 0.103 11.364  0.000    0.965    1.368
## 26 SDQ2N22 ~~ SDQ2N22 1.043 0.092 11.360  0.000    0.863    1.223
## 27 SDQ2N34 ~~ SDQ2N34 2.888 0.251 11.510  0.000    2.396    3.380
## 28 SDQ2N46 ~~ SDQ2N46 1.554 0.136 11.425  0.000    1.287    1.820
## 29 SDQ2N07 ~~ SDQ2N07 1.191 0.123  9.654  0.000    0.949    1.432
## 30 SDQ2N19 ~~ SDQ2N19 1.247 0.124 10.067  0.000    1.004    1.489
## 31 SDQ2N31 ~~ SDQ2N31 0.575 0.073  7.852  0.000    0.431    0.718
## 32 SDQ2N43 ~~ SDQ2N43 0.996 0.095 10.442  0.000    0.809    1.183
## 33      GSC ~~     GSC 0.641 0.142  4.508  0.000    0.362    0.920
## 34      ASC ~~     ASC 0.461 0.114  4.034  0.000    0.237    0.684
## 35      GSC ~~     ASC 0.340 0.068  4.975  0.000    0.206    0.474
```

- Obtaining goodness of fit indicators of the model

```
fitMeasures(fit1, c("chisq", "rmsea", "srmr", "gfi", "ecvi"))
```

```
##   chisq   rmsea    srmr     gfi    ecvi 
## 457.653   0.114   0.101   0.754   1.976
```

- The GFI should be > 0.95. Here, it is 0.75.

*Obtaining reliability

```r
reliability(fit1)
```

```
##              GSC       ASC     total
## alpha  0.6925568 0.8448618 0.8646270
## omega  0.6911301 0.8547893 0.8745261
## omega2 0.6911301 0.8547893 0.8745261
## omega3 0.6879643 0.8153354 0.8177602
## avevar 0.3602449 0.3858905 0.3805607
```

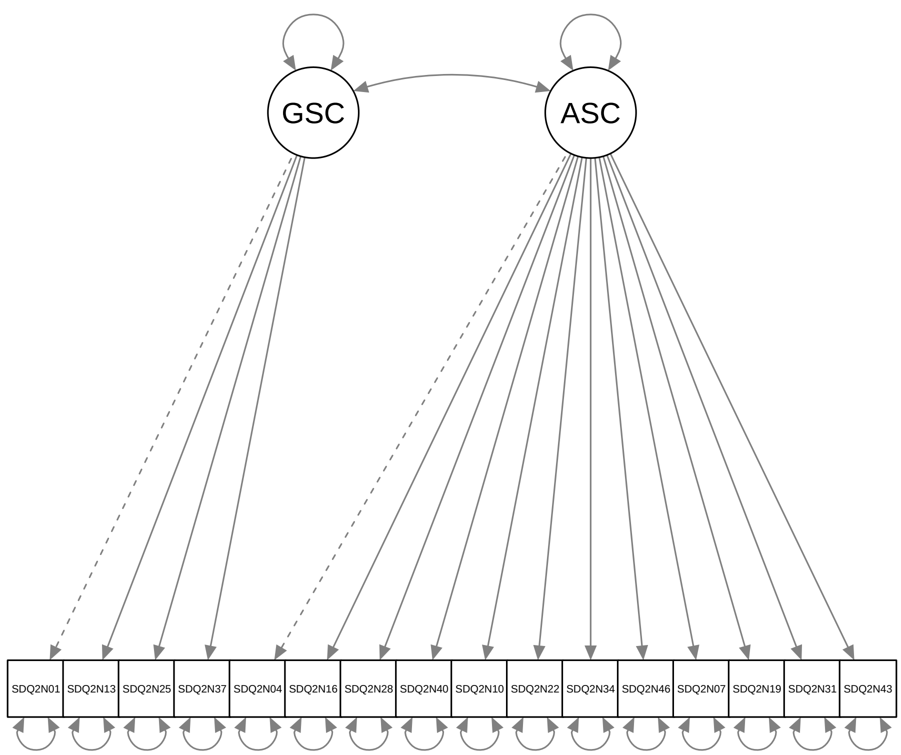
```r
inspect(fit1)
```

```
## $lambda
##         GSC ASC
## SDQ2N01   0   0
## SDQ2N13   1   0
## SDQ2N25   2   0
## SDQ2N37   3   0
## SDQ2N04   0   0
## SDQ2N16   0   4
## SDQ2N28   0   5
## SDQ2N40   0   6
## SDQ2N10   0   7
## SDQ2N22   0   8
## SDQ2N34   0   9
## SDQ2N46   0  10
## SDQ2N07   0  11
## SDQ2N19   0  12
## SDQ2N31   0  13
## SDQ2N43   0  14
## 
## $theta
##         SDQ2N01 SDQ2N13 SDQ2N25 SDQ2N37 SDQ2N04 SDQ2N16 SDQ2N28 SDQ2N40
## SDQ2N01 15                                                             
## SDQ2N13  0      16                                                     
## SDQ2N25  0       0      17                                             
## SDQ2N37  0       0       0      18                                     
## SDQ2N04  0       0       0       0      19                             
## SDQ2N16  0       0       0       0       0      20                     
## SDQ2N28  0       0       0       0       0       0      21             
## SDQ2N40  0       0       0       0       0       0       0      22     
## SDQ2N10  0       0       0       0       0       0       0       0     
## SDQ2N22  0       0       0       0       0       0       0       0     
## SDQ2N34  0       0       0       0       0       0       0       0     
## SDQ2N46  0       0       0       0       0       0       0       0     
## SDQ2N07  0       0       0       0       0       0       0       0     
## SDQ2N19  0       0       0       0       0       0       0       0     
## SDQ2N31  0       0       0       0       0       0       0       0     
## SDQ2N43  0       0       0       0       0       0       0       0     
##         SDQ2N10 SDQ2N22 SDQ2N34 SDQ2N46 SDQ2N07 SDQ2N19 SDQ2N31 SDQ2N43
```

```
## SDQ2N01
## SDQ2N13
## SDQ2N25
## SDQ2N37
## SDQ2N04
## SDQ2N16
## SDQ2N28
## SDQ2N40
## SDQ2N10 23
## SDQ2N22  0      24
## SDQ2N34  0       0      25
## SDQ2N46  0       0       0      26
## SDQ2N07  0       0       0       0      27
## SDQ2N19  0       0       0       0       0      28
## SDQ2N31  0       0       0       0       0       0      29
## SDQ2N43  0       0       0       0       0       0       0      30
##
## $psi
##     GSC ASC
## GSC 31
## ASC 33  32
```

*Creating diagram

```r
semPaths(fit1)
```



2. Hypothesis 3: SC is a one-factor structure. Compare the models with the four-factor model.

*Specify the 1 factor model

```
model2 <-  '
f1 =~ SDQ2N01 + SDQ2N13 + SDQ2N25 + SDQ2N37 + SDQ2N04 +
SDQ2N16 + SDQ2N28 + SDQ2N40 +SDQ2 N10 + SDQ2N22 +
SDQ2N34 + SDQ2N46 + SDQ2N07 + SDQ2N19 + SDQ2N31 + SDQ2N43
'
```

*Fitting the model

```
fit2 <- cfa(model2, data=CFA,  control=list(iter.max=1000))
```

*Displaying summary output

```
summary(fit2, fit.measures=TRUE)
```

```
## lavaan 0.6-3 ended normally after 43 iterations
##
##   Optimization method                           NLMINB
##   Number of free parameters                         32
##
##   Number of observations                           265
##
##   Estimator                                         ML
##   Model Fit Test Statistic                     531.918
##   Degrees of freedom                               104
##   P-value (Chi-square)                           0.000
##
## Model test baseline model:
##
##   Minimum Function Test Statistic             1703.155
##   Degrees of freedom                               120
##   P-value                                        0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                    0.730
##   Tucker-Lewis Index (TLI)                       0.688
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)              -6749.081
##   Loglikelihood unrestricted model (H1)      -6483.122
##
##   Number of free parameters                         32
##   Akaike (AIC)                               13562.162
##   Bayesian (BIC)                             13676.713
##   Sample-size adjusted Bayesian (BIC)        13575.256
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.125
##   90 Percent Confidence Interval          0.114  0.135
##   P-value RMSEA <= 0.05                          0.000
##
## Standardized Root Mean Square Residual:
```

```
##
##   SRMR                                           0.104
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard Errors                             Standard
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   f1 =~
##     SDQ2N01           1.000
##     SDQ2N13           1.158    0.247    4.690    0.000
##     SDQ2N25           0.903    0.209    4.330    0.000
##     SDQ2N37           1.126    0.224    5.018    0.000
##     SDQ2N04           1.407    0.278    5.063    0.000
##     SDQ2N16           1.772    0.310    5.716    0.000
##     SDQ2N28           1.775    0.317    5.605    0.000
##     SDQ2N40           1.744    0.315    5.541    0.000
##     SDQ2N10           0.859    0.197    4.362    0.000
##     SDQ2N22           0.816    0.187    4.371    0.000
##     SDQ2N34           0.181    0.222    0.815    0.415
##     SDQ2N46           0.756    0.202    3.732    0.000
##     SDQ2N07           2.743    0.471    5.826    0.000
##     SDQ2N19           2.505    0.434    5.768    0.000
##     SDQ2N31           2.711    0.454    5.970    0.000
##     SDQ2N43           1.929    0.341    5.659    0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .SDQ2N01           1.565    0.138   11.335    0.000
##    .SDQ2N13           1.508    0.134   11.266    0.000
##    .SDQ2N25           1.299    0.115   11.338    0.000
##    .SDQ2N37           0.994    0.089   11.160    0.000
##    .SDQ2N04           1.469    0.132   11.140    0.000
##    .SDQ2N16           0.762    0.073   10.368    0.000
##    .SDQ2N28           0.994    0.093   10.633    0.000
##    .SDQ2N40           1.093    0.102   10.742    0.000
##    .SDQ2N10           1.140    0.101   11.333    0.000
##    .SDQ2N22           1.022    0.090   11.332    0.000
##    .SDQ2N34           2.882    0.250   11.508    0.000
##    .SDQ2N46           1.535    0.135   11.409    0.000
##    .SDQ2N07           1.311    0.132    9.913    0.000
##    .SDQ2N19           1.316    0.129   10.186    0.000
##    .SDQ2N31           0.650    0.078    8.367    0.000
##    .SDQ2N43           1.040    0.099   10.520    0.000
##     f1                0.246    0.083    2.972    0.003
```

- The model seems to be converged normally, the number of observations is equal to the number of rows in the data.
- Chi-Square Test of Model Fit : Here the ??2 is 1703.155, with 104 degrees of freedom (ideal value >2df). The p-value should be more than >0.05 to have a good model fit and here, the p-value is 0.000.

- Comparative fit index (CFI): The higher the index, the better it is. 1-factor model seems to be not a good fit as the CFI value is 0.730 and it should be >.9.
- TLI (Tucker-Lewis index): The higher the index, the better it is. The TLI again should be more than > .9 and here, it is 0.688.
- The difference between AIC and BIC seems to be okay. The lower the difference, the better it is.
- RMSEA (Root mean square error of approximation): Here, the RMSEA (0.125) is more than 0.05 (ideal value) with a 90%CI from 0.114 to 0.135.
- SRMR (Standardized Root Mean Square Residual) : The cut-off of good fit is <0.08. Here, the SRMR is 0.104.

*Obtaining confidence intervals for the estimated coefficients

```
parameterEstimates(fit2, ci = TRUE, level = 0.95)
```

```
##        lhs op     rhs   est    se      z pvalue ci.lower ci.upper
## 1       f1 =~ SDQ2N01 1.000 0.000     NA     NA    1.000    1.000
## 2       f1 =~ SDQ2N13 1.158 0.247  4.690  0.000    0.674    1.642
## 3       f1 =~ SDQ2N25 0.903 0.209  4.330  0.000    0.494    1.312
## 4       f1 =~ SDQ2N37 1.126 0.224  5.018  0.000    0.686    1.566
## 5       f1 =~ SDQ2N04 1.407 0.278  5.063  0.000    0.862    1.952
## 6       f1 =~ SDQ2N16 1.772 0.310  5.716  0.000    1.164    2.379
## 7       f1 =~ SDQ2N28 1.775 0.317  5.605  0.000    1.154    2.396
## 8       f1 =~ SDQ2N40 1.744 0.315  5.541  0.000    1.127    2.361
## 9       f1 =~ SDQ2N10 0.859 0.197  4.362  0.000    0.473    1.245
## 10      f1 =~ SDQ2N22 0.816 0.187  4.371  0.000    0.450    1.182
## 11      f1 =~ SDQ2N34 0.181 0.222  0.815  0.415   -0.254    0.617
## 12      f1 =~ SDQ2N46 0.756 0.202  3.732  0.000    0.359    1.152
## 13      f1 =~ SDQ2N07 2.743 0.471  5.826  0.000    1.820    3.666
## 14      f1 =~ SDQ2N19 2.505 0.434  5.768  0.000    1.654    3.357
## 15      f1 =~ SDQ2N31 2.711 0.454  5.970  0.000    1.821    3.601
## 16      f1 =~ SDQ2N43 1.929 0.341  5.659  0.000    1.261    2.597
## 17 SDQ2N01 ~~ SDQ2N01 1.565 0.138 11.335  0.000    1.295    1.836
## 18 SDQ2N13 ~~ SDQ2N13 1.508 0.134 11.266  0.000    1.246    1.771
## 19 SDQ2N25 ~~ SDQ2N25 1.299 0.115 11.338  0.000    1.075    1.524
## 20 SDQ2N37 ~~ SDQ2N37 0.994 0.089 11.160  0.000    0.820    1.169
## 21 SDQ2N04 ~~ SDQ2N04 1.469 0.132 11.140  0.000    1.210    1.727
## 22 SDQ2N16 ~~ SDQ2N16 0.762 0.073 10.368  0.000    0.618    0.906
## 23 SDQ2N28 ~~ SDQ2N28 0.994 0.093 10.633  0.000    0.811    1.177
## 24 SDQ2N40 ~~ SDQ2N40 1.093 0.102 10.742  0.000    0.894    1.293
## 25 SDQ2N10 ~~ SDQ2N10 1.140 0.101 11.333  0.000    0.943    1.338
## 26 SDQ2N22 ~~ SDQ2N22 1.022 0.090 11.332  0.000    0.845    1.199
## 27 SDQ2N34 ~~ SDQ2N34 2.882 0.250 11.508  0.000    2.391    3.373
## 28 SDQ2N46 ~~ SDQ2N46 1.535 0.135 11.409  0.000    1.271    1.799
## 29 SDQ2N07 ~~ SDQ2N07 1.311 0.132  9.913  0.000    1.052    1.571
## 30 SDQ2N19 ~~ SDQ2N19 1.316 0.129 10.186  0.000    1.063    1.570
## 31 SDQ2N31 ~~ SDQ2N31 0.650 0.078  8.367  0.000    0.498    0.803
## 32 SDQ2N43 ~~ SDQ2N43 1.040 0.099 10.520  0.000    0.846    1.233
## 33      f1 ~~      f1 0.246 0.083  2.972  0.003    0.084    0.408
```

*Obtaining goodness of fit indicators of the model

```
fitMeasures(fit2, c("chisq", "rmsea", "srmr", "gfi", "ecvi"))
```

```
##   chisq   rmsea    srmr     gfi    ecvi
```

```
## 531.918   0.125   0.104   0.724   2.249
```

- – The GFI should be >0.95. Here, it is 0.72.

*Obtaining reliability

```r
reliability(fit2)
```

```
##               f1     total
## alpha  0.8646270 0.8646270
## omega  0.8672223 0.8672223
## omega2 0.8672223 0.8672223
## omega3 0.8198549 0.8198549
## avevar 0.3372906 0.3372906
```

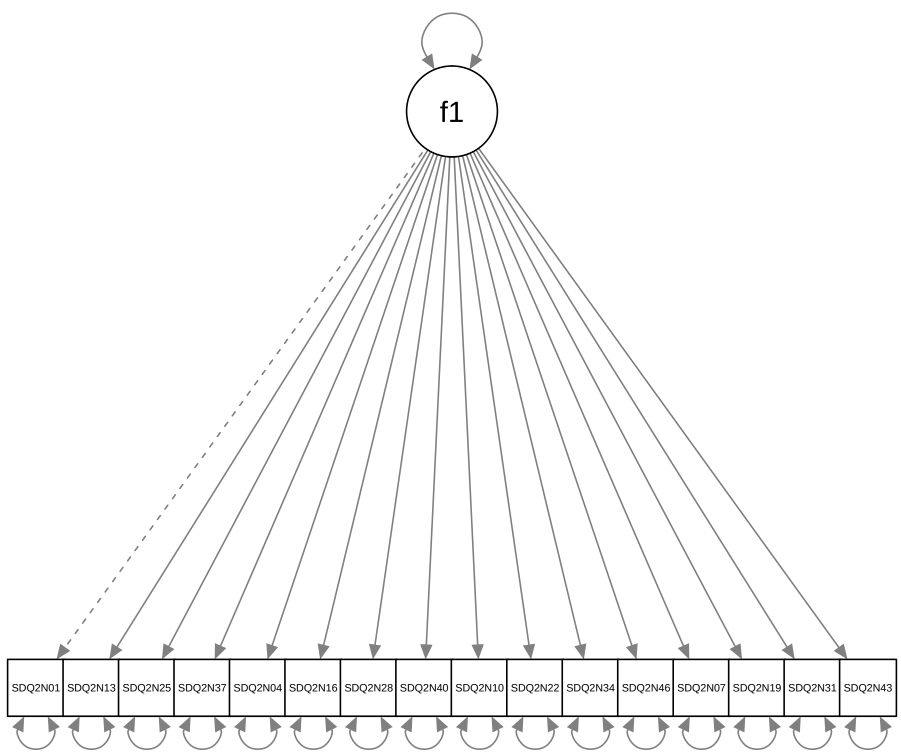
```r
inspect(fit2)
```

```
## $lambda
##         f1
## SDQ2N01  0
## SDQ2N13  1
## SDQ2N25  2
## SDQ2N37  3
## SDQ2N04  4
## SDQ2N16  5
## SDQ2N28  6
## SDQ2N40  7
## SDQ2N10  8
## SDQ2N22  9
## SDQ2N34 10
## SDQ2N46 11
## SDQ2N07 12
## SDQ2N19 13
## SDQ2N31 14
## SDQ2N43 15
##
## $theta
##         SDQ2N01 SDQ2N13 SDQ2N25 SDQ2N37 SDQ2N04 SDQ2N16 SDQ2N28 SDQ2N40
## SDQ2N01 16
## SDQ2N13  0      17
## SDQ2N25  0       0      18
## SDQ2N37  0       0       0      19
## SDQ2N04  0       0       0       0      20
## SDQ2N16  0       0       0       0       0      21
## SDQ2N28  0       0       0       0       0       0      22
## SDQ2N40  0       0       0       0       0       0       0      23
## SDQ2N10  0       0       0       0       0       0       0       0
## SDQ2N22  0       0       0       0       0       0       0       0
## SDQ2N34  0       0       0       0       0       0       0       0
## SDQ2N46  0       0       0       0       0       0       0       0
## SDQ2N07  0       0       0       0       0       0       0       0
## SDQ2N19  0       0       0       0       0       0       0       0
## SDQ2N31  0       0       0       0       0       0       0       0
## SDQ2N43  0       0       0       0       0       0       0       0
##         SDQ2N10 SDQ2N22 SDQ2N34 SDQ2N46 SDQ2N07 SDQ2N19 SDQ2N31 SDQ2N43
## SDQ2N01
```

```
## SDQ2N13
## SDQ2N25
## SDQ2N37
## SDQ2N04
## SDQ2N16
## SDQ2N28
## SDQ2N40
## SDQ2N10 24
## SDQ2N22  0       25
## SDQ2N34  0        0       26
## SDQ2N46  0        0        0       27
## SDQ2N07  0        0        0        0       28
## SDQ2N19  0        0        0        0        0       29
## SDQ2N31  0        0        0        0        0        0       30
## SDQ2N43  0        0        0        0        0        0        0       31
##
## $psi
##    f1
## f1 32
```

*Creating diagram

```r
semPaths(fit2)
```



*Model Comparison

```r
anova(fit, fit1, fit2)
```

```
## Chi Square Difference Test
##
##       Df   AIC   BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## fit   98 13201 13337 159.11
## fit1 103 13490 13608 457.65    298.541       5  < 2.2e-16 ***
## fit2 104 13562 13677 531.92     74.265       1  < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Final Interpretation

The p-value is significant in all the 3 models. The other values of good model fit will be considered. As seen from the results above, four factor model is acceptable but not excellent as compared to the other two models with CFI and TLI of .961 and .953 resp and RMSEA of .049 90%CI(.03 to .06). The Standardized Root Mean Square Residual (0.048) is below the cut off value suggesting good model fit. The other two models (2-factor and 1-factor) seems to have low CFI, TLI values and high RMSEA and SRMR as compared to their ideal cut-offs.

References

- Week 2 SEM materials
- https://www.cscu.cornell.edu/news/Handouts/SEM_fit.pdf
- http://www.understandingdata.net/2017/03/22/cfa-in-lavaan/

Week 3 SEM Assignment

Shweta Goswami

04-02-2019

Exercise 3.1

TITLE: CFA of MBI for Male Elementary Teachers (Calibration Group), Initial Model - ML Estimation, (Byrne 2012, p. 102)

Reading the data

```
CFA <- read.fortran("ELEMM1.DAT", format=c("22F1.0"))
glimpse(CFA)
```

```
## Observations: 372
## Variables: 22
## $ V1  <dbl> 4, 2, 6, 7, 6, 2, 6, 4, 6, 4, 6, 2, 4, 6, 6, 2, 7, 6, 4, 4...
## $ V2  <dbl> 4, 2, 6, 7, 6, 2, 6, 6, 5, 6, 6, 2, 6, 6, 6, 2, 7, 6, 6, 4...
## $ V3  <dbl> 5, 1, 7, 7, 6, 2, 6, 3, 5, 2, 3, 2, 2, 4, 3, 1, 6, 3, 4, 2...
## $ V4  <dbl> 4, 7, 7, 7, 6, 7, 7, 7, 7, 4, 6, 7, 7, 6, 4, 7, 7, 4, 7, 7...
## $ V5  <dbl> 4, 2, 3, 1, 4, 6, 2, 2, 4, 2, 1, 1, 2, 6, 2, 1, 1, 6, 1, 1...
## $ V6  <dbl> 2, 1, 5, 1, 2, 2, 7, 3, 3, 2, 3, 1, 1, 2, 3, 1, 4, 6, 2, 2...
## $ V7  <dbl> 7, 7, 6, 7, 6, 7, 7, 7, 7, 6, 6, 7, 7, 7, 5, 7, 6, 6, 7, 7...
## $ V8  <dbl> 2, 2, 6, 7, 2, 1, 7, 3, 4, 1, 6, 1, 1, 4, 4, 2, 5, 6, 4, 2...
## $ V9  <dbl> 7, 7, 5, 7, 7, 7, 4, 7, 6, 7, 6, 7, 6, 7, 7, 7, 6, 6, 7, 7...
## $ V10 <dbl> 2, 1, 4, 1, 6, 1, 1, 3, 4, 2, 4, 1, 2, 2, 3, 2, 1, 6, 2, 1...
## $ V11 <dbl> 2, 1, 5, 1, 6, 1, 1, 3, 4, 2, 1, 1, 2, 1, 7, 1, 1, 6, 1, 1...
## $ V12 <dbl> 6, 4, 4, 1, 7, 7, 1, 6, 6, 6, 6, 7, 5, 6, 6, 7, 6, 4, 6, 7...
## $ V13 <dbl> 3, 2, 4, 1, 4, 3, 6, 3, 3, 3, 6, 1, 3, 4, 4, 2, 5, 5, 4, 1...
## $ V14 <dbl> 4, 2, 4, 4, 7, 2, 6, 3, 6, 5, 4, 1, 7, 3, 5, 2, 3, 4, 6, 1...
## $ V15 <dbl> 1, 1, 2, 1, 5, 1, 1, 3, 4, 1, 1, 1, 2, 4, 1, 1, 1, 1, 1, 1...
## $ V16 <dbl> 1, 1, 5, 1, 2, 2, 7, 3, 4, 2, 2, 1, 1, 2, 4, 1, 2, 6, 1, 1...
## $ V17 <dbl> 7, 7, 5, 7, 7, 7, 6, 7, 6, 6, 6, 7, 7, 6, 5, 7, 7, 6, 7, 7...
## $ V18 <dbl> 6, 4, 6, 5, 7, 6, 2, 6, 6, 6, 4, 7, 5, 6, 7, 6, 6, 7, 6, 7...
## $ V19 <dbl> 6, 6, 6, 7, 7, 5, 4, 6, 7, 6, 5, 7, 5, 6, 6, 7, 6, 7, 6, 7...
## $ V20 <dbl> 2, 1, 2, 4, 3, 2, 2, 2, 3, 2, 5, 1, 1, 1, 2, 2, 6, 1, 1, 1...
## $ V21 <dbl> 6, 6, 4, 7, 5, 6, 6, 6, 6, 2, 5, 7, 6, 6, 2, 7, 6, 6, 7, 7...
## $ V22 <dbl> 2, 1, 3, 1, 2, 2, 1, 6, 3, 2, 1, 1, 4, 1, 2, 1, 6, 2, 1, 4...
```

The dataset has 372 observations (male elementary teachers) of 22 variables (7-point Likert scales).

Creating names for all the variables

```
names(CFA) = c("ITEM1", "ITEM2", "ITEM3", "ITEM4", "ITEM5", "ITEM6", "ITEM7", "ITEM8", "ITEM9", "ITEM10

str(CFA)
```

```
## 'data.frame':    372 obs. of  22 variables:
##  $ ITEM1 : num  4 2 6 7 6 2 6 4 6 4 ...
##  $ ITEM2 : num  4 2 6 7 6 2 6 6 5 6 ...
##  $ ITEM3 : num  5 1 7 7 6 2 6 3 5 2 ...
##  $ ITEM4 : num  4 7 7 7 6 7 7 7 7 4 ...
##  $ ITEM5 : num  4 2 3 1 4 6 2 2 4 2 ...
##  $ ITEM6 : num  2 1 5 1 2 2 7 3 3 2 ...
```

```
##  $ ITEM7 : num  7 7 6 7 6 7 7 7 7 6 ...
##  $ ITEM8 : num  2 2 6 7 2 1 7 3 4 1 ...
##  $ ITEM9 : num  7 7 5 7 7 7 4 7 6 7 ...
##  $ ITEM10: num  2 1 4 1 6 1 1 3 4 2 ...
##  $ ITEM11: num  2 1 5 1 6 1 1 3 4 2 ...
##  $ ITEM12: num  6 4 4 1 7 7 1 6 6 6 ...
##  $ ITEM13: num  3 2 4 1 4 3 6 3 3 3 ...
##  $ ITEM14: num  4 2 4 4 7 2 6 3 6 5 ...
##  $ ITEM15: num  1 1 2 1 5 1 1 3 4 1 ...
##  $ ITEM16: num  1 1 5 1 2 2 7 3 4 2 ...
##  $ ITEM17: num  7 7 5 7 7 7 6 7 6 6 ...
##  $ ITEM18: num  6 4 6 5 7 6 2 6 6 6 ...
##  $ ITEM19: num  6 6 6 7 7 5 4 6 7 6 ...
##  $ ITEM20: num  2 1 2 4 3 2 2 2 3 2 ...
##  $ ITEM21: num  6 6 4 7 5 6 6 6 6 2 ...
##  $ ITEM22: num  2 1 3 1 2 2 1 6 3 2 ...
```

The aim of this analysis is to test the factorial validity for a widely used measuring instrument called MBI (Maslach Burnout Inventory) which combines Emotional Exhaustion (EE), Depersonalization (DP) and Personal Accomplishment (PA).

According to the lecture materials, the hypothesized model includes MBI responses that can be explained by EE, DP and PA factors, each item has a nonzero loading on the appropriate factor and zero loadings on all other factors, the three factors are correlated, residuals of the items are uncorrelated

Exploratory data analysis to understand data properties

```r
#Data type
df_status(CFA)
```

```
##    variable q_zeros p_zeros q_na p_na q_inf p_inf    type unique
## 1     ITEM1       0       0    0    0     0     0 numeric      7
## 2     ITEM2       0       0    0    0     0     0 numeric      7
## 3     ITEM3       0       0    0    0     0     0 numeric      7
## 4     ITEM4       0       0    0    0     0     0 numeric      6
## 5     ITEM5       0       0    0    0     0     0 numeric      7
## 6     ITEM6       0       0    0    0     0     0 numeric      7
## 7     ITEM7       0       0    0    0     0     0 numeric      6
## 8     ITEM8       0       0    0    0     0     0 numeric      7
## 9     ITEM9       0       0    0    0     0     0 numeric      7
## 10   ITEM10       0       0    0    0     0     0 numeric      7
## 11   ITEM11       0       0    0    0     0     0 numeric      7
## 12   ITEM12       0       0    0    0     0     0 numeric      7
## 13   ITEM13       0       0    0    0     0     0 numeric      7
## 14   ITEM14       0       0    0    0     0     0 numeric      7
## 15   ITEM15       0       0    0    0     0     0 numeric      7
## 16   ITEM16       0       0    0    0     0     0 numeric      7
## 17   ITEM17       0       0    0    0     0     0 numeric      6
## 18   ITEM18       0       0    0    0     0     0 numeric      7
## 19   ITEM19       0       0    0    0     0     0 numeric      7
## 20   ITEM20       0       0    0    0     0     0 numeric      7
## 21   ITEM21       0       0    0    0     0     0 numeric      6
## 22   ITEM22       0       0    0    0     0     0 numeric      7
```

```r
#Analyzing quantitatively
data_prof=profiling_num(CFA)
```

```
##    variable mean std_dev variation_coef p_01 p_05 p_25 p_50 p_75 p_95 p_99
## 1     ITEM1  4.4    1.66           0.38  1.7    2    3  4.0    6  7.0    7
## 2     ITEM2  4.9    1.55           0.32  1.7    2    4  5.0    6  7.0    7
## 3     ITEM3  3.5    1.73           0.49  1.0    1    2  3.0    5  6.0    7
## 4     ITEM4  6.3    1.00           0.16  2.7    4    6  7.0    7  7.0    7
## 5     ITEM5  2.2    1.49           0.68  1.0    1    1  2.0    3  6.0    6
## 6     ITEM6  2.7    1.58           0.59  1.0    1    2  2.0    4  6.0    7
## 7     ITEM7  6.3    0.84           0.13  3.0    5    6  6.0    7  7.0    7
## 8     ITEM8  3.0    1.73           0.57  1.0    1    2  2.0    4  6.0    7
## 9     ITEM9  6.0    1.32           0.22  2.0    3    6  7.0    7  7.0    7
## 10   ITEM10  2.2    1.45           0.66  1.0    1    1  2.0    3  5.4    6
## 11   ITEM11  2.2    1.53           0.68  1.0    1    1  2.0    3  5.4    7
## 12   ITEM12  5.7    1.19           0.21  2.0    3    5  6.0    6  7.0    7
## 13   ITEM13  3.6    1.68           0.47  1.0    1    2  3.5    5  7.0    7
## 14   ITEM14  4.0    1.73           0.43  1.0    1    3  4.0    5  7.0    7
## 15   ITEM15  1.8    1.30           0.73  1.0    1    1  1.0    2  5.0    7
## 16   ITEM16  2.5    1.44           0.58  1.0    1    1  2.0    3  5.0    6
## 17   ITEM17  6.4    0.85           0.13  3.7    5    6  7.0    7  7.0    7
## 18   ITEM18  5.7    1.27           0.22  2.0    3    5  6.0    7  7.0    7
## 19   ITEM19  5.9    1.19           0.20  2.0    4    6  6.0    7  7.0    7
## 20   ITEM20  2.2    1.41           0.63  1.0    1    1  2.0    3  5.0    7
## 21   ITEM21  5.9    1.27           0.22  2.0    3    5  6.0    7  7.0    7
## 22   ITEM22  2.6    1.58           0.61  1.0    1    1  2.0    3  6.0    7
##    skewness kurtosis iqr  range_98 range_80
## 1    -0.115      1.8   3 [1.71, 7]   [2, 6]
## 2    -0.507      2.3   2 [1.71, 7]   [2, 7]
## 3     0.317      1.9   3    [1, 7]   [2, 6]
## 4    -1.811      6.7   1 [2.71, 7]   [5, 7]
## 5     1.328      3.9   2    [1, 6]   [1, 4]
## 6     0.924      3.0   2    [1, 7]   [1, 5]
## 7    -1.649      6.8   1    [3, 7]   [5, 7]
## 8     0.741      2.4   2    [1, 7]   [1, 6]
## 9    -1.542      4.9   1    [2, 7]   [4, 7]
## 10    1.202      3.6   2    [1, 6]   [1, 4]
## 11    1.273      3.8   2    [1, 7]   [1, 5]
## 12   -1.320      4.9   1    [2, 7]   [4, 7]
## 13    0.347      2.2   3    [1, 7]   [2, 6]
## 14    0.031      2.1   2    [1, 7]   [2, 6]
## 15    2.096      7.3   1    [1, 7]   [1, 3]
## 16    0.971      3.2   2    [1, 6]   [1, 5]
## 17   -1.978      8.1   1 [3.71, 7]   [6, 7]
## 18   -1.231      4.4   2    [2, 7]   [4, 7]
## 19   -1.484      5.2   1    [2, 7]   [4, 7]
## 20    1.300      4.2   2    [1, 7]   [1, 4]
## 21   -1.300      4.2   2    [2, 7]   [4, 7]
## 22    1.066      3.2   2    [1, 7]   [1, 5]
```

All the numeric variables have bunch of statistics. The kurtosis seems to be high than the acceptable values in most of the variables suggesting data is not normally distributed.

Three factor CFA model using estimation method (ML)

Specifying model

```
model <- '
F1 =~  ITEM1 + ITEM2+ ITEM3 + ITEM6 + ITEM8 + ITEM13 + ITEM14 + ITEM16 + ITEM20
```

```
F2 =~ ITEM5 + ITEM10 + ITEM11 + ITEM15 + ITEM22
F3 =~ ITEM4 + ITEM7 + ITEM9 + ITEM12 + ITEM17 + ITEM18 + ITEM19 + ITEM21
'
```

Fitting the model

```
fit <- cfa(model, data=CFA)
```

Display summary output

```
summary(fit, fit.measures=TRUE)
```

```
## lavaan 0.6-3 ended normally after 46 iterations
##
##   Optimization method                           NLMINB
##   Number of free parameters                         47
##
##   Number of observations                           372
##
##   Estimator                                         ML
##   Model Fit Test Statistic                     695.719
##   Degrees of freedom                               206
##   P-value (Chi-square)                           0.000
##
## Model test baseline model:
##
##   Minimum Function Test Statistic             3452.269
##   Degrees of freedom                               231
##   P-value                                        0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                    0.848
##   Tucker-Lewis Index (TLI)                       0.830
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)             -12811.043
##   Loglikelihood unrestricted model (H1)     -12463.184
##
##   Number of free parameters                         47
##   Akaike (AIC)                               25716.087
##   Bayesian (BIC)                             25900.275
##   Sample-size adjusted Bayesian (BIC)        25751.158
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.080
##   90 Percent Confidence Interval          0.073  0.087
##   P-value RMSEA <= 0.05                          0.000
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.073
##
```

```
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard Errors                             Standard
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   F1 =~
##     ITEM1             1.000
##     ITEM2             0.887    0.061   14.621    0.000
##     ITEM3             1.021    0.068   15.085    0.000
##     ITEM6             0.764    0.064   12.013    0.000
##     ITEM8             1.143    0.066   17.299    0.000
##     ITEM13            1.017    0.065   15.544    0.000
##     ITEM14            0.848    0.069   12.251    0.000
##     ITEM16            0.715    0.058   12.410    0.000
##     ITEM20            0.753    0.056   13.410    0.000
##   F2 =~
##     ITEM5             1.000
##     ITEM10            1.142    0.127    8.986    0.000
##     ITEM11            1.353    0.142    9.511    0.000
##     ITEM15            0.905    0.109    8.318    0.000
##     ITEM22            0.768    0.121    6.361    0.000
##   F3 =~
##     ITEM4             1.000
##     ITEM7             0.970    0.150    6.482    0.000
##     ITEM9             1.780    0.254    7.007    0.000
##     ITEM12            1.499    0.221    6.769    0.000
##     ITEM17            1.348    0.181    7.463    0.000
##     ITEM18            1.918    0.262    7.329    0.000
##     ITEM19            1.716    0.238    7.205    0.000
##     ITEM21            1.356    0.218    6.219    0.000
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   F1 ~~
##     F2                0.701    0.099    7.061    0.000
##     F3               -0.192    0.042   -4.537    0.000
##   F2 ~~
##     F3               -0.172    0.035   -4.850    0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .ITEM1             1.128    0.095   11.861    0.000
##    .ITEM2             1.105    0.090   12.214    0.000
##    .ITEM3             1.301    0.108   12.031    0.000
##    .ITEM6             1.553    0.121   12.888    0.000
##    .ITEM8             0.852    0.081   10.553    0.000
##    .ITEM13            1.142    0.097   11.821    0.000
##    .ITEM14            1.804    0.140   12.844    0.000
##    .ITEM16            1.235    0.096   12.812    0.000
##    .ITEM20            1.075    0.085   12.585    0.000
##    .ITEM5             1.503    0.125   12.026    0.000
```

```
##    .ITEM10             1.169    0.107   10.901    0.000
##    .ITEM11             1.044    0.112    9.330    0.000
##    .ITEM15             1.106    0.093   11.838    0.000
##    .ITEM22             2.076    0.160   12.958    0.000
##    .ITEM4              0.802    0.062   12.901    0.000
##    .ITEM7              0.523    0.042   12.572    0.000
##    .ITEM9              1.117    0.093   11.952    0.000
##    .ITEM12             0.987    0.080   12.287    0.000
##    .ITEM17             0.375    0.035   10.739    0.000
##    .ITEM18             0.909    0.081   11.224    0.000
##    .ITEM19             0.844    0.073   11.557    0.000
##    .ITEM21             1.245    0.098   12.764    0.000
##     F1                 1.625    0.190    8.551    0.000
##     F2                 0.705    0.132    5.321    0.000
##     F3                 0.193    0.048    4.047    0.000
```

The x2 is 695.719, with 206 degrees of freedom. The p-value should be more than >0.05 to have a good model fit and here, the p-value is 0.000. The CFI and TLI is 0.848 and 0.830 respectively and both values are less than the acceptable value (> 0.9). The value of RMSEA and SRMR is 0.080 with a 90%CI from 0.073 to 0.087 and 0.073 respectively and it should be <0.08.

Three factor CFA model using estimation method (MLM)

Specifying model

```
model1 <- '
F1 =~  ITEM1 + ITEM2+ ITEM3 + ITEM6 + ITEM8 + ITEM13 + ITEM14 + ITEM16 + ITEM20
F2 =~ ITEM5 + ITEM10 + ITEM11 + ITEM15 + ITEM22
F3 =~ ITEM4 + ITEM7 + ITEM9 + ITEM12 + ITEM17 + ITEM18 + ITEM19 + ITEM21
'
```

Fitting the model

```
fit1 <- cfa(model1, data=CFA, estimator = "MLM")
```

Display summary output

```
summary(fit1, fit.measures=TRUE)
```

```
## lavaan 0.6-3 ended normally after 46 iterations
##
##   Optimization method                           NLMINB
##   Number of free parameters                         47
##
##   Number of observations                           372
##
##   Estimator                                         ML      Robust
##   Model Fit Test Statistic                     695.719     567.753
##   Degrees of freedom                               206         206
##   P-value (Chi-square)                           0.000       0.000
##   Scaling correction factor                                  1.225
##     for the Satorra-Bentler correction
##
## Model test baseline model:
##
##   Minimum Function Test Statistic             3452.269    2911.466
##   Degrees of freedom                               231         231
##   P-value                                        0.000       0.000
```

```
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                    0.848       0.865
##   Tucker-Lewis Index (TLI)                       0.830       0.849
##
##   Robust Comparative Fit Index (CFI)                         0.861
##   Robust Tucker-Lewis Index (TLI)                            0.844
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)             -12811.043  -12811.043
##   Loglikelihood unrestricted model (H1)     -12463.184  -12463.184
##
##   Number of free parameters                         47          47
##   Akaike (AIC)                               25716.087   25716.087
##   Bayesian (BIC)                             25900.275   25900.275
##   Sample-size adjusted Bayesian (BIC)        25751.158   25751.158
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.080       0.069
##   90 Percent Confidence Interval          0.073  0.087       0.063  0.075
##   P-value RMSEA <= 0.05                          0.000       0.000
##
##   Robust RMSEA                                               0.076
##   90 Percent Confidence Interval                             0.069  0.084
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.073       0.073
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard Errors                           Robust.sem
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   F1 =~
##     ITEM1             1.000
##     ITEM2             0.887    0.040   22.391    0.000
##     ITEM3             1.021    0.053   19.310    0.000
##     ITEM6             0.764    0.070   10.974    0.000
##     ITEM8             1.143    0.059   19.366    0.000
##     ITEM13            1.017    0.062   16.340    0.000
##     ITEM14            0.848    0.058   14.584    0.000
##     ITEM16            0.715    0.066   10.826    0.000
##     ITEM20            0.753    0.061   12.303    0.000
##   F2 =~
##     ITEM5             1.000
##     ITEM10            1.142    0.152    7.509    0.000
##     ITEM11            1.353    0.162    8.368    0.000
```

```
##     ITEM15            0.905    0.123    7.366    0.000
##     ITEM22            0.768    0.122    6.284    0.000
##   F3 =~
##     ITEM4             1.000
##     ITEM7             0.970    0.128    7.563    0.000
##     ITEM9             1.780    0.322    5.529    0.000
##     ITEM12            1.499    0.241    6.232    0.000
##     ITEM17            1.348    0.200    6.757    0.000
##     ITEM18            1.918    0.298    6.435    0.000
##     ITEM19            1.716    0.287    5.978    0.000
##     ITEM21            1.356    0.227    5.984    0.000
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   F1 ~~
##     F2                0.701    0.106    6.608    0.000
##     F3               -0.192    0.040   -4.796    0.000
##   F2 ~~
##     F3               -0.172    0.036   -4.777    0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .ITEM1             1.128    0.093   12.177    0.000
##    .ITEM2             1.105    0.088   12.506    0.000
##    .ITEM3             1.301    0.106   12.317    0.000
##    .ITEM6             1.553    0.134   11.550    0.000
##    .ITEM8             0.852    0.082   10.450    0.000
##    .ITEM13            1.142    0.124    9.173    0.000
##    .ITEM14            1.804    0.142   12.730    0.000
##    .ITEM16            1.235    0.110   11.278    0.000
##    .ITEM20            1.075    0.137    7.860    0.000
##    .ITEM5             1.503    0.179    8.381    0.000
##    .ITEM10            1.169    0.147    7.959    0.000
##    .ITEM11            1.044    0.141    7.398    0.000
##    .ITEM15            1.106    0.153    7.220    0.000
##    .ITEM22            2.076    0.184   11.266    0.000
##    .ITEM4             0.802    0.113    7.124    0.000
##    .ITEM7             0.523    0.075    7.010    0.000
##    .ITEM9             1.117    0.149    7.487    0.000
##    .ITEM12            0.987    0.126    7.852    0.000
##    .ITEM17            0.375    0.056    6.635    0.000
##    .ITEM18            0.909    0.143    6.376    0.000
##    .ITEM19            0.844    0.111    7.622    0.000
##    .ITEM21            1.245    0.133    9.338    0.000
##     F1                1.625    0.148   11.004    0.000
##     F2                0.705    0.158    4.452    0.000
##     F3                0.193    0.050    3.839    0.000
```

The MLM estimator is used here to provide robust standard errors and a scaled test statistic. The Satorra-Bentler correction accounts for non-normality or when distributional assumptions are violated. In the current dataset, this approach seems to be better to incorporate scaling corections of the non-normal data.

The indices seems to improve a bit in this model. The x2 is 567.753, with 206 degrees of freedom. The p-value is 0.000. The CFI and TLI is 0.865 and 0.849 respectively and both values are still less than the acceptable value (> 0.9). The value of RMSEA and SRMR is 0.069 with a 90%CI from 0.063 to 0.075 and

0.073 respectively and it should be <0.08.

Final Interpretation

```
fitMeasures(fit, c("chisq", "rmsea", "srmr", "cfi", "tli"))
```

```
##   chisq   rmsea    srmr     cfi     tli
## 695.719   0.080   0.073   0.848   0.830
```

```
fitMeasures(fit1, c("chisq", "rmsea", "srmr", "cfi", "tli"))
```

```
##   chisq   rmsea    srmr     cfi     tli
## 695.719   0.080   0.073   0.848   0.830
```

The second model has improved indices

The values of CFI and TLI improved in the second model but still not above the acceptable value

The value of RMSEA has lowered down to 0.069 and SRMR is same in both the models. RMSEA and SRMR values are under the aceeptable range (<0.08) in the second model

The chi-square statistic shows considerable difference as compared to the first model

The Satorra-Bentler correction is 1.225 in the second model indicating normality assumptions are violated.

The hypothesized model cannot be accepted.

Exercise 3.2

Continuing with post hoc model fitting (exploratory approach).

Aim: to modify the model in a sound and responsible manner (step by step)

Model 2

Model Modification indices for model 2

```
modindices(fit1, minimum = 30)
```

```
##        lhs op    rhs mi   epc sepc.lv sepc.all sepc.nox
## 59      F1 =~ ITEM12 42 -0.31   -0.40    -0.34    -0.34
## 95   ITEM1 ~~  ITEM2 82  0.61    0.61     0.55     0.55
## 158  ITEM6 ~~ ITEM16 91  0.73    0.73     0.53     0.53
## 260 ITEM10 ~~ ITEM11 38  0.58    0.58     0.52     0.52
## 298  ITEM4 ~~  ITEM7 33  0.21    0.21     0.32     0.32
## 310  ITEM7 ~~ ITEM21 34  0.26    0.26     0.33     0.33
```

The largest modification indices for the covariances is addressed. Item 6 and Item 16 seems to have the largest modification and is included in the model.

Also, Item12 on the F1 has higher modification and could have more appropriate loading on F1 (Emotional Exhaustion) than F3 (Personal Accomplishment).

Specifying model

```
model2 <- '
F1 =~  ITEM1 + ITEM2+ ITEM3 + ITEM6 + ITEM8 + ITEM13 + ITEM14 + ITEM16 + ITEM20
F2 =~ ITEM5 + ITEM10 + ITEM11 + ITEM15 + ITEM22
F3 =~ ITEM4 + ITEM7 + ITEM9 + ITEM12 + ITEM17 + ITEM18 + ITEM19 + ITEM21
#Residual covariance
ITEM6~~ITEM16
'
```

Fitting the model

```
fit2 <- cfa(model2, data=CFA, estimator = "MLM")
```

Display summary output

```
summary(fit2, fit.measures=TRUE)
```

```
## lavaan 0.6-3 ended normally after 48 iterations
##
##   Optimization method                           NLMINB
##   Number of free parameters                         48
##
##   Number of observations                           372
##
##   Estimator                                         ML      Robust
##   Model Fit Test Statistic                     597.731     493.398
##   Degrees of freedom                               205         205
##   P-value (Chi-square)                           0.000       0.000
##   Scaling correction factor                                  1.211
##     for the Satorra-Bentler correction
##
## Model test baseline model:
##
##   Minimum Function Test Statistic             3452.269    2911.466
##   Degrees of freedom                               231         231
##   P-value                                        0.000       0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                    0.878       0.892
##   Tucker-Lewis Index (TLI)                       0.863       0.879
##
##   Robust Comparative Fit Index (CFI)                         0.890
##   Robust Tucker-Lewis Index (TLI)                            0.876
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)             -12762.049  -12762.049
##   Loglikelihood unrestricted model (H1)     -12463.184  -12463.184
##
##   Number of free parameters                         48          48
##   Akaike (AIC)                               25620.098   25620.098
##   Bayesian (BIC)                             25808.205   25808.205
##   Sample-size adjusted Bayesian (BIC)        25655.916   25655.916
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.072       0.061
##   90 Percent Confidence Interval          0.065  0.078       0.055  0.068
##   P-value RMSEA <= 0.05                          0.000       0.002
##
##   Robust RMSEA                                               0.068
##   90 Percent Confidence Interval                             0.060  0.075
##
```

```
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.071       0.071
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard Errors                           Robust.sem
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   F1 =~
##     ITEM1             1.000
##     ITEM2             0.887    0.040   22.303    0.000
##     ITEM3             1.015    0.052   19.632    0.000
##     ITEM6             0.715    0.069   10.369    0.000
##     ITEM8             1.133    0.058   19.698    0.000
##     ITEM13            1.002    0.062   16.227    0.000
##     ITEM14            0.847    0.058   14.692    0.000
##     ITEM16            0.672    0.065   10.294    0.000
##     ITEM20            0.746    0.061   12.288    0.000
##   F2 =~
##     ITEM5             1.000
##     ITEM10            1.151    0.154    7.473    0.000
##     ITEM11            1.363    0.164    8.329    0.000
##     ITEM15            0.909    0.124    7.351    0.000
##     ITEM22            0.771    0.123    6.252    0.000
##   F3 =~
##     ITEM4             1.000
##     ITEM7             0.969    0.128    7.564    0.000
##     ITEM9             1.779    0.322    5.529    0.000
##     ITEM12            1.496    0.240    6.232    0.000
##     ITEM17            1.347    0.199    6.756    0.000
##     ITEM18            1.917    0.298    6.441    0.000
##     ITEM19            1.714    0.287    5.979    0.000
##     ITEM21            1.356    0.227    5.985    0.000
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##  .ITEM6 ~~
##    .ITEM16            0.733    0.121    6.069    0.000
##   F1 ~~
##     F2                0.697    0.106    6.605    0.000
##     F3               -0.188    0.040   -4.670    0.000
##   F2 ~~
##     F3               -0.171    0.036   -4.768    0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .ITEM1             1.091    0.092   11.824    0.000
##    .ITEM2             1.076    0.088   12.219    0.000
##    .ITEM3             1.283    0.105   12.211    0.000
##    .ITEM6             1.654    0.141   11.710    0.000
```

```
##    .ITEM8             0.844    0.080   10.559    0.000
##    .ITEM13            1.156    0.129    8.945    0.000
##    .ITEM14            1.780    0.141   12.655    0.000
##    .ITEM16            1.317    0.115   11.413    0.000
##    .ITEM20            1.071    0.136    7.863    0.000
##    .ITEM5             1.511    0.180    8.414    0.000
##    .ITEM10            1.164    0.147    7.927    0.000
##    .ITEM11            1.038    0.141    7.364    0.000
##    .ITEM15            1.108    0.153    7.225    0.000
##    .ITEM22            2.077    0.184   11.269    0.000
##    .ITEM4             0.801    0.112    7.124    0.000
##    .ITEM7             0.523    0.075    7.011    0.000
##    .ITEM9             1.116    0.149    7.484    0.000
##    .ITEM12            0.988    0.126    7.855    0.000
##    .ITEM17            0.375    0.056    6.636    0.000
##    .ITEM18            0.909    0.143    6.376    0.000
##    .ITEM19            0.844    0.111    7.626    0.000
##    .ITEM21            1.244    0.133    9.339    0.000
##     F1               1.662    0.148   11.216    0.000
##     F2               0.697    0.158    4.424    0.000
##     F3               0.193    0.050    3.842    0.000
```

There seems to be a considerable improvement in fit measures. The x2 statistics showing drop (493.398) using estimator MLM as compared to fit1 (567.753).The p-value is still 0.000. CFI (0.892) and TLI(0.879) values have increased and RMSEA(0.061) and SRMR (0.071) values have lowered down suggesting effective inclusion of parameters.

Model 3

Model Modification indices for model 3

```r
modindices(fit2, minimum = 30)
```

```
##        lhs op    rhs mi   epc sepc.lv sepc.all sepc.nox
## 60      F1 =~ ITEM12 42 -0.31   -0.40    -0.34    -0.34
## 96   ITEM1 ~~  ITEM2 78  0.59    0.59     0.54     0.54
## 260 ITEM10 ~~ ITEM11 37  0.58    0.58     0.53     0.53
## 298  ITEM4 ~~  ITEM7 33  0.21    0.21     0.32     0.32
## 310  ITEM7 ~~ ITEM21 33  0.26    0.26     0.33     0.33
```

The residual covariance Item 1 and 2 has higher modification and is included in the model.

Specifying model

```r
model3 <- '
F1 =~  ITEM1 + ITEM2+ ITEM3 + ITEM6 + ITEM8 + ITEM13 + ITEM14 + ITEM16 + ITEM20
F2 =~ ITEM5 + ITEM10 + ITEM11 + ITEM15 + ITEM22
F3 =~ ITEM4 + ITEM7 + ITEM9 + ITEM12 + ITEM17 + ITEM18 + ITEM19 + ITEM21
#Residual covariance
ITEM6~~ITEM16
ITEM1~~ITEM2
'
```

Fitting the model

```r
fit3 <- cfa(model3, data=CFA, estimator = "MLM")
```

Display summary output

```r
summary(fit3, fit.measures=TRUE)
```

```
## lavaan 0.6-3 ended normally after 46 iterations
##
##   Optimization method                           NLMINB
##   Number of free parameters                         49
##
##   Number of observations                           372
##
##   Estimator                                         ML      Robust
##   Model Fit Test Statistic                     520.481     431.496
##   Degrees of freedom                               204         204
##   P-value (Chi-square)                           0.000       0.000
##   Scaling correction factor                                  1.206
##     for the Satorra-Bentler correction
##
## Model test baseline model:
##
##   Minimum Function Test Statistic             3452.269    2911.466
##   Degrees of freedom                               231         231
##   P-value                                        0.000       0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                    0.902       0.915
##   Tucker-Lewis Index (TLI)                       0.889       0.904
##
##   Robust Comparative Fit Index (CFI)                         0.914
##   Robust Tucker-Lewis Index (TLI)                            0.902
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)             -12723.424  -12723.424
##   Loglikelihood unrestricted model (H1)     -12463.184  -12463.184
##
##   Number of free parameters                         49          49
##   Akaike (AIC)                               25544.849   25544.849
##   Bayesian (BIC)                             25736.875   25736.875
##   Sample-size adjusted Bayesian (BIC)        25581.413   25581.413
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.065       0.055
##   90 Percent Confidence Interval          0.058  0.071       0.048  0.061
##   P-value RMSEA <= 0.05                          0.000       0.114
##
##   Robust RMSEA                                               0.060
##   90 Percent Confidence Interval                             0.052  0.068
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.069       0.069
##
## Parameter Estimates:
```

```
##
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard Errors                           Robust.sem
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   F1 =~
##     ITEM1             1.000
##     ITEM2             0.877    0.041   21.156    0.000
##     ITEM3             1.068    0.059   18.221    0.000
##     ITEM6             0.767    0.077   10.025    0.000
##     ITEM8             1.216    0.067   18.238    0.000
##     ITEM13            1.086    0.069   15.688    0.000
##     ITEM14            0.884    0.063   14.109    0.000
##     ITEM16            0.727    0.072   10.053    0.000
##     ITEM20            0.811    0.067   12.137    0.000
##   F2 =~
##     ITEM5             1.000
##     ITEM10            1.151    0.154    7.478    0.000
##     ITEM11            1.363    0.163    8.346    0.000
##     ITEM15            0.910    0.124    7.363    0.000
##     ITEM22            0.769    0.123    6.264    0.000
##   F3 =~
##     ITEM4             1.000
##     ITEM7             0.969    0.128    7.566    0.000
##     ITEM9             1.782    0.323    5.524    0.000
##     ITEM12            1.505    0.241    6.239    0.000
##     ITEM17            1.349    0.200    6.759    0.000
##     ITEM18            1.919    0.298    6.431    0.000
##     ITEM19            1.718    0.287    5.979    0.000
##     ITEM21            1.356    0.227    5.977    0.000
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##  .ITEM6 ~~
##    .ITEM16            0.708    0.122    5.804    0.000
##  .ITEM1 ~~
##    .ITEM2             0.596    0.087    6.891    0.000
##   F1 ~~
##     F2                0.672    0.103    6.524    0.000
##     F3               -0.193    0.039   -4.914    0.000
##   F2 ~~
##     F3               -0.171    0.036   -4.764    0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .ITEM1             1.276    0.105   12.210    0.000
##    .ITEM2             1.246    0.098   12.669    0.000
##    .ITEM3             1.312    0.110   11.931    0.000
##    .ITEM6             1.633    0.143   11.444    0.000
##    .ITEM8             0.793    0.083    9.559    0.000
##    .ITEM13            1.081    0.124    8.712    0.000
##    .ITEM14            1.819    0.145   12.567    0.000
```

```
##    .ITEM16            1.287    0.117   11.021    0.000
##    .ITEM20            1.024    0.136    7.506    0.000
##    .ITEM5             1.511    0.179    8.429    0.000
##    .ITEM10            1.165    0.147    7.912    0.000
##    .ITEM11            1.037    0.140    7.392    0.000
##    .ITEM15            1.106    0.153    7.238    0.000
##    .ITEM22            2.079    0.184   11.292    0.000
##    .ITEM4             0.802    0.113    7.126    0.000
##    .ITEM7             0.523    0.075    7.018    0.000
##    .ITEM9             1.116    0.149    7.495    0.000
##    .ITEM12            0.985    0.125    7.853    0.000
##    .ITEM17            0.375    0.056    6.643    0.000
##    .ITEM18            0.909    0.143    6.374    0.000
##    .ITEM19            0.844    0.110    7.636    0.000
##    .ITEM21            1.245    0.133    9.334    0.000
##     F1                1.477    0.150    9.869    0.000
##     F2                0.697    0.157    4.428    0.000
##     F3                0.192    0.050    3.836    0.000
```

The improvement can be seen in fit measures. The x2 statistics showing drop (431.496) using estimator MLM as compared to fit2 (493.398).The p-value is still 0.000. CFI (0.915) and TLI (0.904) values have increased and RMSEA(0.055) and SRMR (0.069) values have lowered down suggesting effective inclusion of mispecified parameter.

Model 4

Model Modification indices for model 4

```
modindices(fit3, minimum = 30)
```

```
##        lhs op    rhs mi   epc sepc.lv sepc.all sepc.nox
## 61      F1 =~ ITEM12 41 -0.33   -0.40    -0.34    -0.34
## 260 ITEM10 ~~ ITEM11 37  0.57    0.57     0.52     0.52
## 298  ITEM4 ~~  ITEM7 34  0.21    0.21     0.32     0.32
## 310  ITEM7 ~~ ITEM21 34  0.26    0.26     0.33     0.33
```

The Modification Indices suggest links to change in the model structure. The greatest modification relates to the misspecified factor loading i.e.item 12 as mentioned previously. Therefore, cross-loading of Item 12 on both F1 and F3 is included in the model.

Specifying model

```
model4 <- '
F1 =~  ITEM1 + ITEM2+ ITEM3 + ITEM6 + ITEM8 + ITEM12 + ITEM13 + ITEM14 + ITEM16 + ITEM20
F2 =~ ITEM5 + ITEM10 + ITEM11 + ITEM15 + ITEM22
F3 =~ ITEM4 + ITEM7 + ITEM9 + ITEM12 + ITEM17 + ITEM18 + ITEM19 + ITEM21
#Residual covariance
ITEM6~~ITEM16
ITEM1~~ITEM2
'
```

Fitting the model

```
fit4 <- cfa(model4, data=CFA, estimator = "MLM")
```

Display summary output

```
summary(fit4, fit.measures=TRUE)
```

```
## lavaan 0.6-3 ended normally after 46 iterations
##
##   Optimization method                           NLMINB
##   Number of free parameters                         50
##
##   Number of observations                           372
##
##   Estimator                                         ML      Robust
##   Model Fit Test Statistic                     478.584     398.090
##   Degrees of freedom                               203         203
##   P-value (Chi-square)                           0.000       0.000
##   Scaling correction factor                                  1.202
##     for the Satorra-Bentler correction
##
## Model test baseline model:
##
##   Minimum Function Test Statistic             3452.269    2911.466
##   Degrees of freedom                               231         231
##   P-value                                        0.000       0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                    0.914       0.927
##   Tucker-Lewis Index (TLI)                       0.903       0.917
##
##   Robust Comparative Fit Index (CFI)                         0.926
##   Robust Tucker-Lewis Index (TLI)                            0.916
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)             -12702.476  -12702.476
##   Loglikelihood unrestricted model (H1)     -12463.184  -12463.184
##
##   Number of free parameters                         50          50
##   Akaike (AIC)                               25504.952   25504.952
##   Bayesian (BIC)                             25700.897   25700.897
##   Sample-size adjusted Bayesian (BIC)        25542.262   25542.262
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.060       0.051
##   90 Percent Confidence Interval          0.053  0.067       0.044  0.058
##   P-value RMSEA <= 0.05                          0.008       0.411
##
##   Robust RMSEA                                               0.056
##   90 Percent Confidence Interval                             0.048  0.064
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.058       0.058
##
## Parameter Estimates:
##
##   Information                                 Expected
```

```
##   Information saturated (h1) model          Structured
##   Standard Errors                           Robust.sem
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   F1 =~
##     ITEM1             1.000
##     ITEM2             0.877    0.041   21.316    0.000
##     ITEM3             1.074    0.058   18.409    0.000
##     ITEM6             0.761    0.076    9.948    0.000
##     ITEM8             1.217    0.066   18.437    0.000
##     ITEM12           -0.317    0.054   -5.902    0.000
##     ITEM13            1.072    0.070   15.421    0.000
##     ITEM14            0.879    0.062   14.089    0.000
##     ITEM16            0.726    0.073   10.015    0.000
##     ITEM20            0.806    0.066   12.138    0.000
##   F2 =~
##     ITEM5             1.000
##     ITEM10            1.155    0.155    7.450    0.000
##     ITEM11            1.368    0.165    8.318    0.000
##     ITEM15            0.912    0.124    7.329    0.000
##     ITEM22            0.769    0.123    6.246    0.000
##   F3 =~
##     ITEM4             1.000
##     ITEM7             0.967    0.127    7.587    0.000
##     ITEM9             1.762    0.316    5.581    0.000
##     ITEM12            1.135    0.202    5.610    0.000
##     ITEM17            1.328    0.198    6.704    0.000
##     ITEM18            1.892    0.291    6.498    0.000
##     ITEM19            1.689    0.284    5.940    0.000
##     ITEM21            1.342    0.223    6.023    0.000
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##  .ITEM6 ~~
##    .ITEM16            0.710    0.122    5.807    0.000
##  .ITEM1 ~~
##    .ITEM2             0.589    0.086    6.859    0.000
##   F1 ~~
##     F2                0.669    0.103    6.491    0.000
##     F3               -0.167    0.038   -4.353    0.000
##   F2 ~~
##     F3               -0.162    0.035   -4.669    0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .ITEM1             1.268    0.103   12.293    0.000
##    .ITEM2             1.239    0.098   12.607    0.000
##    .ITEM3             1.284    0.107   11.967    0.000
##    .ITEM6             1.642    0.143   11.485    0.000
##    .ITEM8             0.777    0.080    9.745    0.000
##    .ITEM12            0.894    0.105    8.520    0.000
##    .ITEM13            1.116    0.128    8.701    0.000
##    .ITEM14            1.825    0.144   12.637    0.000
```

```
##    .ITEM16            1.283    0.116   11.053    0.000
##    .ITEM20            1.031    0.137    7.516    0.000
##    .ITEM5             1.514    0.180    8.425    0.000
##    .ITEM10            1.162    0.147    7.884    0.000
##    .ITEM11            1.034    0.141    7.353    0.000
##    .ITEM15            1.107    0.153    7.235    0.000
##    .ITEM22            2.081    0.184   11.296    0.000
##    .ITEM4             0.795    0.112    7.109    0.000
##    .ITEM7             0.517    0.074    7.008    0.000
##    .ITEM9             1.108    0.149    7.411    0.000
##    .ITEM17            0.373    0.056    6.693    0.000
##    .ITEM18            0.903    0.143    6.323    0.000
##    .ITEM19            0.842    0.113    7.464    0.000
##    .ITEM21            1.240    0.132    9.367    0.000
##     F1                1.486    0.150    9.933    0.000
##     F2                0.693    0.157    4.408    0.000
##     F3                0.200    0.051    3.904    0.000
```

The resuts are progressive towards good model fit. The x2 statistics showing drop (398.090) using estimator MLM as compared to fit3 (431.496).The p-value is still 0.000. CFI (0.927) and TLI (0.917) values have increased and RMSEA (0.051) and SRMR (0.058) values have lowered down suggesting effective loading of item 12 on both F1 and F3.

Model 5

Model Modification indices for model 5

```r
modindices(fit4, minimum = 30)
```

```
##         lhs op    rhs mi  epc sepc.lv sepc.all sepc.nox
## 271 ITEM10 ~~ ITEM11 37 0.57    0.57     0.52     0.52
## 305  ITEM4 ~~  ITEM7 32 0.20    0.20     0.32     0.32
## 315  ITEM7 ~~ ITEM21 33 0.26    0.26     0.32     0.32
```

The highest MI as seen above relates to items 11 and 10 and thus included in the model.

Specifying model

```r
model5 <- '
F1 =~  ITEM1 + ITEM2+ ITEM3 + ITEM6 + ITEM8 + ITEM12 + ITEM13 + ITEM14 + ITEM16 + ITEM20
F2 =~ ITEM5 + ITEM10 + ITEM11 + ITEM15 + ITEM22
F3 =~ ITEM4 + ITEM7 + ITEM9 + ITEM12 + ITEM17 + ITEM18 + ITEM19 + ITEM21
#Residual covariance
ITEM6~~ITEM16
ITEM1~~ITEM2
ITEM10~~ITEM11
'
```

Fitting the model

```r
fit5 <- cfa(model5, data=CFA, estimator = "MLM")
standardizedSolution(fit)
```

```
##        lhs op    rhs est.std    se    z pvalue ci.lower ci.upper
## 1       F1 =~  ITEM1    0.77 0.024 32.1      0     0.72     0.81
## 2       F1 =~  ITEM2    0.73 0.027 27.5      0     0.68     0.78
## 3       F1 =~  ITEM3    0.75 0.025 29.9      0     0.70     0.80
## 4       F1 =~  ITEM6    0.62 0.035 17.8      0     0.55     0.68
```

```
## 5       F1 =~  ITEM8    0.84 0.018 47.0      0     0.81     0.88
## 6       F1 =~ ITEM13    0.77 0.024 32.6      0     0.72     0.82
## 7       F1 =~ ITEM14    0.63 0.034 18.5      0     0.56     0.69
## 8       F1 =~ ITEM16    0.63 0.033 19.0      0     0.57     0.70
## 9       F1 =~ ITEM20    0.68 0.030 22.3      0     0.62     0.74
## 10      F2 =~  ITEM5    0.56 0.042 13.3      0     0.48     0.65
## 11      F2 =~ ITEM10    0.66 0.037 17.8      0     0.59     0.74
## 12      F2 =~ ITEM11    0.74 0.033 22.5      0     0.68     0.81
## 13      F2 =~ ITEM15    0.59 0.041 14.1      0     0.50     0.67
## 14      F2 =~ ITEM22    0.41 0.050  8.2      0     0.31     0.51
## 15      F3 =~  ITEM4    0.44 0.048  9.2      0     0.35     0.53
## 16      F3 =~  ITEM7    0.51 0.045 11.4      0     0.42     0.59
## 17      F3 =~  ITEM9    0.59 0.040 14.8      0     0.52     0.67
## 18      F3 =~ ITEM12    0.55 0.042 13.0      0     0.47     0.64
## 19      F3 =~ ITEM17    0.69 0.034 20.3      0     0.63     0.76
## 20      F3 =~ ITEM18    0.66 0.036 18.3      0     0.59     0.73
## 21      F3 =~ ITEM19    0.63 0.038 16.8      0     0.56     0.71
## 22      F3 =~ ITEM21    0.47 0.046 10.2      0     0.38     0.56
## 23   ITEM1 ~~  ITEM1    0.41 0.037 11.1      0     0.34     0.48
## 24   ITEM2 ~~  ITEM2    0.46 0.039 11.9      0     0.39     0.54
## 25   ITEM3 ~~  ITEM3    0.43 0.038 11.5      0     0.36     0.51
## 26   ITEM6 ~~  ITEM6    0.62 0.043 14.5      0     0.54     0.70
## 27   ITEM8 ~~  ITEM8    0.29 0.030  9.4      0     0.23     0.35
## 28  ITEM13 ~~ ITEM13    0.40 0.037 11.1      0     0.33     0.48
## 29  ITEM14 ~~ ITEM14    0.61 0.043 14.3      0     0.52     0.69
## 30  ITEM16 ~~ ITEM16    0.60 0.042 14.1      0     0.52     0.68
## 31  ITEM20 ~~ ITEM20    0.54 0.041 13.0      0     0.46     0.62
## 32   ITEM5 ~~  ITEM5    0.68 0.048 14.2      0     0.59     0.78
## 33  ITEM10 ~~ ITEM10    0.56 0.049 11.3      0     0.46     0.66
## 34  ITEM11 ~~ ITEM11    0.45 0.049  9.1      0     0.35     0.54
## 35  ITEM15 ~~ ITEM15    0.66 0.048 13.5      0     0.56     0.75
## 36  ITEM22 ~~ ITEM22    0.83 0.041 20.5      0     0.75     0.91
## 37   ITEM4 ~~  ITEM4    0.81 0.042 19.2      0     0.72     0.89
## 38   ITEM7 ~~  ITEM7    0.74 0.045 16.4      0     0.65     0.83
## 39   ITEM9 ~~  ITEM9    0.65 0.048 13.6      0     0.55     0.74
## 40  ITEM12 ~~ ITEM12    0.69 0.047 14.9      0     0.60     0.79
## 41  ITEM17 ~~ ITEM17    0.52 0.048 10.9      0     0.42     0.61
## 42  ITEM18 ~~ ITEM18    0.56 0.048 11.7      0     0.47     0.66
## 43  ITEM19 ~~ ITEM19    0.60 0.048 12.5      0     0.50     0.69
## 44  ITEM21 ~~ ITEM21    0.78 0.044 17.8      0     0.69     0.86
## 45      F1 ~~     F1    1.00 0.000   NA     NA     1.00     1.00
## 46      F2 ~~     F2    1.00 0.000   NA     NA     1.00     1.00
## 47      F3 ~~     F3    1.00 0.000   NA     NA     1.00     1.00
## 48      F1 ~~     F2    0.66 0.041 16.1      0     0.57     0.73
## 49      F1 ~~     F3   -0.34 0.054 -6.3      0    -0.45    -0.24
## 50      F2 ~~     F3   -0.47 0.055 -8.4      0    -0.57    -0.36
```

Display summary output

```r
summary(fit5, fit.measures=TRUE)
```

```
## lavaan 0.6-3 ended normally after 52 iterations
##
##   Optimization method                           NLMINB
##   Number of free parameters                         51
```

```
##
##   Number of observations                           372
##
##   Estimator                                         ML      Robust
##   Model Fit Test Statistic                     446.419     369.998
##   Degrees of freedom                               202         202
##   P-value (Chi-square)                           0.000       0.000
##   Scaling correction factor                                  1.207
##     for the Satorra-Bentler correction
##
## Model test baseline model:
##
##   Minimum Function Test Statistic             3452.269    2911.466
##   Degrees of freedom                               231         231
##   P-value                                        0.000       0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                    0.924       0.937
##   Tucker-Lewis Index (TLI)                       0.913       0.928
##
##   Robust Comparative Fit Index (CFI)                         0.936
##   Robust Tucker-Lewis Index (TLI)                            0.927
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)             -12686.394  -12686.394
##   Loglikelihood unrestricted model (H1)     -12463.184  -12463.184
##
##   Number of free parameters                         51          51
##   Akaike (AIC)                               25474.787   25474.787
##   Bayesian (BIC)                             25674.651   25674.651
##   Sample-size adjusted Bayesian (BIC)        25512.844   25512.844
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.057       0.047
##   90 Percent Confidence Interval          0.050  0.064       0.040  0.054
##   P-value RMSEA <= 0.05                          0.052       0.735
##
##   Robust RMSEA                                               0.052
##   90 Percent Confidence Interval                             0.044  0.060
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.057       0.057
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard Errors                           Robust.sem
##
## Latent Variables:
```

```
##                    Estimate  Std.Err  z-value  P(>|z|)
##   F1 =~
##     ITEM1             1.000
##     ITEM2             0.878    0.041   21.316    0.000
##     ITEM3             1.073    0.058   18.460    0.000
##     ITEM6             0.764    0.076    9.992    0.000
##     ITEM8             1.215    0.066   18.382    0.000
##     ITEM12           -0.316    0.054   -5.890    0.000
##     ITEM13            1.072    0.070   15.415    0.000
##     ITEM14            0.880    0.063   14.071    0.000
##     ITEM16            0.727    0.072   10.032    0.000
##     ITEM20            0.806    0.066   12.127    0.000
##   F2 =~
##     ITEM5             1.000
##     ITEM10            0.889    0.124    7.178    0.000
##     ITEM11            1.105    0.130    8.530    0.000
##     ITEM15            0.921    0.120    7.671    0.000
##     ITEM22            0.776    0.116    6.668    0.000
##   F3 =~
##     ITEM4             1.000
##     ITEM7             0.973    0.128    7.602    0.000
##     ITEM9             1.763    0.317    5.561    0.000
##     ITEM12            1.131    0.202    5.607    0.000
##     ITEM17            1.327    0.198    6.717    0.000
##     ITEM18            1.890    0.291    6.497    0.000
##     ITEM19            1.695    0.286    5.933    0.000
##     ITEM21            1.342    0.224    5.993    0.000
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##  .ITEM6 ~~
##    .ITEM16            0.706    0.122    5.773    0.000
##  .ITEM1 ~~
##    .ITEM2             0.588    0.086    6.870    0.000
##  .ITEM10 ~~
##    .ITEM11            0.517    0.110    4.719    0.000
##   F1 ~~
##     F2                0.747    0.106    7.038    0.000
##     F3               -0.167    0.038   -4.355    0.000
##   F2 ~~
##     F3               -0.181    0.038   -4.788    0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .ITEM1             1.268    0.103   12.268    0.000
##    .ITEM2             1.238    0.098   12.631    0.000
##    .ITEM3             1.285    0.108   11.939    0.000
##    .ITEM6             1.636    0.143   11.474    0.000
##    .ITEM8             0.783    0.080    9.828    0.000
##    .ITEM12            0.898    0.105    8.557    0.000
##    .ITEM13            1.115    0.128    8.693    0.000
##    .ITEM14            1.822    0.144   12.651    0.000
##    .ITEM16            1.281    0.116   11.047    0.000
##    .ITEM20            1.031    0.137    7.519    0.000
```

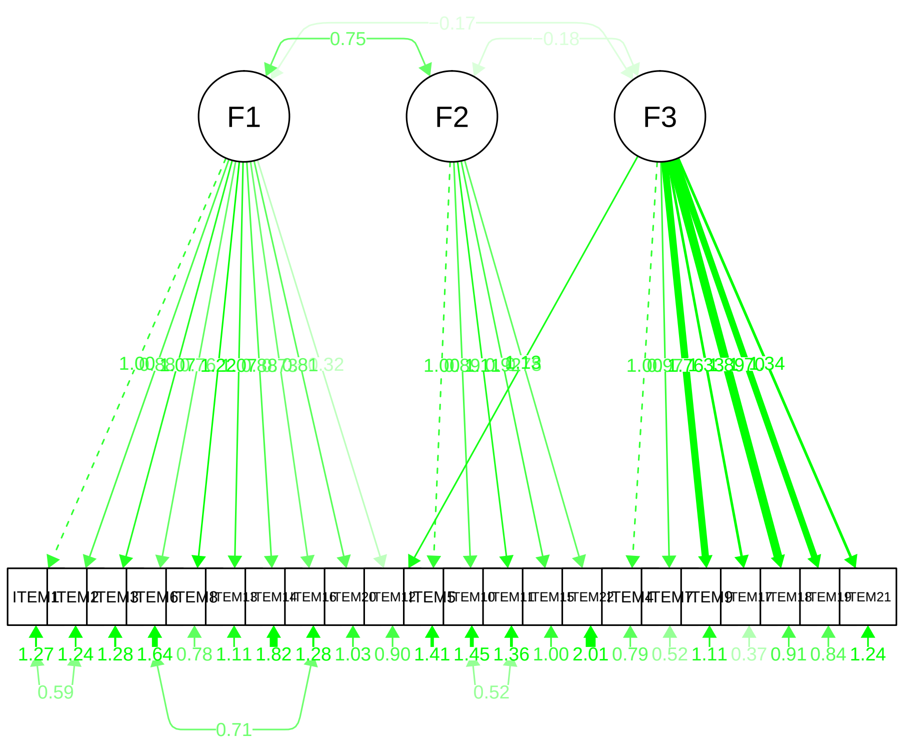
```
##    .ITEM5             1.407    0.181    7.771    0.000
##    .ITEM10            1.455    0.150    9.710    0.000
##    .ITEM11            1.355    0.159    8.504    0.000
##    .ITEM15            1.004    0.142    7.094    0.000
##    .ITEM22            2.008    0.182   11.021    0.000
##    .ITEM4             0.795    0.112    7.108    0.000
##    .ITEM7             0.515    0.074    6.997    0.000
##    .ITEM9             1.108    0.150    7.407    0.000
##    .ITEM17            0.374    0.056    6.694    0.000
##    .ITEM18            0.906    0.143    6.335    0.000
##    .ITEM19            0.838    0.113    7.436    0.000
##    .ITEM21            1.240    0.132    9.366    0.000
##     F1                1.486    0.150    9.933    0.000
##     F2                0.800    0.171    4.684    0.000
##     F3                0.199    0.051    3.896    0.000
```

The resuts are progressive towards good model fit. The x2 statistics showing drop (369.998) using estimator MLM as compared to the previous model (398.090).The p-value is still 0.000. CFI (0.937) and TLI (0.928) values have increased and RMSEA (0.047) and SRMR (0.057) values have lowered down suggesting effective inclusion of items 10 and 11.

Creating diagram

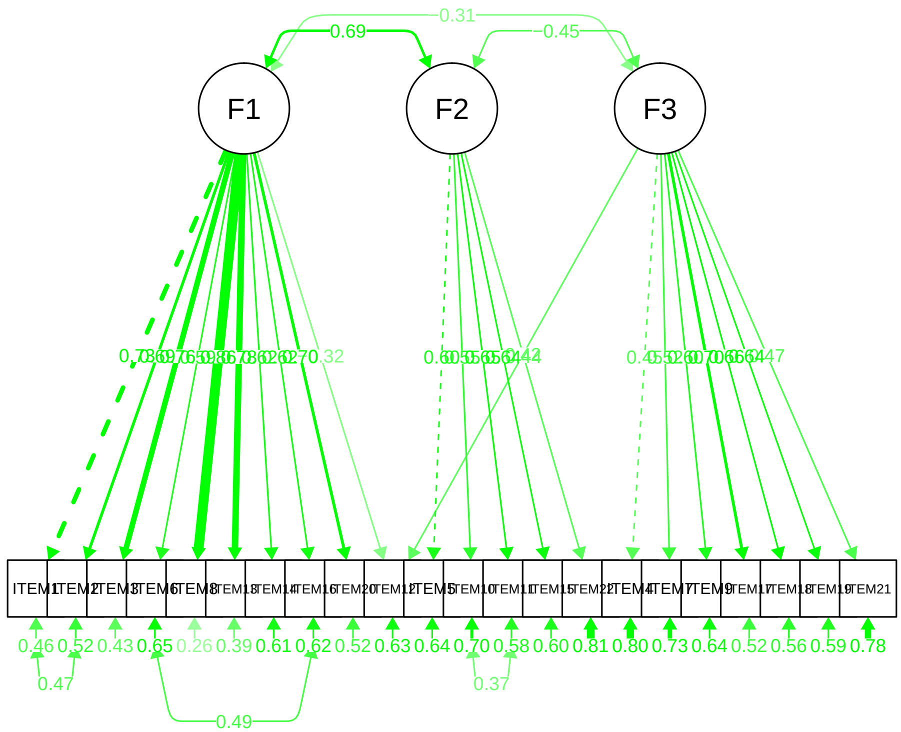
- Unstandardized plot

```
semPaths(fit5, "estimates", curvePivot = TRUE, style = "lisrel", edge.label.cex=0.75, edge.color="green
```



- Standardized plot

```r
semPaths(fit5, "standardized", curvePivot = TRUE, style = "lisrel", edge.label.cex=0.75, edge.color="gr
```



Model 6

With the remaining mispecified parameters

Model Modification indices for model 5

```r
modindices(fit5, minimum = 30)
```

```
##       lhs op    rhs mi  epc sepc.lv sepc.all sepc.nox
## 305 ITEM4 ~~  ITEM7 32 0.20    0.20     0.32     0.32
## 315 ITEM7 ~~ ITEM21 33 0.26    0.26     0.32     0.32
```

Specifying model 6

```r
model6 <- '
F1 =~  ITEM1 + ITEM2+ ITEM3 + ITEM6 + ITEM8 + ITEM12 + ITEM13 + ITEM14 + ITEM16 + ITEM20
F2 =~ ITEM5 + ITEM10 + ITEM11 + ITEM15 + ITEM22
F3 =~ ITEM4 + ITEM7 + ITEM9 + ITEM17 + ITEM18 + ITEM19 + ITEM21
#Residual covariance
ITEM6~~ITEM16
ITEM1~~ITEM2
ITEM10~~ITEM11
ITEM7~~ITEM21
'
```

Fitting the model

```r
fit6 <- cfa(model6, data=CFA, estimator = "MLM")
```

Display summary output

```r
summary(fit6, fit.measures=TRUE, standardized=TRUE)
```

```
## lavaan 0.6-3 ended normally after 50 iterations
##
##   Optimization method                           NLMINB
##   Number of free parameters                         51
##
##   Number of observations                           372
##
##   Estimator                                         ML      Robust
##   Model Fit Test Statistic                     477.384     398.637
##   Degrees of freedom                               202         202
##   P-value (Chi-square)                           0.000       0.000
##   Scaling correction factor                                  1.198
##     for the Satorra-Bentler correction
##
## Model test baseline model:
##
##   Minimum Function Test Statistic             3452.269    2911.466
##   Degrees of freedom                               231         231
##   P-value                                        0.000       0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                    0.915       0.927
##   Tucker-Lewis Index (TLI)                       0.902       0.916
##
##   Robust Comparative Fit Index (CFI)                         0.926
##   Robust Tucker-Lewis Index (TLI)                            0.915
##
## Loglikelihood and Information Criteria:
##
##   Loglikelihood user model (H0)             -12701.876  -12701.876
##   Loglikelihood unrestricted model (H1)     -12463.184  -12463.184
##
##   Number of free parameters                         51          51
##   Akaike (AIC)                               25505.752   25505.752
##   Bayesian (BIC)                             25705.616   25705.616
##   Sample-size adjusted Bayesian (BIC)        25543.808   25543.808
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.061       0.051
##   90 Percent Confidence Interval          0.054  0.068       0.044  0.058
##   P-value RMSEA <= 0.05                          0.007       0.380
##
##   Robust RMSEA                                               0.056
##   90 Percent Confidence Interval                             0.048  0.064
##
## Standardized Root Mean Square Residual:
```

```
##
##   SRMR                                          0.066       0.066
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard Errors                           Robust.sem
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   F1 =~
##     ITEM1             1.000                               1.208    0.728
##     ITEM2             0.879    0.042   21.116    0.000    1.062    0.688
##     ITEM3             1.081    0.059   18.344    0.000    1.306    0.754
##     ITEM6             0.774    0.077   10.005    0.000    0.935    0.591
##     ITEM8             1.227    0.067   18.330    0.000    1.482    0.859
##     ITEM12           -0.460    0.058   -7.887    0.000   -0.556   -0.466
##     ITEM13            1.085    0.070   15.461    0.000    1.311    0.780
##     ITEM14            0.882    0.063   13.943    0.000    1.066    0.618
##     ITEM16            0.737    0.073   10.051    0.000    0.891    0.620
##     ITEM20            0.814    0.067   12.093    0.000    0.984    0.696
##   F2 =~
##     ITEM5             1.000                               0.897    0.604
##     ITEM10            0.886    0.123    7.202    0.000    0.794    0.550
##     ITEM11            1.100    0.129    8.544    0.000    0.986    0.646
##     ITEM15            0.919    0.119    7.717    0.000    0.824    0.635
##     ITEM22            0.776    0.116    6.657    0.000    0.695    0.441
##   F3 =~
##     ITEM4             1.000                               0.416    0.418
##     ITEM7             0.975    0.137    7.106    0.000    0.406    0.484
##     ITEM9             1.894    0.359    5.280    0.000    0.789    0.600
##     ITEM17            1.419    0.226    6.271    0.000    0.591    0.694
##     ITEM18            2.054    0.338    6.082    0.000    0.855    0.672
##     ITEM19            1.901    0.341    5.575    0.000    0.792    0.666
##     ITEM21            1.289    0.231    5.584    0.000    0.537    0.424
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##  .ITEM6 ~~
##    .ITEM16            0.699    0.122    5.708    0.000    0.699    0.485
##  .ITEM1 ~~
##    .ITEM2             0.610    0.087    7.035    0.000    0.610    0.478
##  .ITEM10 ~~
##    .ITEM11            0.520    0.110    4.721    0.000    0.520    0.369
##  .ITEM7 ~~
##    .ITEM21            0.258    0.063    4.127    0.000    0.258    0.307
##   F1 ~~
##     F2                0.749    0.106    7.084    0.000    0.691    0.691
##     F3               -0.169    0.038   -4.436    0.000   -0.336   -0.336
##   F2 ~~
##     F3               -0.173    0.037   -4.732    0.000   -0.463   -0.463
##
## Variances:
```

```
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##    .ITEM1             1.295    0.104   12.421    0.000    1.295    0.470
##    .ITEM2             1.255    0.099   12.721    0.000    1.255    0.527
##    .ITEM3             1.292    0.107   12.082    0.000    1.292    0.431
##    .ITEM6             1.629    0.143   11.433    0.000    1.629    0.651
##    .ITEM8             0.781    0.078    9.948    0.000    0.781    0.262
##    .ITEM12            1.111    0.110   10.115    0.000    1.111    0.783
##    .ITEM13            1.105    0.126    8.754    0.000    1.105    0.391
##    .ITEM14            1.837    0.145   12.686    0.000    1.837    0.618
##    .ITEM16            1.273    0.116   10.977    0.000    1.273    0.616
##    .ITEM20            1.029    0.137    7.486    0.000    1.029    0.516
##    .ITEM5             1.404    0.181    7.776    0.000    1.404    0.636
##    .ITEM10            1.457    0.150    9.701    0.000    1.457    0.698
##    .ITEM11            1.360    0.160    8.520    0.000    1.360    0.583
##    .ITEM15            1.004    0.141    7.093    0.000    1.004    0.596
##    .ITEM22            2.007    0.182   11.021    0.000    2.007    0.806
##    .ITEM4             0.821    0.113    7.240    0.000    0.821    0.826
##    .ITEM7             0.539    0.077    6.956    0.000    0.539    0.766
##    .ITEM9             1.105    0.150    7.367    0.000    1.105    0.640
##    .ITEM17            0.376    0.057    6.578    0.000    0.376    0.518
##    .ITEM18            0.887    0.145    6.126    0.000    0.887    0.548
##    .ITEM19            0.785    0.107    7.339    0.000    0.785    0.556
##    .ITEM21            1.311    0.136    9.623    0.000    1.311    0.820
##     F1                1.459    0.149    9.775    0.000    1.000    1.000
##     F2                0.804    0.171    4.705    0.000    1.000    1.000
##     F3                0.173    0.048    3.618    0.000    1.000    1.000
```

There seems to have slighty higher x2 values (398.637) than the final model (369.998). The p-value is still 0.000. CFI (0.927) and TLI (0.916) values have lowered down and RMSEA (0.051) and SRMR (0.066) values have increased suggesting ineffective inclusion of items 7 and 21.

According to the results, model 5 has a better model fit and seems to somewhat accept the hypothesized model that includes MBI responses explained by EE, DP and PA factors, each item has a nonzero loading on the appropriate factor and zero loadings on all other factors (except one item 12) and the three factors are correlated.

Week 4 SEM Assignment

Shweta Goswami

12-02-2019

TITLE: Full SEM Model of Burnout for Secondary Teachers, Hypothesized Model (Byrne 2012, p. 154)

Exercise 4.1

Reading the data

```
alsec <- read.delim("~/sem2019/allsecondary.DAT", header=FALSE)
glimpse(alsec)
```

```
## Observations: 1,430
## Variables: 32
## $ V1  <dbl> 1.33, 2.33, 3.33, 2.00, 3.00, 2.67, 1.67, 2.00, 4.00, 2.67...
## $ V2  <dbl> 1.5, 2.0, 4.5, 2.0, 1.0, 3.0, 1.5, 3.5, 3.5, 3.5, 2.5, 1.5...
## $ V3  <dbl> 3.33, 2.67, 4.00, 3.00, 5.00, 4.33, 2.33, 2.67, 3.00, 3.67...
## $ V4  <dbl> 3.0, 3.0, 5.0, 3.0, 5.0, 3.0, 2.5, 1.5, 3.0, 2.0, 4.0, 1.5...
## $ V5  <dbl> 2.33, 4.00, 5.33, 3.67, 3.00, 3.33, 3.00, 2.00, 4.00, 3.33...
## $ V6  <dbl> 2.0, 2.5, 5.0, 3.0, 1.5, 4.5, 3.0, 1.5, 3.0, 2.0, 2.5, 1.0...
## $ V7  <dbl> 3.33, 3.00, 3.33, 3.33, 2.67, 3.67, 2.67, 3.00, 2.67, 4.00...
## $ V8  <dbl> 3.67, 3.33, 2.67, 3.33, 2.67, 2.67, 3.33, 2.67, 2.53, 3.00...
## $ V9  <dbl> 4.00, 3.33, 3.00, 3.33, 3.33, 3.67, 3.33, 3.33, 2.97, 3.00...
## $ V10 <dbl> 4.00, 2.50, 2.50, 3.00, 4.00, 3.50, 3.50, 4.00, 3.35, 2.50...
## $ V11 <dbl> 5.33, 4.67, 3.67, 4.67, 4.33, 3.67, 5.33, 3.67, 3.00, 4.67...
## $ V12 <dbl> 5.0, 5.0, 3.5, 5.0, 3.0, 1.5, 5.0, 3.0, 3.5, 5.5, 5.5, 5.0...
## $ V13 <dbl> 5.67, 2.33, 3.00, 4.67, 4.00, 2.67, 5.67, 5.00, 5.33, 4.67...
## $ V14 <dbl> 5.5, 3.5, 4.5, 5.0, 1.5, 1.0, 6.0, 5.0, 4.5, 4.5, 5.0, 5.5...
## $ V15 <dbl> 5.67, 5.00, 3.67, 4.67, 5.33, 3.33, 5.00, 4.00, 4.67, 5.33...
## $ V16 <dbl> 5.5, 5.0, 3.5, 4.5, 5.5, 5.5, 5.0, 3.5, 5.0, 4.5, 4.5, 5.0...
## $ V17 <dbl> 3.33, 4.00, 3.67, 3.67, 4.00, 3.67, 4.00, 4.00, 4.00, 4.00...
## $ V18 <dbl> 3.00, 4.00, 3.75, 3.50, 3.75, 4.00, 4.00, 3.25, 3.75, 4.00...
## $ V19 <dbl> 3.00, 4.00, 3.67, 4.00, 3.00, 3.00, 3.67, 3.33, 3.67, 4.00...
## $ V20 <dbl> 3.2, 2.6, 2.6, 2.8, 4.0, 1.8, 2.8, 2.4, 2.4, 2.4, 2.0, 3.4...
## $ V21 <dbl> 3.50, 2.00, 2.75, 3.25, 4.25, 3.25, 2.25, 4.00, 2.75, 2.25...
## $ V22 <dbl> 2.6, 2.8, 2.4, 3.4, 4.0, 2.4, 2.2, 2.6, 2.6, 2.4, 2.8, 2.4...
## $ V23 <dbl> 3.25, 1.75, 2.50, 2.75, 3.75, 1.75, 2.00, 2.50, 2.00, 1.75...
## $ V24 <dbl> 2.60, 2.00, 2.80, 2.60, 3.00, 2.20, 1.60, 2.80, 1.80, 1.80...
## $ V25 <dbl> 3.67, 3.33, 5.67, 5.00, 2.67, 2.33, 4.67, 2.00, 4.33, 3.00...
## $ V26 <dbl> 3.67, 4.00, 4.67, 3.67, 3.00, 3.33, 3.33, 2.67, 4.67, 3.33...
## $ V27 <dbl> 1.67, 3.00, 5.67, 3.00, 2.00, 2.00, 2.33, 2.67, 3.67, 2.33...
## $ V28 <dbl> 2.00, 2.33, 1.67, 2.00, 3.00, 2.67, 1.67, 2.33, 2.00, 1.00...
## $ V29 <dbl> 1.5, 3.0, 1.5, 1.5, 1.5, 3.5, 1.5, 1.5, 1.5, 2.0, 1.5, 1.0...
## $ V30 <dbl> 6.33, 6.00, 5.67, 5.33, 5.33, 6.00, 6.33, 5.67, 4.67, 7.00...
## $ V31 <dbl> 6.5, 5.0, 5.5, 5.5, 5.5, 6.0, 6.5, 6.0, 5.5, 6.5, 6.5, 7.0...
## $ V32 <dbl> 6.33, 5.33, 5.33, 5.33, 5.33, 5.33, 7.00, 6.00, 5.00, 5.00...
```

The dataset has 1,430 observations (sample of secondary teachers) of 32 unidimensional indicator variables and is carefully grouped according to content.

Creating names for all the variables

```
names(alsec) <- c("ROLEA1", "ROLEA2", "ROLEC1", "ROLEC2", "WORK1", "WORK2", "CCLIM1", "CCLIM2", "CCLIM3

str(alsec)
```

```
## 'data.frame':    1430 obs. of  32 variables:
##  $ ROLEA1: num  1.33 2.33 3.33 2 3 2.67 1.67 2 4 2.67 ...
##  $ ROLEA2: num  1.5 2 4.5 2 1 3 1.5 3.5 3.5 3.5 ...
##  $ ROLEC1: num  3.33 2.67 4 3 5 4.33 2.33 2.67 3 3.67 ...
##  $ ROLEC2: num  3 3 5 3 5 3 2.5 1.5 3 2 ...
##  $ WORK1 : num  2.33 4 5.33 3.67 3 3.33 3 2 4 3.33 ...
##  $ WORK2 : num  2 2.5 5 3 1.5 4.5 3 1.5 3 2 ...
##  $ CCLIM1: num  3.33 3 3.33 3.33 2.67 3.67 2.67 3 2.67 4 ...
##  $ CCLIM2: num  3.67 3.33 2.67 3.33 2.67 2.67 3.33 2.67 2.53 3 ...
##  $ CCLIM3: num  4 3.33 3 3.33 3.33 3.67 3.33 3.33 2.97 3 ...
##  $ CCLIM4: num  4 2.5 2.5 3 4 3.5 3.5 4 3.35 2.5 ...
##  $ DEC1  : num  5.33 4.67 3.67 4.67 4.33 3.67 5.33 3.67 3 4.67 ...
##  $ DEC2  : num  5 5 3.5 5 3 1.5 5 3 3.5 5.5 ...
##  $ SSUP1 : num  5.67 2.33 3 4.67 4 2.67 5.67 5 5.33 4.67 ...
##  $ SSUP2 : num  5.5 3.5 4.5 5 1.5 1 6 5 4.5 4.5 ...
##  $ PSUP1 : num  5.67 5 3.67 4.67 5.33 3.33 5 4 4.67 5.33 ...
##  $ PSUP2 : num  5.5 5 3.5 4.5 5.5 5.5 5 3.5 5 4.5 ...
##  $ SELF1 : num  3.33 4 3.67 3.67 4 3.67 4 4 4 4 ...
##  $ SELF2 : num  3 4 3.75 3.5 3.75 4 4 3.25 3.75 4 ...
##  $ SELF3 : num  3 4 3.67 4 3 3 3.67 3.33 3.67 4 ...
##  $ ELC1  : num  3.2 2.6 2.6 2.8 4 1.8 2.8 2.4 2.4 2.4 ...
##  $ ELC2  : num  3.5 2 2.75 3.25 4.25 3.25 2.25 4 2.75 2.25 ...
##  $ ELC3  : num  2.6 2.8 2.4 3.4 4 2.4 2.2 2.6 2.6 2.4 ...
##  $ ELC4  : num  3.25 1.75 2.5 2.75 3.75 1.75 2 2.5 2 1.75 ...
##  $ ELC5  : num  2.6 2 2.8 2.6 3 2.2 1.6 2.8 1.8 1.8 ...
##  $ EE1   : num  3.67 3.33 5.67 5 2.67 2.33 4.67 2 4.33 3 ...
##  $ EE2   : num  3.67 4 4.67 3.67 3 3.33 3.33 2.67 4.67 3.33 ...
##  $ EE3   : num  1.67 3 5.67 3 2 2 2.33 2.67 3.67 2.33 ...
##  $ DP1   : num  2 2.33 1.67 2 3 2.67 1.67 2.33 2 1 ...
##  $ DP2   : num  1.5 3 1.5 1.5 1.5 3.5 1.5 1.5 1.5 2 ...
##  $ PA1   : num  6.33 6 5.67 5.33 5.33 6 6.33 5.67 4.67 7 ...
##  $ PA2   : num  6.5 5 5.5 5.5 5.5 6 6.5 6 5.5 6.5 ...
##  $ PA3   : num  6.33 5.33 5.33 5.33 5.33 5.33 7 6 5 5 ...
```

As mentioned in the lecture material and proposed structural model of teacher burnout:

The Teacher Stress Scale has six subscales designed to measure Role Ambiguity, Role Conflict, Work Overload, Decision Making, Superior Support, and Peer Support. The MBI consists of three subscales designed to measure three facets of burnout : Emotional Exhaustion, Depersonalization and Personal Accomplishment.

The aim of this analysis is to test the validity of a causal structure. The subject is the impact of organizational and personality variables on three conceptually distinct factors of burnout i.e. Emotional Exhaustion (EE), Depersonalization (DP), Personal Accomplishment (PA). This is a single-group analyses of SEM.

EE is the central facet to different stressor in the teacher's work environment. As shown in the model paths, EE hypothesized to positively impact DP but negatively impact PA. DP hypothesized to have negative imapct on PA.

The independent latent variables are F1 - F7 and the dependent latent variables are F8 - F12.

Specifying model 1

```r
model1 <- '
 F1 =~ ROLEA1 + ROLEA2 + DEC2
 F2 =~ ROLEC1 + ROLEC2
 F3 =~ WORK1 + WORK2
 F4 =~ CCLIM1 + CCLIM2 + CCLIM3 + CCLIM4
 F5 =~ DEC1 + DEC2
 F6 =~ SSUP1 + SSUP2 + DEC2
 F7 =~ PSUP1 + PSUP2
 F8 =~ SELF1 + SELF2 + SELF3
 F9 =~ ELC1 + ELC2 + ELC3 + ELC4 + ELC5
 F10 =~ EE1 + EE2 + EE3
 F11 =~ DP1 + DP2
 F12 =~ PA1 + PA2 + PA3

  F8  ~  F5 + F6 + F7
  F9  ~  F5
  F10  ~ F2 +  F3 + F4
  F11  ~ F2 + F10
  F12  ~  F1 + F8 + F9 + F10 + F11
  '
```

Fitting the model

```r
fit1 <- sem(model1, data=alsec, estimator = "MLM")
```

```
## Warning in lav_object_post_check(object): lavaan WARNING: some estimated lv
## variances are negative
```

Display summary output

```r
summary(fit1, fit.measures=FALSE)
```

```
## lavaan 0.6-3 ended normally after 199 iterations
##
##   Optimization method                           NLMINB
##   Number of free parameters                        101
##
##   Number of observations                          1430
##
##   Estimator                                         ML      Robust
##   Model Fit Test Statistic                    1737.090    1541.844
##   Degrees of freedom                               427         427
##   P-value (Chi-square)                           0.000       0.000
##   Scaling correction factor                                  1.127
##     for the Satorra-Bentler correction
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard Errors                           Robust.sem
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   F1 =~
##     ROLEA1            1.000
```

```
##     ROLEA2            1.238    0.058   21.499    0.000
##     DEC2              0.229    0.089    2.579    0.010
##   F2 =~
##     ROLEC1            1.000
##     ROLEC2            1.308    0.053   24.767    0.000
##   F3 =~
##     WORK1             1.000
##     WORK2             0.749    0.032   23.203    0.000
##   F4 =~
##     CCLIM1            1.000
##     CCLIM2            1.478    0.077   19.254    0.000
##     CCLIM3            0.958    0.056   17.114    0.000
##     CCLIM4            1.334    0.080   16.764    0.000
##   F5 =~
##     DEC1              1.000
##     DEC2              0.407    0.106    3.852    0.000
##   F6 =~
##     SSUP1             1.000
##     SSUP2             1.098    0.026   42.261    0.000
##     DEC2              0.859    0.049   17.574    0.000
##   F7 =~
##     PSUP1             1.000
##     PSUP2             1.079    0.046   23.684    0.000
##   F8 =~
##     SELF1             1.000
##     SELF2             1.278    0.045   28.157    0.000
##     SELF3             1.357    0.057   23.744    0.000
##   F9 =~
##     ELC1              1.000
##     ELC2              0.848    0.042   20.398    0.000
##     ELC3              0.944    0.041   23.153    0.000
##     ELC4              0.904    0.047   19.274    0.000
##     ELC5              1.110    0.050   22.388    0.000
##   F10 =~
##     EE1               1.000
##     EE2               1.020    0.019   53.503    0.000
##     EE3               0.973    0.023   43.048    0.000
##   F11 =~
##     DP1               1.000
##     DP2               0.918    0.046   20.022    0.000
##   F12 =~
##     PA1               1.000
##     PA2               1.039    0.038   27.420    0.000
##     PA3               0.963    0.040   23.869    0.000
##
## Regressions:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   F8 ~
##     F5                0.475    0.054    8.784    0.000
##     F6               -0.155    0.026   -5.890    0.000
##     F7               -0.066    0.030   -2.223    0.026
##   F9 ~
##     F5               -0.288    0.023  -12.787    0.000
##   F10 ~
```

```
##     F2                -8.707    6.705   -1.298    0.194
##     F3                 8.082    5.647    1.431    0.152
##     F4                -0.930    0.740   -1.257    0.209
##   F11 ~
##     F2                 0.258    0.054    4.789    0.000
##     F10                0.373    0.036   10.242    0.000
##   F12 ~
##     F1                -0.071    0.048   -1.474    0.140
##     F8                 0.472    0.090    5.245    0.000
##     F9                -0.208    0.052   -3.975    0.000
##     F10               -0.064    0.026   -2.416    0.016
##     F11               -0.218    0.033   -6.556    0.000
##
## Covariances:
##                   Estimate  Std.Err  z-value  P(>|z|)
##   F1 ~~
##     F2                 0.360    0.025   14.389    0.000
##     F3                 0.419    0.027   15.239    0.000
##     F4                -0.065    0.008   -7.755    0.000
##     F5                -0.373    0.026  -14.497    0.000
##     F6                -0.386    0.030  -12.736    0.000
##     F7                -0.242    0.022  -10.976    0.000
##   F2 ~~
##     F3                 0.666    0.035   19.038    0.000
##     F4                -0.086    0.011   -8.092    0.000
##     F5                -0.407    0.028  -14.530    0.000
##     F6                -0.429    0.032  -13.235    0.000
##     F7                -0.234    0.023  -10.351    0.000
##   F3 ~~
##     F4                -0.097    0.013   -7.504    0.000
##     F5                -0.491    0.030  -16.117    0.000
##     F6                -0.501    0.035  -14.309    0.000
##     F7                -0.277    0.026  -10.790    0.000
##   F4 ~~
##     F5                 0.100    0.011    9.329    0.000
##     F6                 0.120    0.014    8.728    0.000
##     F7                 0.055    0.009    5.897    0.000
##   F5 ~~
##     F6                 0.616    0.038   16.239    0.000
##     F7                 0.385    0.028   13.835    0.000
##   F6 ~~
##     F7                 0.394    0.032   12.431    0.000
##
## Variances:
##                   Estimate  Std.Err  z-value  P(>|z|)
##    .ROLEA1             0.422    0.024   17.386    0.000
##    .ROLEA2             0.313    0.027   11.556    0.000
##    .DEC2               0.598    0.033   18.016    0.000
##    .ROLEC1             0.642    0.029   22.304    0.000
##    .ROLEC2             0.546    0.037   14.798    0.000
##    .WORK1              0.646    0.030   21.317    0.000
##    .WORK2              0.739    0.035   20.903    0.000
##    .CCLIM1             0.180    0.008   22.588    0.000
##    .CCLIM2             0.151    0.010   14.874    0.000
```

```
##    .CCLIM3           0.141    0.007   19.356    0.000
##    .CCLIM4           0.337    0.015   21.843    0.000
##    .DEC1             0.515    0.027   19.233    0.000
##    .SSUP1            0.398    0.026   15.205    0.000
##    .SSUP2            0.200    0.022    8.898    0.000
##    .PSUP1            0.336    0.027   12.238    0.000
##    .PSUP2            0.164    0.026    6.287    0.000
##    .SELF1            0.082    0.005   16.563    0.000
##    .SELF2            0.065    0.005   13.033    0.000
##    .SELF3            0.083    0.006   13.021    0.000
##    .ELC1             0.204    0.010   20.506    0.000
##    .ELC2             0.259    0.011   23.326    0.000
##    .ELC3             0.135    0.007   18.174    0.000
##    .ELC4             0.215    0.010   21.720    0.000
##    .ELC5             0.187    0.010   18.595    0.000
##    .EE1              0.413    0.024   17.250    0.000
##    .EE2              0.225    0.019   11.753    0.000
##    .EE3              0.449    0.025   17.799    0.000
##    .DP1              0.278    0.045    6.144    0.000
##    .DP2              0.622    0.049   12.655    0.000
##    .PA1              0.270    0.022   12.414    0.000
##    .PA2              0.319    0.025   12.783    0.000
##    .PA3              0.407    0.024   17.000    0.000
##     F1               0.413    0.033   12.434    0.000
##     F2               0.571    0.041   13.843    0.000
##     F3               0.797    0.047   16.926    0.000
##     F4               0.112    0.010   10.732    0.000
##     F5               0.504    0.038   13.435    0.000
##     F6               1.151    0.061   18.983    0.000
##     F7               0.595    0.043   13.894    0.000
##    .F8               0.079    0.008    9.693    0.000
##    .F9               0.143    0.012   12.447    0.000
##    .F10             -0.432    0.816   -0.530    0.596
##    .F11              0.605    0.053   11.482    0.000
##    .F12              0.383    0.025   15.337    0.000
```

```r
fitMeasures(fit1, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.robust", "rmsea.robu
```

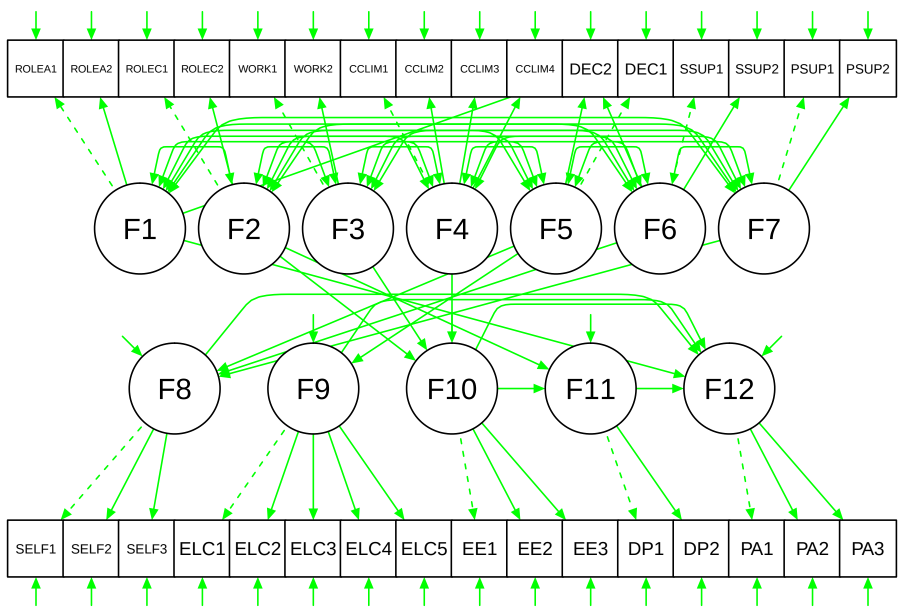
```
##   chisq.scaled     df.scaled pvalue.scaled    cfi.robust    tli.robust
##       1541.844       427.000         0.000         0.945         0.936
##   rmsea.robust          srmr
##          0.045         0.053
```

The non-significant parameters are F10 (Emotional Exhaustion) on F2 (Role Conflict), F10 (Emotional Exhaustion) on F3 (Work Overload), F10 (Emotional Exhaustion) on F4 (Classroom Climate) and F12 (Personal Accomplishment) on F1 (Role Ambiguity). In the final model, all parameters should be statistically significant.

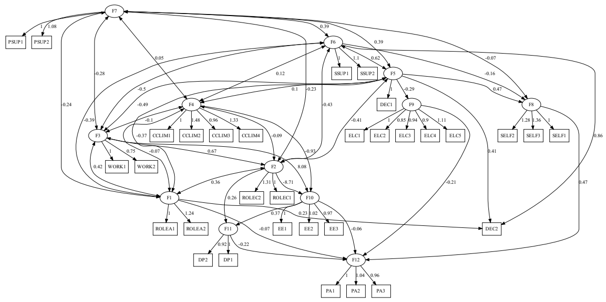
The MLM estimator is used to have robust standard errors and a scaled test statistic. The Satorra-Bentler correction is 1.127. The x2 is 1541.844, with 427 degrees of freedom. The p-value is 0.000. The CFI (0.940) and TLI (0.930) values are more than the acceptable value (> 0.9). The value of RMSEA and SRMR is 0.043 (90%CI from 0.041 to 0.045) and 0.053 respectively and it should be <0.08. The model seems to have sound fit.

Creating graph

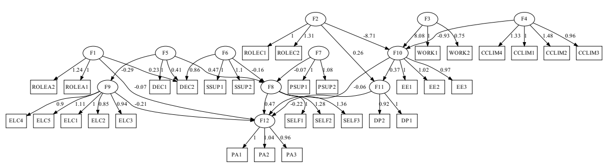
```r
labels = list(F1 = "Role Ambiguity", F2 = " Role Conflict", F3 = " Work Overload", F4 = " Classroom Cli

# standardized path

semPaths(fit1, curvePivot = TRUE, style = "lisrel", edge.label.cex=0.75, edge.color="green")
```




```r
lavaanPlot(model = fit1, coefs = TRUE, covs = TRUE, stars = TRUE)
```



```r
# unstandardized path
lavaanPlot(model = fit1, coefs = TRUE, stand = FALSE)
```



Exercise 4.2 & 4.3

Aim: to modify the model in a sound and responsible manner (step by step)

Model Modification

Model 2

Model Modification indices for model 2

```
mi <- modindices(fit1, minimum.value = 60, sort. = TRUE)
mi[mi$op == "~",]
```

```
##       lhs op rhs      mi    epc sepc.lv sepc.all sepc.nox
## 1038 F11  ~   F4 112.597 -0.974  -0.339   -0.339   -0.339
## 1104  F4  ~ F11  90.818 -0.141  -0.404   -0.404   -0.404
## 1037 F11  ~   F3  85.322 -4.799  -4.467   -4.467   -4.467
```

The largest MI (113) for the regression associates with F11 on F4 (Depersonalization on Classroom Climate) and hence, included in the model. The EPC is -0.974.

Re-specifying model

```
model2 <- '
 F1 =~ ROLEA1 + ROLEA2 + DEC2
 F2 =~ ROLEC1 + ROLEC2
 F3 =~ WORK1 + WORK2
 F4 =~ CCLIM1 + CCLIM2 + CCLIM3 + CCLIM4
 F5 =~ DEC1 + DEC2
 F6 =~ SSUP1 + SSUP2 + DEC2
 F7 =~ PSUP1 + PSUP2
 F8 =~ SELF1 + SELF2 + SELF3
 F9 =~ ELC1 + ELC2 + ELC3 + ELC4 + ELC5
 F10 =~ EE1 + EE2 + EE3
 F11 =~ DP1 + DP2
 F12 =~ PA1 + PA2 + PA3

  F8  ~  F5 + F6 + F7
  F9  ~  F5
  F10  ~ F2 +  F3 + F4
  F11  ~ F2 + F4 + F10
  F12  ~  F1 + F8 + F9 + F10 + F11
  '
```

Fitting the model

```
fit2 <- sem(model2, data=alsec, estimator = "MLM")
```

```
## Warning in lav_object_post_check(object): lavaan WARNING: some estimated lv
## variances are negative
```

Display summary output

```
fitMeasures(fit2, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.robust", "rmsea.robu
```

```
##  chisq.scaled     df.scaled pvalue.scaled    cfi.robust    tli.robust
##      1440.864       426.000         0.000         0.950         0.942
##  rmsea.robust          srmr
##         0.043         0.048
```

The x2 is 1440.86, with 426 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.950 and 0.942 respectively. The value of RMSEA and SRMR indices are 0.043 and 0.048 respectively.

Comparison of model 1 and 2

```r
options(scipen=999)
compareFit(fit1,fit2, nested = FALSE)
```

```
## ####################### Model Fit Indices ###########################
##      chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust        aic
## fit2    1440.864†       426          .000      .950†      .942† 94567.591†
## fit1    1541.844        427          .000      .945       .936  94682.256
##              bic rmsea.robust  srmr
## fit2 95104.665†        .043† .048†
## fit1 95214.064         .045  .053
```

```r
anova(fit1,fit2)
```

```
## Scaled Chi Square Difference Test (method = "satorra.bentler.2001")
##
##       Df   AIC   BIC  Chisq Chisq diff Df diff          Pr(>Chisq)
## fit2 426 94568 95105 1620.4
## fit1 427 94682 95214 1737.1     58.818       1 0.00000000000001729 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The model has improved as compared to the previous model. The chi-square difference test is statistically significant with 1 df indicating the addition of non-significant parameters appropriate.

Model 3

The warning message (negative variance) is still there in the previous model and to determine the best fitting model which includes only significant structural paths and remove all unsignificant paths, post hoc analysis will be continued with model 3.

Model Modification indices for model 3

```r
mi1 <- modindices(fit2, minimum.value = 40, sort. = TRUE)
mi1[mi1$op == "~",]
```

```
##      lhs op rhs     mi    epc sepc.lv sepc.all sepc.nox
## 1009  F8  ~ F12 49.856  0.330   0.720    0.720    0.720
## 1058  F6  ~  F9 48.895  0.530   0.213    0.213    0.213
## 1040 F12  ~  F5 47.087  0.480   0.458    0.458    0.458
## 1024 F10  ~  F8 42.769 -1.029  -0.306   -0.306   -0.306
## 1014  F9  ~  F8 42.452 -0.295  -0.234   -0.234   -0.234
```

The largest MI (50) for the regression associates with F8 on F12. But according to Byrne, F12 ON F5 with MI (47) is the most appropriate both substantially and statistically and is included in model 3. It makes sense as participation of teachers in decision making (F5) raise the sense of personal accomplishment (F12)

Re-specifying model 3

```r
model3 <- '
 F1 =~ ROLEA1 + ROLEA2 + DEC2
 F2 =~ ROLEC1 + ROLEC2
 F3 =~ WORK1 + WORK2
 F4 =~ CCLIM1 + CCLIM2 + CCLIM3 + CCLIM4
 F5 =~ DEC1 + DEC2
 F6 =~ SSUP1 + SSUP2 + DEC2
 F7 =~ PSUP1 + PSUP2
 F8 =~ SELF1 + SELF2 + SELF3
 F9 =~ ELC1 + ELC2 + ELC3 + ELC4 + ELC5
```

```
F10 =~ EE1 + EE2 + EE3
F11 =~ DP1 + DP2
F12 =~ PA1 + PA2 + PA3

 F8  ~  F5 + F6 + F7
 F9  ~  F5
 F10  ~ F2 +  F3 + F4
 F11  ~ F2 + F4 + F10
 F12  ~  F1 + F5 + F8 + F9 + F10 + F11
 '
```

Fitting the model

```
fit3 <- sem(model3, data=alsec, estimator = "MLM")
```

```
## Warning in lav_object_post_check(object): lavaan WARNING: some estimated lv
## variances are negative
```

Display summary output

```
 fitMeasures(fit3, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.robust", "rmsea.rol
```

```
##   chisq.scaled     df.scaled pvalue.scaled    cfi.robust    tli.robust
##       1396.527       425.000         0.000         0.952         0.944
##   rmsea.robust          srmr
##          0.042         0.045
```

The x2 is 1396.527, with 425 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.952 and 0.944 respectively. The value of RMSEA and SRMR indices are 0.042 and 0.045 respectively.

Comparison of model 1, 2 and 3

```
options(scipen=999)
compareFit(fit1, fit2, fit3, nested = FALSE)
```

```
## ####################### Model Fit Indices ###########################
##      chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust        aic
## fit3    1396.527†       425          .000      .952†      .944† 94520.133†
## fit2    1440.864        426          .000      .950       .942  94567.591
## fit1    1541.844        427          .000      .945       .936  94682.256
##              bic rmsea.robust  srmr
## fit3 95062.473†        .042† .045†
## fit2 95104.665         .043  .048
## fit1 95214.064         .045  .053
```

```
anova(fit2, fit3)
```

```
## Scaled Chi Square Difference Test (method = "satorra.bentler.2001")
##
##       Df   AIC   BIC  Chisq Chisq diff Df diff        Pr(>Chisq)
## fit3 425 94520 95062 1571.0
## fit2 426 94568 95105 1620.4     49.398       1 0.000000000002089 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The chi-square difference test is statistically significant with 1 df indicating the addition of non-significant parameters appropriate.

Model 4

The warning message (negative variance) is still there in the model 3.

Model Modification indices for model 4

```
mi2 <- modindices(fit3, minimum.value = 30, sort. = TRUE)
mi2[mi2$op == "~",]
```

```
##       lhs op rhs     mi    epc sepc.lv sepc.all sepc.nox
## 1058  F6  ~  F9 48.571  0.523   0.210    0.210    0.210
## 1025 F10  ~  F8 43.412 -1.021  -0.304   -0.304   -0.304
## 1021  F9  ~  F2 41.343  0.191   0.336    0.336    0.336
## 1015  F9  ~  F8 39.841 -0.284  -0.225   -0.225   -0.225
## 1010  F8  ~ F12 39.568  0.295   0.647    0.647    0.647
## 1090  F3  ~  F8 38.645 -0.172  -0.065   -0.065   -0.065
## 1022  F9  ~  F3 36.061  0.154   0.321    0.321    0.321
## 1079  F2  ~  F8 35.047  0.134   0.060    0.060    0.060
## 1008  F8  ~ F10 34.969 -0.116  -0.389   -0.389   -0.389
## 1019  F9  ~  F6 33.752  0.130   0.323    0.323    0.323
```

F9 ON F2is the most appropriate to include in model 4. F10 ON F8 and F9 ON F8 seems to have incorrect ???ow of causal direction according to the lecture material.

Re-specifying model 4

```
model4 <- '
 F1 =~ ROLEA1 + ROLEA2 + DEC2
 F2 =~ ROLEC1 + ROLEC2
 F3 =~ WORK1 + WORK2
 F4 =~ CCLIM1 + CCLIM2 + CCLIM3 + CCLIM4
 F5 =~ DEC1 + DEC2
 F6 =~ SSUP1 + SSUP2 + DEC2
 F7 =~ PSUP1 + PSUP2
 F8 =~ SELF1 + SELF2 + SELF3
 F9 =~ ELC1 + ELC2 + ELC3 + ELC4 + ELC5
 F10 =~ EE1 + EE2 + EE3
 F11 =~ DP1 + DP2
 F12 =~ PA1 + PA2 + PA3

  F8  ~  F5 + F6 + F7
  F9  ~  F2 + F5
  F10  ~ F2 +  F3 + F4
  F11  ~ F2 + F4 + F10
  F12  ~  F1 + F5 + F8 + F9 + F10 + F11
  '
```

Fitting the model

```
fit4 <- sem(model4, data=alsec, estimator = "MLM")
```

```
## Warning in lav_object_post_check(object): lavaan WARNING: some estimated lv
## variances are negative
```

Display summary output

```
fitMeasures(fit4, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.robust", "rmsea.robu
```

```
##   chisq.scaled     df.scaled pvalue.scaled    cfi.robust    tli.robust
##       1356.810       424.000         0.000         0.954         0.946
```

```
##  rmsea.robust          srmr
##         0.042         0.042
```

The x2 is 1356.810, with 424 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.954 and 0.946 respectively. The value of RMSEA and SRMR indices are 0.042 and 0.042 respectively.

Comparison of model 1, 2, 3 and 4

```
options(scipen=999)
compareFit(fit1, fit2, fit3, fit4, nested = FALSE)
```

```
## ###################### Model Fit Indices ###########################
##      chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust        aic
## fit4    1356.810†       424          .000      .954†      .946† 94477.933†
## fit3    1396.527        425          .000      .952       .944  94520.133
## fit2    1440.864        426          .000      .950       .942  94567.591
## fit1    1541.844        427          .000      .945       .936  94682.256
##             bic rmsea.robust  srmr
## fit4 95025.537†        .042† .042†
## fit3 95062.473         .042  .045
## fit2 95104.665         .043  .048
## fit1 95214.064         .045  .053
```

```
anova(fit3, fit4)
```

```
## Scaled Chi Square Difference Test (method = "satorra.bentler.2001")
##
##       Df   AIC   BIC  Chisq Chisq diff Df diff       Pr(>Chisq)
## fit4 424 94478 95026 1526.8
## fit3 425 94520 95062 1571.0     45.294       1 0.00000000001696 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The difference in fit between model 3 and model 4 is statistically significant.

Model 5

The warning message (negative variance) is still there in the model 4.

Model Modification indices for model 5

```
mi3 <- modindices(fit4, minimum.value = 30, sort. = TRUE)
mi3[mi3$op == "~",]
```

```
##      lhs op rhs     mi    epc sepc.lv sepc.all sepc.nox
## 1016  F9  ~  F8 38.685 -0.261  -0.208   -0.208   -0.208
## 1068  F7  ~  F8 38.309  3.764   1.659    1.659    1.659
## 1011  F8  ~ F12 37.408  0.302   0.662    0.662    0.662
## 1058  F6  ~  F9 33.241  0.418   0.166    0.166    0.166
## 1019  F9  ~ F12 30.392 -0.265  -0.464   -0.464   -0.464
```

F9 (External Locus of Control) ON F8 (Self-Esteem) is the most appropriate to include in model 5.

Re-specifying model 5

```
model5 <- '
 F1 =~ ROLEA1 + ROLEA2 + DEC2
 F2 =~ ROLEC1 + ROLEC2
 F3 =~ WORK1 + WORK2
 F4 =~ CCLIM1 + CCLIM2 + CCLIM3 + CCLIM4
```

```
F5 =~ DEC1 + DEC2
F6 =~ SSUP1 + SSUP2 + DEC2
F7 =~ PSUP1 + PSUP2
F8 =~ SELF1 + SELF2 + SELF3
F9 =~ ELC1 + ELC2 + ELC3 + ELC4 + ELC5
F10 =~ EE1 + EE2 + EE3
F11 =~ DP1 + DP2
F12 =~ PA1 + PA2 + PA3

 F8  ~  F5 + F6 + F7
 F9  ~  F2 + F5 + F8
 F10  ~ F2 +  F3 + F4
 F11  ~ F2 + F4 + F10
 F12  ~  F1 + F5 + F8 + F9 + F10 + F11
 '
```

Fitting the model

```
fit5 <- sem(model5, data=alsec, estimator = "MLM")

## Warning in lav_object_post_check(object): lavaan WARNING: some estimated lv
## variances are negative
```

Display summary output

```
fitMeasures(fit5, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.robust", "rmsea.robu

##  chisq.scaled     df.scaled pvalue.scaled    cfi.robust    tli.robust
##      1323.061       423.000         0.000         0.956         0.948
##  rmsea.robust          srmr
##         0.041         0.040
```

The x2 is 1323.061, with 423 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.956 and 0.948 respectively. The value of RMSEA and SRMR indices are 0.041 and 0.040 respectively.

Comparison of model 1, 2, 3, 4 and 5

```
options(scipen=999)
compareFit(fit1, fit2, fit3, fit4, fit5, nested = FALSE)

## ####################### Model Fit Indices ###########################
##      chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust        aic
## fit5    1323.061†       423          .000      .956†      .948† 94440.776†
## fit4    1356.810        424          .000      .954       .946  94477.933
## fit3    1396.527        425          .000      .952       .944  94520.133
## fit2    1440.864        426          .000      .950       .942  94567.591
## fit1    1541.844        427          .000      .945       .936  94682.256
##              bic rmsea.robust  srmr
## fit5 94993.646†        .041† .040†
## fit4 95025.537         .042  .042
## fit3 95062.473         .042  .045
## fit2 95104.665         .043  .048
## fit1 95214.064         .045  .053

anova(fit4, fit5)

## Scaled Chi Square Difference Test (method = "satorra.bentler.2001")
##
```

```
##       Df   AIC   BIC  Chisq Chisq diff Df diff   Pr(>Chisq)
## fit5 423 94441 94994 1487.6
## fit4 424 94478 95026 1526.8     26.059       1 0.0000003312 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The difference in fit between Model 5 and ModeL 4 is found to be statistically significant

Model 6

The warning message (negative variance) is still there in the model 5.

Model Modification indices for model 6

```r
mi4 <- modindices(fit5, minimum.value = 20, sort. = TRUE)
mi4[mi4$op == "~",]
```

```
##      lhs op rhs     mi    epc sepc.lv sepc.all sepc.nox
## 1068  F7  ~  F8 44.064  4.164   1.829    1.829    1.829
## 1057  F6  ~  F8 31.635  2.552   0.808    0.808    0.808
## 1025 F10  ~  F8 30.096 -1.068  -0.318   -0.318   -0.318
## 1011  F8  ~ F11 25.670 -0.066  -0.188   -0.188   -0.188
## 1090  F3  ~  F8 25.621 -0.175  -0.066   -0.066   -0.066
## 1016  F8  ~  F1 25.474  0.261   0.491    0.491    0.491
## 1033 F11  ~  F8 21.980 -0.404  -0.142   -0.142   -0.142
## 1079  F2  ~  F8 21.296  0.129   0.058    0.058    0.058
## 1012  F8  ~ F12 20.836  0.239   0.526    0.526    0.526
## 1010  F8  ~ F10 20.767 -0.121  -0.406   -0.406   -0.406
```

F10 (Emotional Exhaustion) ON F8 (Self-Esteem) with MI (30.096) and EPC (-1.068) is the most appropriate to include in model 6. High self-esteem acquaint less emotional exhaustion.

Re-specifying model

```r
model6 <- '
 F1 =~ ROLEA1 + ROLEA2 + DEC2
 F2 =~ ROLEC1 + ROLEC2
 F3 =~ WORK1 + WORK2
 F4 =~ CCLIM1 + CCLIM2 + CCLIM3 + CCLIM4
 F5 =~ DEC1 + DEC2
 F6 =~ SSUP1 + SSUP2 + DEC2
 F7 =~ PSUP1 + PSUP2
 F8 =~ SELF1 + SELF2 + SELF3
 F9 =~ ELC1 + ELC2 + ELC3 + ELC4 + ELC5
 F10 =~ EE1 + EE2 + EE3
 F11 =~ DP1 + DP2
 F12 =~ PA1 + PA2 + PA3

  F8  ~  F5 + F6 + F7
  F9  ~  F2 + F5 + F8
  F10  ~ F2 +  F3 + F4 + F8
  F11  ~ F2 + F4 + F10
  F12  ~  F1 + F5 + F8 + F9 + F10 + F11
  '
```

Fitting the model

```r
fit6 <- sem(model6, data=alsec, estimator = "MLM")
```

Display summary output

```r
fitMeasures(fit6, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.robust", "rmsea.robu
```

```
##   chisq.scaled     df.scaled pvalue.scaled    cfi.robust    tli.robust
##       1288.246       422.000         0.000         0.958         0.950
##   rmsea.robust          srmr
##          0.040         0.040
```

The x2 is 1288.246, with 422 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.958 and 0.950 respectively. The value of RMSEA and SRMR indices are 0.040 and 0.040 respectively.

Comparison of model 1, 2, 3, 4, 5 and 6

```r
options(scipen=999)
compareFit(fit1, fit2, fit3, fit4, fit5, fit6, nested = FALSE)
```

```
## ####################### Model Fit Indices ###########################
##      chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust        aic
## fit6    1288.246†       422          .000      .958†      .950† 94402.803†
## fit5    1323.061        423          .000      .956       .948  94440.776
## fit4    1356.810        424          .000      .954       .946  94477.933
## fit3    1396.527        425          .000      .952       .944  94520.133
## fit2    1440.864        426          .000      .950       .942  94567.591
## fit1    1541.844        427          .000      .945       .936  94682.256
##             bic rmsea.robust  srmr
## fit6 94960.938†        .040† .040
## fit5 94993.646         .041  .040†
## fit4 95025.537         .042  .042
## fit3 95062.473         .042  .045
## fit2 95104.665         .043  .048
## fit1 95214.064         .045  .053
```

```r
anova(fit5, fit6)
```

```
## Scaled Chi Square Difference Test (method = "satorra.bentler.2001")
##
##       Df   AIC   BIC  Chisq Chisq diff Df diff    Pr(>Chisq)
## fit6 422 94403 94961 1447.6
## fit5 423 94441 94994 1487.6     28.646       1 0.00000008691 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The difference in fit between Model 6 and ModeL 5 is found to be statistically significant.

Model 7

Model Modification indices for model 7

```r
mi5 <- modindices(fit6, minimum.value = 20, sort. = TRUE)
mi5[mi5$op == "~",]
```

```
##      lhs op rhs     mi    epc sepc.lv sepc.all sepc.nox
## 1012  F8  ~ F11 31.478 -0.076  -0.216   -0.216   -0.216
## 1043 F12  ~  F2 22.794  0.339   0.345    0.345    0.345
## 1033 F11  ~  F8 22.713 -0.409  -0.144   -0.144   -0.144
```

```
## 1044 F12  ~  F3 21.857  0.259   0.325    0.325    0.325
## 1039 F11  ~  F3 21.417 -0.937  -0.911   -0.911   -0.911
## 1093  F3  ~ F11 21.099 -0.190  -0.196   -0.196   -0.196
```

F12 (Personal Accomplishment) ON F2 (Role conflict) is the most appropriate to include in model 7.

Specifying model 7

```
model7 <- '
 F1 =~ ROLEA1 + ROLEA2 + DEC2
 F2 =~ ROLEC1 + ROLEC2
 F3 =~ WORK1 + WORK2
 F4 =~ CCLIM1 + CCLIM2 + CCLIM3 + CCLIM4
 F5 =~ DEC1 + DEC2
 F6 =~ SSUP1 + SSUP2 + DEC2
 F7 =~ PSUP1 + PSUP2
 F8 =~ SELF1 + SELF2 + SELF3
 F9 =~ ELC1 + ELC2 + ELC3 + ELC4 + ELC5
 F10 =~ EE1 + EE2 + EE3
 F11 =~ DP1 + DP2
 F12 =~ PA1 + PA2 + PA3

  F8  ~  F5 + F6 + F7
  F9  ~  F2 + F5 + F8
  F10  ~ F2 +  F3 + F4 + F8
  F11  ~ F2 + F4 + F10
  F12  ~  F1 + F2 + F5 + F8 + F9 + F10 + F11
  '
```

Fitting the model

```
fit7 <- sem(model7, data=alsec, estimator = "MLM")
```

Display summary output

```
fitMeasures(fit7, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.robust", "rmsea.robu
```

```
##   chisq.scaled     df.scaled pvalue.scaled    cfi.robust    tli.robust
##       1267.581       421.000         0.000         0.958         0.951
##   rmsea.robust          srmr
##          0.040         0.039
```

The x2 is 1267.581, with 421 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.958 and 0.951 respectively. The value of RMSEA and SRMR indices are 0.040 and 0.039 respectively.

Comparison of model 1, 2, 3, 4, 5, 6 and 7

```
options(scipen=999)
compareFit(fit1, fit2, fit3, fit4, fit5, fit6, fit7, nested = FALSE)
```

```
## ####################### Model Fit Indices ###########################
##      chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust        aic
## fit7    1267.581†       421          .000      .958†      .951† 94381.519†
## fit6    1288.246        422          .000      .958       .950  94402.803
## fit5    1323.061        423          .000      .956       .948  94440.776
## fit4    1356.810        424          .000      .954       .946  94477.933
## fit3    1396.527        425          .000      .952       .944  94520.133
## fit2    1440.864        426          .000      .950       .942  94567.591
## fit1    1541.844        427          .000      .945       .936  94682.256
```

```
##             bic rmsea.robust  srmr
## fit7 94944.920†        .040† .039†
## fit6 94960.938         .040  .040
## fit5 94993.646         .041  .040
## fit4 95025.537         .042  .042
## fit3 95062.473         .042  .045
## fit2 95104.665         .043  .048
## fit1 95214.064         .045  .053
```

```
anova(fit6, fit7)
```

```
## Scaled Chi Square Difference Test (method = "satorra.bentler.2001")
##
##       Df   AIC   BIC  Chisq Chisq diff Df diff  Pr(>Chisq)
## fit7 421 94382 94945 1424.4
## fit6 422 94403 94961 1447.6     20.346       1 0.000006463 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The difference in fit between Model 7 and ModeL 6 is found to be statistically significant.

Final Model

Identification of all paths in the hypothesized model that remain statistically non-significant till the results of model 7 are F8 ON F7 and F12 ON F1 and will be excluded in the final model.

Specifying final model

```
model8 <- '
 F1 =~ ROLEA1 + ROLEA2 + DEC2
 F2 =~ ROLEC1 + ROLEC2
 F3 =~ WORK1 + WORK2
 F4 =~ CCLIM1 + CCLIM2 + CCLIM3 + CCLIM4
 F5 =~ DEC1 + DEC2
 F6 =~ SSUP1 + SSUP2 + DEC2
 F7 =~ PSUP1 + PSUP2
 F8 =~ SELF1 + SELF2 + SELF3
 F9 =~ ELC1 + ELC2 + ELC3 + ELC4 + ELC5
 F10 =~ EE1 + EE2 + EE3
 F11 =~ DP1 + DP2
 F12 =~ PA1 + PA2 + PA3

  F8  ~  F5 + F6
  F9  ~  F2 + F5 + F8
  F10  ~ F2 +  F3 + F4 + F8
  F11  ~ F2 + F4 + F10
  F12  ~ F2 + F5 + F8 + F9 + F10 + F11
  '
```

Fitting the model

```
fit8 <- sem(model8, data=alsec, estimator = "MLM", std.ov=TRUE)
```

Display summary output

```
summary(fit8, fit.measures=FALSE, standardized = TRUE)
```

```
## lavaan 0.6-3 ended normally after 93 iterations
```

```
##
##   Optimization method                           NLMINB
##   Number of free parameters                        105
##
##   Number of observations                          1430
##
##   Estimator                                         ML      Robust
##   Model Fit Test Statistic                    1425.779    1268.075
##   Degrees of freedom                               423         423
##   P-value (Chi-square)                           0.000       0.000
##   Scaling correction factor                                 1.124
##     for the Satorra-Bentler correction
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard Errors                           Robust.sem
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   F1 =~
##     ROLEA1            1.000                               0.704    0.704
##     ROLEA2            1.159    0.054   21.545    0.000    0.816    0.816
##     DEC2              0.258    0.080    3.210    0.001    0.182    0.182
##   F2 =~
##     ROLEC1            1.000                               0.698    0.698
##     ROLEC2            1.130    0.044   25.495    0.000    0.788    0.789
##   F3 =~
##     WORK1             1.000                               0.792    0.792
##     WORK2             0.793    0.035   22.587    0.000    0.629    0.629
##   F4 =~
##     CCLIM1            1.000                               0.618    0.618
##     CCLIM2            1.274    0.065   19.675    0.000    0.787    0.787
##     CCLIM3            1.052    0.061   17.351    0.000    0.650    0.650
##     CCLIM4            0.980    0.058   16.796    0.000    0.605    0.605
##   F5 =~
##     DEC1              1.000                               0.726    0.726
##     DEC2              0.473    0.115    4.123    0.000    0.343    0.344
##   F6 =~
##     SSUP1             1.000                               0.862    0.863
##     SSUP2             1.084    0.026   42.343    0.000    0.935    0.935
##     DEC2              0.729    0.057   12.847    0.000    0.629    0.629
##   F7 =~
##     PSUP1             1.000                               0.798    0.799
##     PSUP2             1.128    0.048   23.468    0.000    0.900    0.901
##   F8 =~
##     SELF1             1.000                               0.764    0.765
##     SELF2             1.127    0.040   28.076    0.000    0.861    0.862
##     SELF3             1.110    0.047   23.691    0.000    0.849    0.849
##   F9 =~
##     ELC1              1.000                               0.682    0.683
##     ELC2              0.844    0.042   20.287    0.000    0.575    0.576
##     ELC3              1.087    0.047   23.216    0.000    0.741    0.742
```

```
##     ELC4              0.947    0.049   19.184    0.000    0.646    0.646
##     ELC5              1.095    0.049   22.485    0.000    0.747    0.748
##   F10 =~
##     EE1               1.000                               0.869    0.871
##     EE2               1.063    0.020   53.246    0.000    0.924    0.927
##     EE3               0.981    0.023   42.735    0.000    0.853    0.855
##   F11 =~
##     DP1               1.000                               0.884    0.885
##     DP2               0.830    0.039   21.281    0.000    0.733    0.734
##   F12 =~
##     PA1               1.000                               0.821    0.825
##     PA2               0.974    0.035   27.677    0.000    0.800    0.804
##     PA3               0.905    0.038   24.110    0.000    0.743    0.746
##
## Regressions:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   F8 ~
##     F5                0.787    0.097    8.105    0.000    0.748    0.748
##     F6               -0.329    0.071   -4.664    0.000   -0.371   -0.371
##   F9 ~
##     F2                0.292    0.054    5.436    0.000    0.299    0.299
##     F5               -0.131    0.054   -2.403    0.016   -0.139   -0.139
##     F8               -0.180    0.035   -5.149    0.000   -0.201   -0.201
##   F10 ~
##     F2               -0.723    0.275   -2.632    0.008   -0.581   -0.581
##     F3                1.190    0.254    4.690    0.000    1.085    1.085
##     F4               -0.223    0.051   -4.398    0.000   -0.158   -0.158
##     F8               -0.307    0.037   -8.290    0.000   -0.270   -0.270
##   F11 ~
##     F2                0.177    0.051    3.466    0.001    0.140    0.140
##     F4               -0.465    0.052   -8.916    0.000   -0.325   -0.325
##     F10               0.362    0.041    8.794    0.000    0.356    0.356
##   F12 ~
##     F2                0.449    0.079    5.655    0.000    0.382    0.382
##     F5                0.506    0.068    7.389    0.000    0.448    0.448
##     F8                0.186    0.045    4.184    0.000    0.174    0.174
##     F9               -0.145    0.041   -3.514    0.000   -0.120   -0.120
##     F10              -0.122    0.042   -2.880    0.004   -0.129   -0.129
##     F11              -0.255    0.039   -6.483    0.000   -0.275   -0.275
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##   F1 ~~
##     F2                0.382    0.026   14.780    0.000    0.777    0.777
##     F3                0.366    0.026   14.278    0.000    0.657    0.657
##     F4               -0.131    0.017   -7.745    0.000   -0.302   -0.302
##     F5               -0.419    0.028  -14.789    0.000   -0.819   -0.819
##     F6               -0.337    0.027  -12.641    0.000   -0.555   -0.555
##     F7               -0.274    0.025  -10.947    0.000   -0.488   -0.488
##   F2 ~~
##     F3                0.512    0.026   19.347    0.000    0.926    0.926
##     F4               -0.137    0.018   -7.729    0.000   -0.317   -0.317
##     F5               -0.386    0.026  -14.879    0.000   -0.762   -0.762
##     F6               -0.323    0.024  -13.488    0.000   -0.537   -0.537
```

```
##     F7                -0.232    0.022  -10.599    0.000   -0.417   -0.417
##   F3 ~~
##     F4                -0.149    0.020   -7.396    0.000   -0.304   -0.304
##     F5                -0.409    0.026  -15.878    0.000   -0.710   -0.710
##     F6                -0.324    0.025  -13.081    0.000   -0.474   -0.474
##     F7                -0.233    0.023   -9.919    0.000   -0.368   -0.368
##   F4 ~~
##     F5                 0.190    0.020    9.378    0.000    0.425    0.425
##     F6                 0.179    0.020    8.836    0.000    0.337    0.337
##     F7                 0.107    0.018    5.993    0.000    0.216    0.216
##   F5 ~~
##     F6                 0.510    0.031   16.644    0.000    0.814    0.814
##     F7                 0.387    0.028   14.060    0.000    0.667    0.667
##   F6 ~~
##     F7                 0.327    0.026   12.370    0.000    0.475    0.475
##
## Variances:
##                     Estimate  Std.Err  z-value  P(>|z|)   Std.lv  Std.all
##    .ROLEA1             0.504    0.029   17.397    0.000    0.504    0.504
##    .ROLEA2             0.334    0.028   11.794    0.000    0.334    0.334
##    .DEC2               0.331    0.019   17.754    0.000    0.331    0.331
##    .ROLEC1             0.512    0.024   21.777    0.000    0.512    0.512
##    .ROLEC2             0.378    0.024   15.472    0.000    0.378    0.378
##    .WORK1              0.372    0.023   16.238    0.000    0.372    0.372
##    .WORK2              0.604    0.030   19.962    0.000    0.604    0.605
##    .CCLIM1             0.618    0.027   22.703    0.000    0.618    0.618
##    .CCLIM2             0.380    0.025   15.044    0.000    0.380    0.380
##    .CCLIM3             0.577    0.030   19.345    0.000    0.577    0.577
##    .CCLIM4             0.633    0.029   22.093    0.000    0.633    0.634
##    .DEC1               0.472    0.027   17.704    0.000    0.472    0.472
##    .SSUP1              0.256    0.017   15.194    0.000    0.256    0.256
##    .SSUP2              0.125    0.014    8.788    0.000    0.125    0.125
##    .PSUP1              0.362    0.029   12.270    0.000    0.362    0.362
##    .PSUP2              0.189    0.031    6.163    0.000    0.189    0.189
##    .SELF1              0.415    0.025   16.528    0.000    0.415    0.415
##    .SELF2              0.257    0.020   13.060    0.000    0.257    0.257
##    .SELF3              0.279    0.022   12.942    0.000    0.279    0.279
##    .ELC1               0.533    0.025   20.915    0.000    0.533    0.534
##    .ELC2               0.668    0.028   23.511    0.000    0.668    0.669
##    .ELC3               0.449    0.025   18.271    0.000    0.449    0.450
##    .ELC4               0.582    0.027   21.653    0.000    0.582    0.582
##    .ELC5               0.440    0.024   18.582    0.000    0.440    0.441
##    .EE1                0.240    0.014   17.240    0.000    0.240    0.241
##    .EE2                0.141    0.012   11.761    0.000    0.141    0.141
##    .EE3                0.268    0.015   17.784    0.000    0.268    0.270
##    .DP1                0.215    0.036    5.994    0.000    0.215    0.216
##    .DP2                0.460    0.034   13.668    0.000    0.460    0.461
##    .PA1                0.316    0.026   12.391    0.000    0.316    0.319
##    .PA2                0.351    0.027   13.009    0.000    0.351    0.354
##    .PA3                0.440    0.025   17.423    0.000    0.440    0.444
##     F1                 0.496    0.040   12.426    0.000    1.000    1.000
##     F2                 0.487    0.034   14.183    0.000    1.000    1.000
##     F3                 0.628    0.035   17.776    0.000    1.000    1.000
##     F4                 0.381    0.035   10.844    0.000    1.000    1.000
```

```
##     F5                  0.527    0.038    13.831    0.000    1.000    1.000
##     F6                  0.744    0.039    19.005    0.000    1.000    1.000
##     F7                  0.637    0.046    13.855    0.000    1.000    1.000
##    .F8                  0.441    0.043    10.325    0.000    0.755    0.755
##    .F9                  0.334    0.028    11.987    0.000    0.718    0.718
##    .F10                 0.303    0.034     9.002    0.000    0.401    0.401
##    .F11                 0.453    0.039    11.645    0.000    0.580    0.580
##    .F12                 0.410    0.029    14.004    0.000    0.608    0.608
```

```r
fitMeasures(fit8, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.robust", "rmsea.robu
```

```
##   chisq.scaled     df.scaled pvalue.scaled    cfi.robust    tli.robust
##       1268.075       423.000         0.000         0.959         0.951
##   rmsea.robust          srmr
##          0.040         0.039
```

The x2 is 1268.075, with 423 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.959 and 0.951 respectively. The value of RMSEA and SRMR indices are 0.040 and 0.039 respectively.

High correlation of 0.926 between F3 (Work Overload) and F2 (Role Conflict) is found.

Comparison of model 7 and 8

```r
options(scipen=999)
compareFit(fit7, fit8, nested = FALSE)
```

```
## ####################### Model Fit Indices ###########################
##      chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust
## fit7    1267.581†       421          .000      .958       .951
## fit8    1268.075        423          .000      .959†      .951†
##                aic         bic rmsea.robust  srmr
## fit7  94381.519†  94944.920†         .040  .039†
## fit8 107932.398  108485.268         .040† .039
```

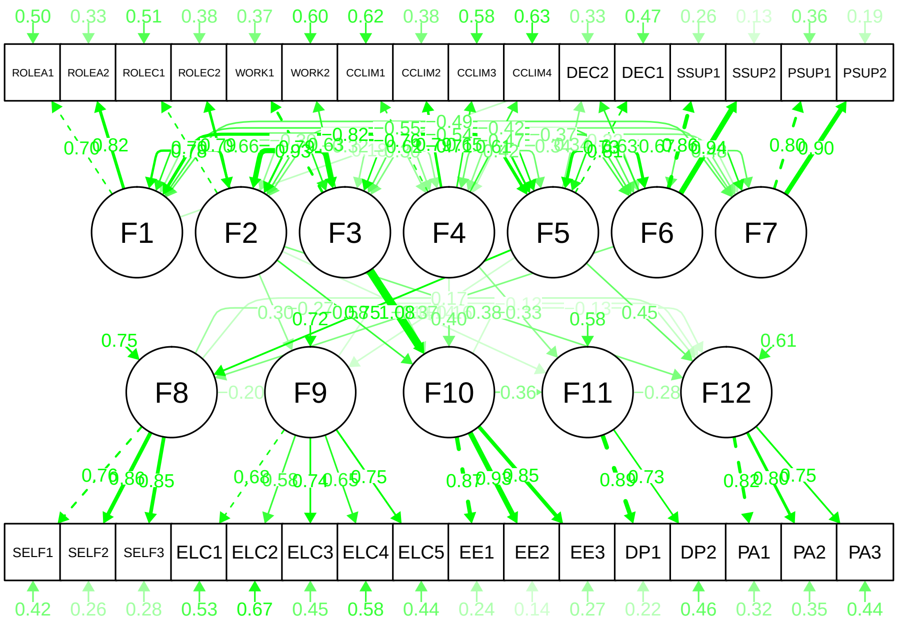
```r
anova(fit7, fit8)
```

```
## Scaled Chi Square Difference Test (method = "satorra.bentler.2001")
##
##       Df    AIC    BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## fit7 421  94382  94945 1424.4
## fit8 423 107932 108485 1425.8     1.1236       2     0.5702
```

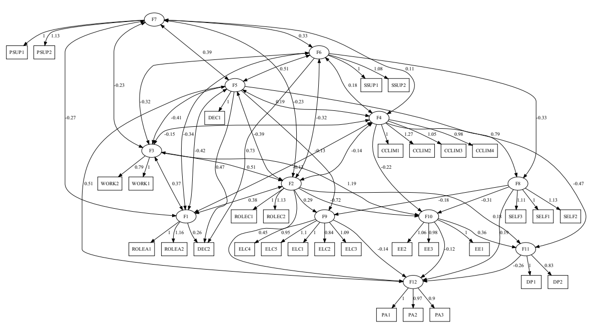
The two structural regression paths has been excluded in the final model which gives 2 degrees of freedom. The CFI value has increased to 0.959 indicating good fit. The difference in fit between final model and ModeL 7 is not found to be statistically significant.

Creating final graph

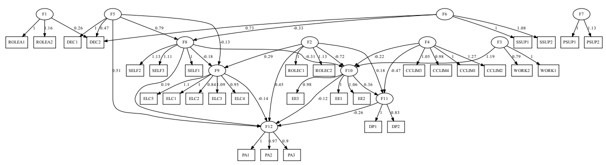
```r
labels = list(F1 = "Role Ambiguity", F2 = " Role Conflict", F3 = " Work Overload", F4 = " Classroom Cli

semPaths(fit8, "standardized", curvePivot = TRUE, style = "lisrel", edge.label.cex=0.75, edge.color="gr
```




```r
# standardized path
lavaanPlot(model = fit8, coefs = TRUE, covs = TRUE, stars = TRUE)
```



```r
# unstandardized path
lavaanPlot(model = fit8, coefs = TRUE, stand = FALSE)
```



The path reflects:

Decision making on external locus of control

Role conflict, emotional exhaustion on depersonalization

Decision making, self-esteem, external locus of control, emotional exhaustion, and depersonalization on personal accomplishment.

Superior support and decision making on self-esteem

Workoverload on emotional exhaustion. The teachers having work overload seems to have increased levels of emotional exhaustion.

Classroom climate on depersonalization. Positive classroom climate associates with low level of depersonalization.

Week 5 SEM Assignment

Shweta Goswami

17-02-2019

TITLE: "CFA invariance & teacher burnout" (ch7)

Exercise 5.1

Reading the data

```
secondary <- read.delim("~/sem2019/mbisec1.DAT", header=FALSE)
elementary <- read.delim("~/sem2019/mbielm1.DAT", header=FALSE)
glimpse(secondary)
```

```
## Observations: 692
## Variables: 22
## $ V1  <dbl> 3, 3, 5, 5, 1, 2, 5, 5, 1, 3, 5, 0, 1, 4, 4, 4, 5, 1, 2, 3...
## $ V2  <dbl> 4, 5, 5, 5, 2, 4, 5, 5, 3, 5, 5, 0, 3, 4, 5, 4, 5, 2, 2, 4...
## $ V3  <dbl> 0, 3, 5, 3, 1, 0, 2, 1, 3, 5, 4, 0, 1, 5, 3, 2, 3, 0, 2, 4...
## $ V4  <dbl> 6, 5, 5, 4, 6, 6, 5, 6, 3, 5, 6, 6, 6, 6, 4, 6, 6, 3, 6, 6...
## $ V5  <dbl> 0, 1, 0, 1, 1, 1, 0, 1, 1, 1, 2, 1, 0, 1, 5, 0, 0, 0, 1, 1...
## $ V6  <dbl> 2, 1, 5, 3, 3, 2, 3, 2, 1, 2, 4, 0, 0, 2, 5, 3, 1, 1, 0, 1...
## $ V7  <dbl> 6, 3, 5, 5, 5, 5, 5, 6, 5, 5, 5, 5, 6, 6, 3, 5, 4, 3, 4, 6...
## $ V8  <dbl> 1, 2, 5, 2, 1, 2, 2, 1, 1, 3, 1, 0, 1, 3, 3, 3, 3, 2, 0, 1...
## $ V9  <dbl> 5, 3, 4, 5, 5, 5, 5, 6, 6, 3, 6, 6, 6, 5, 1, 3, 4, 4, 5, 5...
## $ V10 <dbl> 1, 2, 1, 1, 0, 4, 2, 1, 1, 0, 0, 0, 0, 2, 2, 2, 0, 1, 1, 0...
## $ V11 <dbl> 2, 2, 2, 1, 0, 2, 1, 0, 1, 0, 0, 0, 0, 3, 1, 2, 0, 0, 0, 0...
## $ V12 <dbl> 5, 5, 5, 4, 2, 5, 5, 5, 5, 2, 4, 6, 6, 6, 4, 4, 4, 3, 4, 5...
## $ V13 <dbl> 1, 3, 5, 2, 1, 2, 4, 2, 1, 2, 6, 0, 0, 5, 5, 4, 3, 3, 2, 1...
## $ V14 <dbl> 3, 3, 4, 4, 1, 0, 3, 4, 1, 5, 4, 0, 1, 3, 4, 2, 4, 4, 1, 2...
## $ V15 <dbl> 0, 2, 0, 0, 1, 1, 1, 0, 0, 1, 1, 0, 0, 1, 2, 0, 0, 2, 1, 0...
## $ V16 <dbl> 3, 2, 1, 1, 3, 1, 3, 1, 1, 3, 4, 0, 0, 1, 3, 3, 3, 1, 1, 1...
## $ V17 <dbl> 6, 5, 5, 5, 4, 5, 5, 6, 6, 6, 5, 6, 6, 6, 4, 6, 6, 5, 5, 5...
## $ V18 <dbl> 5, 5, 4, 4, 4, 5, 5, 5, 5, 4, 6, 6, 6, 6, 5, 4, 6, 4, 5, 5...
## $ V19 <dbl> 5, 5, 4, 5, 5, 4, 3, 5, 6, 4, 5, 6, 6, 6, 3, 3, 4, 5, 4, 5...
## $ V20 <dbl> 1, 0, 4, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 1, 2, 0, 2, 0, 1, 1...
## $ V21 <dbl> 5, 5, 4, 3, 4, 3, 5, 6, 3, 3, 5, 3, 6, 6, 4, 6, 0, 1, 5, 6...
## $ V22 <dbl> 1, 1, 0, 1, 5, 2, 1, 1, 2, 2, 2, 1, 2, 1, 4, 0, 0, 0, 1, 0...
```

```
glimpse(elementary)
```

```
## Observations: 580
## Variables: 22
## $ V1  <dbl> 1, 5, 3, 6, 1, 5, 3, 6, 2, 4, 5, 2, 3, 2, 5, 6, 5, 4, 6, 3...
## $ V2  <dbl> 1, 5, 4, 6, 1, 5, 5, 6, 1, 4, 5, 1, 5, 3, 5, 6, 5, 5, 6, 5...
## $ V3  <dbl> 0, 6, 3, 6, 1, 5, 2, 5, 1, 3, 3, 2, 1, 2, 5, 3, 2, 3, 6, 2...
## $ V4  <dbl> 6, 6, 6, 6, 6, 6, 6, 6, 5, 6, 5, 6, 3, 6, 6, 6, 5, 6, 6, 6...
## $ V5  <dbl> 1, 2, 3, 0, 5, 1, 1, 4, 1, 0, 4, 0, 1, 0, 0, 3, 0, 1, 0, 0...
## $ V6  <dbl> 0, 4, 2, 0, 1, 6, 2, 3, 0, 0, 5, 0, 1, 1, 2, 4, 2, 3, 3, 0...
## $ V7  <dbl> 6, 5, 6, 6, 6, 6, 6, 5, 6, 5, 6, 6, 5, 6, 6, 6, 5, 6, 6, 6...
## $ V8  <dbl> 1, 5, 2, 6, 0, 6, 2, 6, 1, 2, 3, 0, 0, 1, 5, 1, 5, 3, 5, 0...
## $ V9  <dbl> 6, 4, 6, 6, 6, 3, 6, 3, 6, 6, 6, 6, 6, 6, 6, 6, 5, 6, 6, 6...
```

```
## $ V10 <dbl> 0, 3, 2, 0, 0, 0, 2, 4, 0, 1, 3, 0, 1, 0, 0, 0, 3, 0, 0, 3...
## $ V11 <dbl> 0, 4, 2, 0, 0, 0, 2, 6, 0, 1, 1, 0, 1, 1, 0, 0, 0, 0, 0, 3...
## $ V12 <dbl> 3, 3, 6, 0, 6, 0, 5, 0, 5, 5, 5, 5, 5, 5, 4, 6, 5, 5, 3, 6...
## $ V13 <dbl> 1, 3, 2, 0, 2, 5, 2, 5, 1, 1, 4, 0, 2, 1, 5, 2, 5, 1, 5, 0...
## $ V14 <dbl> 1, 3, 2, 3, 1, 5, 2, 3, 1, 1, 6, 1, 4, 2, 6, 6, 3, 3, 6, 2...
## $ V15 <dbl> 0, 1, 2, 0, 0, 0, 2, 4, 1, 2, 1, 0, 0, 0, 0, 1, 0, 1, 0, 0...
## $ V16 <dbl> 0, 4, 2, 0, 1, 6, 2, 3, 0, 1, 3, 0, 1, 0, 2, 2, 1, 3, 3, 0...
## $ V17 <dbl> 6, 4, 2, 6, 6, 5, 6, 4, 6, 6, 5, 6, 5, 5, 6, 6, 5, 6, 6, 6...
## $ V18 <dbl> 3, 5, 5, 4, 5, 1, 5, 1, 6, 6, 4, 5, 5, 4, 6, 6, 3, 5, 5, 6...
## $ V19 <dbl> 5, 5, 6, 6, 4, 3, 5, 1, 6, 6, 5, 6, 5, 3, 5, 6, 4, 5, 6, 5...
## $ V20 <dbl> 0, 1, 1, 3, 1, 1, 1, 5, 1, 0, 1, 0, 1, 0, 1, 4, 4, 2, 3, 0...
## $ V21 <dbl> 5, 3, 3, 6, 5, 5, 5, 3, 1, 5, 6, 5, 1, 5, 6, 5, 4, 5, 6, 6...
## $ V22 <dbl> 0, 2, 2, 0, 1, 0, 5, 1, 0, 1, 4, 1, 1, 1, 0, 0, 0, 5, 1, 0...
```

The datasets has sample of elementary (N=580) and secondary (N=692) teachers.

The aim of this analysis is to test the invariance of MBI across the samples.The subject corresponds to the relations among the three dimensions of burnout i.e. Emotional Exhaustion (EE), Depersonalization (DP), Personal Accomplishment (PA) and their invariance across elementary and secondary teachers. This is a multiple-group analyses of SEM.

The two questions related to the invariance will be focused as per the lecture materials:

1. Do the **items** operate equivalently across different populations or groups (based on, e.g., gender, age, ability, culture)?

2. Is the **factorial structure** equivalent across populations? (construct validity, measurement and/or structural models)

Creating names for all the variables

```r
names(secondary) <- c("ITEM1", "ITEM2", "ITEM3", "ITEM4", "ITEM5", "ITEM6", "ITEM7", "ITEM8", "ITEM9",

names(elementary) <- c("ITEM1", "ITEM2", "ITEM3", "ITEM4", "ITEM5", "ITEM6", "ITEM7", "ITEM8", "ITEM9",

str(secondary)
```

```
## 'data.frame':    692 obs. of  22 variables:
##  $ ITEM1 : num  3 3 5 5 1 2 5 5 1 3 ...
##  $ ITEM2 : num  4 5 5 5 2 4 5 5 3 5 ...
##  $ ITEM3 : num  0 3 5 3 1 0 2 1 3 5 ...
##  $ ITEM4 : num  6 5 5 4 6 6 5 6 3 5 ...
##  $ ITEM5 : num  0 1 0 1 1 1 0 1 1 1 ...
##  $ ITEM6 : num  2 1 5 3 3 2 3 2 1 2 ...
##  $ ITEM7 : num  6 3 5 5 5 5 5 6 5 5 ...
##  $ ITEM8 : num  1 2 5 2 1 2 2 1 1 3 ...
##  $ ITEM9 : num  5 3 4 5 5 5 5 6 6 3 ...
##  $ ITEM10: num  1 2 1 1 0 4 2 1 1 0 ...
##  $ ITEM11: num  2 2 2 1 0 2 1 0 1 0 ...
##  $ ITEM12: num  5 5 5 4 2 5 5 5 5 2 ...
##  $ ITEM13: num  1 3 5 2 1 2 4 2 1 2 ...
##  $ ITEM14: num  3 3 4 4 1 0 3 4 1 5 ...
##  $ ITEM15: num  0 2 0 0 1 1 1 0 0 1 ...
##  $ ITEM16: num  3 2 1 1 3 1 3 1 1 3 ...
##  $ ITEM17: num  6 5 5 5 4 5 5 6 6 6 ...
##  $ ITEM18: num  5 5 4 4 4 5 5 5 5 4 ...
##  $ ITEM19: num  5 5 4 5 5 4 3 5 6 4 ...
##  $ ITEM20: num  1 0 4 1 1 1 1 1 1 1 ...
```

```
##  $ ITEM21: num  5 5 4 3 4 3 5 6 3 3 ...
##  $ ITEM22: num  1 1 0 1 5 2 1 1 2 2 ...
```

```r
str(elementary)
```

```
## 'data.frame':    580 obs. of  22 variables:
##  $ ITEM1 : num  1 5 3 6 1 5 3 6 2 4 ...
##  $ ITEM2 : num  1 5 4 6 1 5 5 6 1 4 ...
##  $ ITEM3 : num  0 6 3 6 1 5 2 5 1 3 ...
##  $ ITEM4 : num  6 6 6 6 6 6 6 6 5 6 ...
##  $ ITEM5 : num  1 2 3 0 5 1 1 4 1 0 ...
##  $ ITEM6 : num  0 4 2 0 1 6 2 3 0 0 ...
##  $ ITEM7 : num  6 5 6 6 6 6 6 5 6 5 ...
##  $ ITEM8 : num  1 5 2 6 0 6 2 6 1 2 ...
##  $ ITEM9 : num  6 4 6 6 6 3 6 3 6 6 ...
##  $ ITEM10: num  0 3 2 0 0 0 2 4 0 1 ...
##  $ ITEM11: num  0 4 2 0 0 0 2 6 0 1 ...
##  $ ITEM12: num  3 3 6 0 6 0 5 0 5 5 ...
##  $ ITEM13: num  1 3 2 0 2 5 2 5 1 1 ...
##  $ ITEM14: num  1 3 2 3 1 5 2 3 1 1 ...
##  $ ITEM15: num  0 1 2 0 0 0 2 4 1 2 ...
##  $ ITEM16: num  0 4 2 0 1 6 2 3 0 1 ...
##  $ ITEM17: num  6 4 2 6 6 5 6 4 6 6 ...
##  $ ITEM18: num  3 5 5 4 5 1 5 1 6 6 ...
##  $ ITEM19: num  5 5 6 6 4 3 5 1 6 6 ...
##  $ ITEM20: num  0 1 1 3 1 1 1 5 1 0 ...
##  $ ITEM21: num  5 3 3 6 5 5 5 3 1 5 ...
##  $ ITEM22: num  0 2 2 0 1 0 5 1 0 1 ...
```

Specifying baseline model 1 (Secondary)

```r
model1 <- '
F1 =~ ITEM1 + ITEM2 + ITEM3 + ITEM6 + ITEM8 + ITEM13 + ITEM14 + ITEM16 + ITEM20
F2 =~ ITEM5 +  ITEM10 + ITEM11 + ITEM15 + ITEM22
F3 =~ ITEM4 + ITEM7 + ITEM9 + ITEM12 + ITEM17 + ITEM18 + ITEM19 + ITEM21
  '
```

Fitting the model

```r
fit1 <- cfa(model1, data=secondary, estimator = "MLM")
```

Display summary output

```r
fitMeasures(fit1, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.robust", "rmsea.robu
```

```
##  chisq.scaled     df.scaled pvalue.scaled    cfi.robust    tli.robust
##       971.064       206.000         0.000         0.835         0.815
##  rmsea.robust          srmr
##         0.084         0.080
```

Specifying baseline model 1.1 (Elementary)

```r
model1.1 <- '
F1 =~ ITEM1 + ITEM2 + ITEM3 + ITEM6 + ITEM8 + ITEM13 + ITEM14 + ITEM16 + ITEM20
F2 =~ ITEM5 +  ITEM10 + ITEM11 + ITEM15 + ITEM22
F3 =~ ITEM4 + ITEM7 + ITEM9 + ITEM12 + ITEM17 + ITEM18 + ITEM19 + ITEM21
  '
```

Fitting the model

```r
fit1.1 <- cfa(model1.1, data=elementary, estimator = "MLM")
```

Display summary output

```r
fitMeasures(fit1.1, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.robust", "rmsea.r
```

```
##  chisq.scaled     df.scaled pvalue.scaled    cfi.robust    tli.robust
##       802.743       206.000         0.000         0.858         0.841
##  rmsea.robust          srmr
##         0.079         0.071
```

Comparison of model 1 and 1.1

```r
options(scipen=999)
compareFit(fit1,fit1.1, nested = FALSE)
```

```
## ####################### Model Fit Indices ###########################
##        chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust
## fit1       971.064        206          .000      .835       .815
## fit1.1     802.743†       206          .000      .858†      .841†
##                aic        bic rmsea.robust  srmr
## fit1   49296.269  49509.630         .084  .080
## fit1.1 39882.062† 40087.125†        .079† .071†
```

The goodness of fit statistics indicates initial model not a good fit for both secondary and elementary.

For Secondary: (Values less/more than the optimal range) The x2 is 802.743, with 206 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.858 and 0.841 respectively. The value of RMSEA and SRMR indices are 0.079 and 0.071 respectively.

For Elementary: (Values less/more than the optimal range) The x2 is 971.064, with 206 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.835 and 0.815 respectively. The value of RMSEA and SRMR indices are 0.084 and 0.080 respectively.

Model Modification indices for model 1 and 1.1

```r
modindices(fit1, minimum = 50)
```

```
##        lhs op    rhs      mi    epc sepc.lv sepc.all sepc.nox
## 59      F1 =~ ITEM12 118.156 -0.468  -0.561   -0.419   -0.419
## 95   ITEM1 ~~  ITEM2 171.647  0.627   0.627    0.583    0.583
## 122  ITEM2 ~~ ITEM20  53.024 -0.324  -0.324   -0.316   -0.316
## 158  ITEM6 ~~ ITEM16 127.756  0.686   0.686    0.458    0.458
## 250  ITEM5 ~~ ITEM15  77.216  0.580   0.580    0.355    0.355
## 260 ITEM10 ~~ ITEM11 135.841  1.181   1.181    1.426    1.426
## 271 ITEM11 ~~ ITEM15  60.947 -0.485  -0.485   -0.420   -0.420
```

```r
modindices(fit1.1, minimum = 100)
```

```
##       lhs op    rhs      mi   epc sepc.lv sepc.all sepc.nox
## 95  ITEM1 ~~  ITEM2 103.177 0.534   0.534    0.494    0.494
## 158 ITEM6 ~~ ITEM16 180.298 0.893   0.893    0.595    0.595
```

Referring to "CFA of MBI for Male Elementary Teachers (Calibration Group)" and output of both datasets, one cross-loading and three large residual covariances are present. The cross-loading involves loading of Item 12 on Factor 1 (Emotional Exhaustion). The residual covariances involved Items 2 with 1, Items 16 with 6 and Item 11 with 10. Item 16 with 6 is more influential in elementary teachers whereas item 2 with 1 more pronounced in secondary teachers.

Testing for Invariance of MBI across Elementary/Secondary Teachers Common Baseline (Configural) Model (Byrne 2012, p. 209)

Adding all four parameters in a post hoc model

Specifying Model 2 (Secondary)

```
model2 <- '

F1 =~ ITEM1 + ITEM2 + ITEM3 + ITEM6 + ITEM8 + ITEM12 + ITEM13 + ITEM14 + ITEM16 + ITEM20
F2 =~ ITEM5 +  ITEM10 + ITEM11 + ITEM15 + ITEM22
F3 =~ ITEM4 + ITEM7 + ITEM9 + ITEM12 + ITEM17 + ITEM18 + ITEM19 + ITEM21

#residual covariance
ITEM6 ~~ ITEM16
ITEM1 ~~ ITEM2
ITEM10 ~~ ITEM11

'
```

Fitting the model

```
fit2 <- cfa(model2, data=secondary, estimator = "MLM")
```

Display summary output

```
fitMeasures(fit2, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.robust", "rmsea.robu
```

```
##  chisq.scaled     df.scaled pvalue.scaled    cfi.robust    tli.robust
##       572.552       202.000         0.000         0.921         0.909
##  rmsea.robust          srmr
##         0.059         0.058
```

Specifying Model 2.1 (Elementary)

```
model2.1 <- '

F1 =~ ITEM1 + ITEM2 + ITEM3 + ITEM6 + ITEM8 + ITEM12 + ITEM13 + ITEM14 + ITEM16 + ITEM20
F2 =~ ITEM5 +  ITEM10 + ITEM11 + ITEM15 + ITEM22
F3 =~ ITEM4 + ITEM7 + ITEM9 + ITEM12 + ITEM17 + ITEM18 + ITEM19 + ITEM21

#residual covariance
ITEM6 ~~ ITEM16
ITEM1 ~~ ITEM2
ITEM10 ~~ ITEM11

'
```

Fitting the model

```
fit2.1 <- cfa(model2.1, data=elementary, estimator = "MLM")
```

Display summary output

```
fitMeasures(fit2.1, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.robust", "rmsea.r
```

```
##  chisq.scaled     df.scaled pvalue.scaled    cfi.robust    tli.robust
##       470.377       202.000         0.000         0.937         0.928
##  rmsea.robust          srmr
##         0.053         0.053
```

Comparison of model 2 and 2.1

```
options(scipen=999)
compareFit(fit2,fit2.1, nested = FALSE)
```

```
## ####################### Model Fit Indices ###########################
##         chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust
## fit2       572.552        202          .000      .921       .909
## fit2.1     470.377†       202          .000      .937†      .928†
##                 aic        bic rmsea.robust  srmr
## fit2   48772.074  49003.593         .059  .058
## fit2.1 39462.279† 39684.794†        .053† .053†
```

The goodness of fit statistics has improved from the initial model for both teacher groups:

For Secondary: The x2 is 572.552, with 202 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.921 and 0.909 respectively. The value of RMSEA and SRMR indices are 0.059 and 0.058 respectively.

For Elementary: The x2 is 470.377, with 202 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.937 and 0.928 respectively. The value of RMSEA and SRMR indices are 0.053 and 0.053 respectively.

Continuing post hoc modifications

Model Modification indices for model 2 and 2.1

```
modindices(fit2, minimum = 30)
```

```
##       lhs op    rhs     mi   epc sepc.lv sepc.all sepc.nox
## 57     F1 =~ ITEM11 67.177 0.472   0.532    0.339    0.339
## 263 ITEM5 ~~ ITEM15 35.576 0.416   0.416    0.310    0.310
## 318 ITEM9 ~~ ITEM19 43.690 0.355   0.355    0.357    0.357
```

```
modindices(fit2.1, minimum = 30)
```

```
##        lhs op    rhs     mi   epc sepc.lv sepc.all sepc.nox
## 305  ITEM4 ~~  ITEM7 38.931 0.174   0.174    0.284    0.284
## 323 ITEM18 ~~ ITEM19 38.744 0.266   0.266    0.333    0.333
```

For secondary teachers, one misspecified parameter is F1 by ITEM11 and a residual covariance between ITEM 19 and 9 representing large MI. The cross-loading of Item 11 on Factor 1 will be included in the next model.

For Elementary teachers, two MIs that are higher than other MIs are ITEM7 with ITEM4 and ITEM19 with ITEM18. There is a overlap between content ITEM 7 and ITEM 4 and will be included in the next model.

Specifying Model 3 (Secondary)

```
model3 <- '

F1 =~ ITEM1 + ITEM2 + ITEM3 + ITEM6 + ITEM8 + ITEM11 + ITEM12 + ITEM13 + ITEM14 + ITEM16 + ITEM20
F2 =~ ITEM5 +  ITEM10 + ITEM11 + ITEM15 + ITEM22
F3 =~ ITEM4 + ITEM7 + ITEM9 + ITEM12 + ITEM17 + ITEM18 + ITEM19 + ITEM21

#residual covariance
ITEM6 ~~ ITEM16
ITEM1 ~~ ITEM2
ITEM10 ~~ ITEM11
'

fit3 <- cfa(model3, data=secondary, estimator = "MLM")
```

Specifying Model 3.1 (Elementary)

```
model3.1 <- '

F1 =~ ITEM1 + ITEM2 + ITEM3 + ITEM6 + ITEM8 + ITEM12 + ITEM13 + ITEM14 + ITEM16 + ITEM20
F2 =~ ITEM5 +  ITEM10 + ITEM11 + ITEM15 + ITEM22
F3 =~ ITEM4 + ITEM7 + ITEM9 + ITEM12 + ITEM17 + ITEM18 + ITEM19 + ITEM21

#residual covariance
ITEM6 ~~ ITEM16
ITEM1 ~~ ITEM2
ITEM10 ~~ ITEM11
ITEM4 ~~ ITEM7
'

fit3.1 <- cfa(model3.1, data=elementary, estimator = "MLM")
```

Comparison of model 2 and 2.1

```
options(scipen=999)
compareFit(fit3,fit3.1, nested = FALSE)
```

```
## ####################### Model Fit Indices ###########################
##        chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust
## fit3       522.982        201          .000      .931       .921
## fit3.1     445.801†       201          .000      .944†      .935†
##                  aic        bic rmsea.robust  srmr
## fit3   48706.531  48942.589         .055  .055
## fit3.1 39425.255† 39652.132†        .051† .051†
```

The goodness of fit statistics indicates good fit for both teacher groups:

For Secondary: The x2 is 522.982, with 201 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.931 and 0.921 respectively. The value of RMSEA and SRMR indices are 0.055 and 0.055 respectively.

For Elementary: The x2 is 445.801, with 201 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.944 and 0.935 respectively. The value of RMSEA and SRMR indices are 0.051 and 0.051 respectively.

Comparison of model 1.1, 2.1 and 3.1 for elementary teachers

```
options(scipen=999)
compareFit(fit1.1, fit2.1, fit3.1, nested = FALSE)
```

```
## ####################### Model Fit Indices ###########################
##        chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust
## fit3.1     445.801†       201          .000      .944†      .935†
## fit2.1     470.377        202          .000      .937       .928
## fit1.1     802.743        206          .000      .858       .841
##                  aic        bic rmsea.robust  srmr
## fit3.1 39425.255† 39652.132†        .051† .051†
## fit2.1 39462.279  39684.794         .053  .053
## fit1.1 39882.062  40087.125         .079  .071
```

Model 3.1 will be the baseline for the elementary teachers taking into account the model parsimony.

Continuing post hoc modifications for secondary teachers

Model Modification indices for model 3

```r
modindices(fit3, minimum = 30)
```

```
##       lhs op    rhs     mi   epc sepc.lv sepc.all sepc.nox
## 318 ITEM9 ~~ ITEM19 42.687 0.351   0.351    0.355    0.355
```

The residual covariance between Items 19 and 9 is the misspecified parameter in secondary teacher model and will be included in the next model.

Specifying Model 4 (Secondary)

```r
model4 <- '

F1 =~ ITEM1 + ITEM2 + ITEM3 + ITEM6 + ITEM8 + ITEM11 + ITEM12 + ITEM13 + ITEM14 + ITEM16 + ITEM20
F2 =~ ITEM5 +  ITEM10 + ITEM11 + ITEM15 + ITEM22
F3 =~ ITEM4 + ITEM7 + ITEM9 + ITEM12 + ITEM17 + ITEM18 + ITEM19 + ITEM21

#residual covariance
ITEM6 ~~ ITEM16
ITEM1 ~~ ITEM2
ITEM10 ~~ ITEM11
ITEM9 ~~ ITEM19
'

fit4 <- cfa(model4, data=secondary, estimator = "MLM")
```

Display summary output

```r
fitMeasures(fit4, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.robust", "rmsea.robu
```

```
##  chisq.scaled     df.scaled pvalue.scaled    cfi.robust    tli.robust
##       492.282       200.000         0.000         0.938         0.928
##  rmsea.robust          srmr
##         0.053         0.054
```

The goodness of fit statistics indicates satisfactory fit for secondary teachers.

For Secondary: The x2 is 492.282, with 200 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.938 and 0.928 respectively. The value of RMSEA and SRMR indices are 0.053 and 0.054 respectively.

Comparison of model 1, 2,3 and 4 for secondary teachers

```r
options(scipen=999)
compareFit(fit1, fit2,fit3, fit4, nested = FALSE)
```

```
## ####################### Model Fit Indices ###########################
##      chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust        aic
## fit4     492.282†       200          .000      .938†      .928† 48669.181†
## fit3     522.982        201          .000      .931       .921  48706.531
## fit2     572.552        202          .000      .921       .909  48772.074
## fit1     971.064        206          .000      .835       .815  49296.269
##              bic rmsea.robust  srmr
## fit4 48909.779†        .053† .054†
## fit3 48942.589         .055  .055
## fit2 49003.593         .059  .058
## fit1 49509.630         .084  .080
```

Taking into consideration the model parsimony, Model 4 will be the final model for secondary teachers.

Exercise 5.2

TITLE: Testing for Invariance of MBI across Elementary/Secondary Teachers Common Baseline (Configural) Model (Byrne 2012, p. 209)

```
# Combine data

secel <- merge(data.frame(elementary, group = "elementary"), data.frame(secondary, group = "secondary")


# Configural model
modelv1 <- '
F1 =~ ITEM1 + ITEM2 + ITEM3 + ITEM6 + ITEM8 + ITEM13 + ITEM14 + ITEM16 + ITEM20 + ITEM12
F2 =~ ITEM5 + ITEM10 + ITEM11 + ITEM15 + ITEM22
F3 =~ ITEM4 + ITEM7 + ITEM9 + ITEM12 + ITEM17 + ITEM18 + ITEM19 + ITEM21

# Residual Covariances
ITEM1 ~~ ITEM2
ITEM6 ~~ ITEM16
ITEM10 ~~ ITEM11

# Froup specific parameters
ITEM4 ~~ c(NA,0)*ITEM7
F1 =~ c(0,NA)*ITEM11
ITEM9 ~~ c(0,NA)*ITEM19
'

# Displaying summary output

fit_modelv1 <- cfa(modelv1, data = secel, estimator = "MLM", group = "group")

Configural_model <- fitMeasures(fit_modelv1, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust
Configural_model
```

```
##  chisq.scaled     df.scaled pvalue.scaled    cfi.robust    tli.robust
##       939.696       401.000         0.000         0.940         0.931
##  rmsea.robust          srmr
##         0.052         0.051
```

It incorporates baseline models for elementary and secondary teachers as one and known as the configural model.

The x2 is 939.696, with 401 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.940 and 0.931 respectively. The value of RMSEA and SRMR indices are 0.052 and 0.051 respectively.

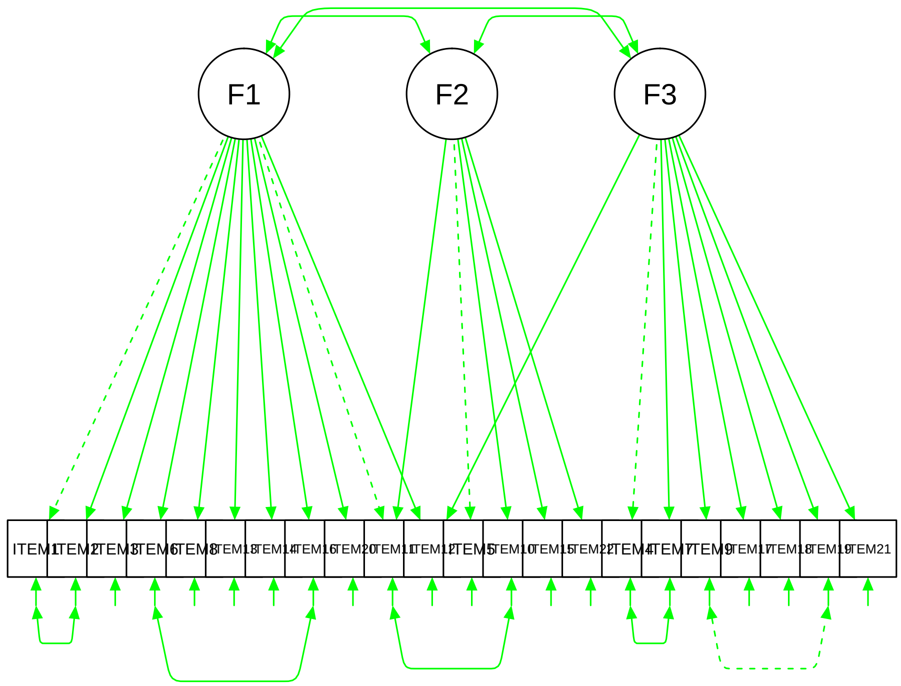
Creating graph

Graph 1 represents elementary school teachers.

Graph 2 represents secondary school teachers.

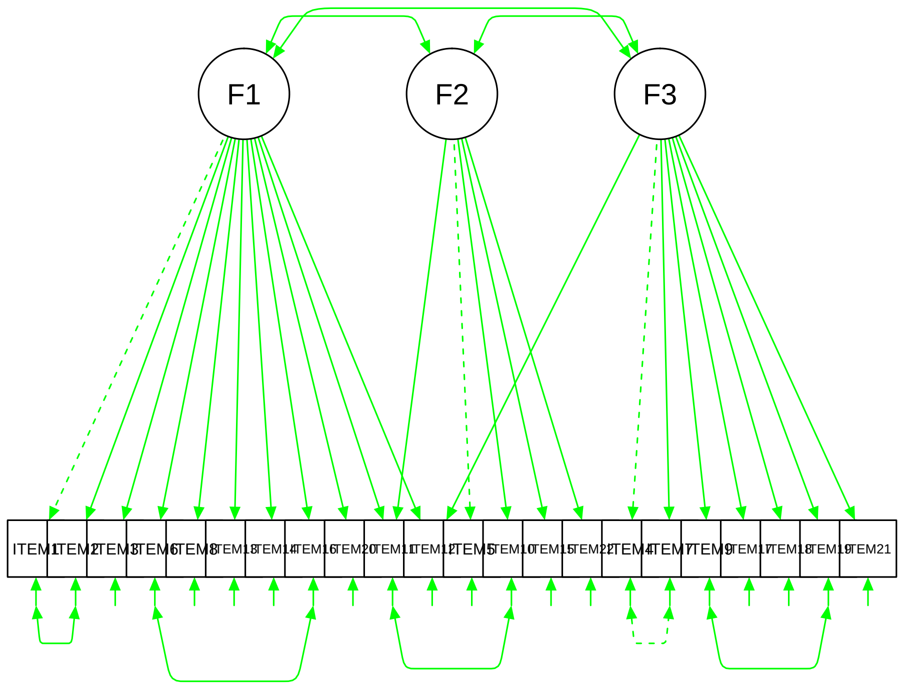
```
semPaths(fit_modelv1, curvePivot = TRUE, style = "lisrel", intercepts = FALSE, edge.label.cex=0.75, edge
```

1



F1
F2
F3
ITEM1
ITEM2
ITEM3
ITEM6
ITEM8
ITEM13
ITEM14
ITEM16
ITEM20
ITEM11
ITEM12
ITEM5
ITEM10
ITEM15
ITEM22
ITEM4
ITEM7
ITEM9
ITEM17
ITEM18
ITEM19
ITEM21

2



Measurement model modifications

Factor Loadings : testing for the equivalence of factor loadings across groups

```
modelv2 <- '
F1 =~ ITEM1 + ITEM2 + ITEM3 + ITEM6 + ITEM8 + ITEM13 + ITEM14 + ITEM16 + ITEM20 + ITEM12
F2 =~ ITEM5 + ITEM10 + ITEM11 + ITEM15 + ITEM22
F3 =~ ITEM4 + ITEM7 + ITEM9 + ITEM12 + ITEM17 + ITEM18 + ITEM19 + ITEM21

# Residual Covariances
ITEM1 ~~ ITEM2
ITEM6 ~~ ITEM16
ITEM10 ~~ ITEM11

# Froup specific parameters
ITEM4 ~~ c(NA,0)*ITEM7
F1 =~ c(0,NA)*ITEM11
ITEM9 ~~ c(0,NA)*ITEM19
'

fit_modelv2 <- cfa(modelv2, group.equal=c("loadings"), group.partial=c("F1 =~ ITEM11"), data = secel,
                   estimator = "MLM", group = "group")

Measurement_Parameter_allfactors <- fitMeasures(fit_modelv2, c("chisq.scaled","df.scaled", "pvalue.scal
Measurement_Parameter_allfactors

##   chisq.scaled     df.scaled pvalue.scaled    cfi.robust    tli.robust
```

```
##       995.433       421.000         0.000         0.937         0.930
##   rmsea.robust          srmr
##         0.052         0.057
```

Comparing modelv1 and modelv2

```r
options(scipen=999)
compareFit(fit_modelv1, fit_modelv2, nested = FALSE)
```

```
## ####################### Model Fit Indices ###########################
##              chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust
## fit_modelv1     939.696†       401          .000      .940†      .931†
## fit_modelv2     995.433        421          .000      .937       .930
##                     aic        bic rmsea.robust  srmr
## fit_modelv1 88182.435† 88949.539         .052† .051†
## fit_modelv2 88210.287  88874.424†        .052  .057
```

```r
anova(fit_modelv1, fit_modelv2)
```

```
## Scaled Chi Square Difference Test (method = "satorra.bentler.2001")
##
##              Df   AIC   BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## fit_modelv1 401 88182 88950 1189.8
## fit_modelv2 421 88210 88874 1257.7      56.14      20  0.0000277 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The difference in degrees of freedom from the configural model is 20. The model statistics suggest not quite a good fit as compared to the configural model.

Partial Invariance model

```r
lavTestScore(fit_modelv2)
```

```
## Warning in lavTestScore(fit_modelv2): lavaan WARNING: se is not `standard';
## not implemented yet; falling back to ordinary score test

## $test
##
## total score test:
##
##    test     X2 df p.value
## 1 score 68.047 20       0
##
## $uni
##
## univariate score tests:
##
##      lhs op    rhs     X2 df p.value
## 1   .p2. ==  .p84.  0.001  1   0.973
## 2   .p3. ==  .p85.  0.075  1   0.784
## 3   .p4. ==  .p86.  1.184  1   0.276
## 4   .p5. ==  .p87.  0.393  1   0.531
## 5   .p6. ==  .p88.  0.715  1   0.398
## 6   .p7. ==  .p89.  0.037  1   0.848
## 7   .p8. ==  .p90.  1.560  1   0.212
## 8   .p9. ==  .p91.  0.024  1   0.876
## 9  .p10. ==  .p92.  1.512  1   0.219
```

```
## 10 .p12. ==  .p94.  4.667  1   0.031
## 11 .p13. ==  .p95. 31.564  1   0.000
## 12 .p14. ==  .p96. 11.596  1   0.001
## 13 .p15. ==  .p97.  6.198  1   0.013
## 14 .p17. ==  .p99.  8.970  1   0.003
## 15 .p18. == .p100.  0.474  1   0.491
## 16 .p19. == .p101.  0.011  1   0.917
## 17 .p20. == .p102.  5.006  1   0.025
## 18 .p21. == .p103.  0.167  1   0.682
## 19 .p22. == .p104.  0.063  1   0.801
## 20 .p23. == .p105.  0.119  1   0.730
```

```
# partable(fit_modelv2) according to the output .p13 is F2 =~ ITEM11
```

The factor loading of Item 11 on Factor 2 (.p13) possess highest chi-square difference and will be included in the next model.

```
modelv3 <- '
F1 =~ ITEM1 + ITEM2 + ITEM3 + ITEM6 + ITEM8 + ITEM13 + ITEM14 + ITEM16 + ITEM20 + ITEM12
F2 =~ ITEM5 + ITEM10 + ITEM11 + ITEM15 + ITEM22
F3 =~ ITEM4 + ITEM7 + ITEM9 + ITEM12 + ITEM17 + ITEM18 + ITEM19 + ITEM21

# Residual Covariances
ITEM1 ~~ ITEM2
ITEM6 ~~ ITEM16
ITEM10 ~~ ITEM11

# Froup specific parameters
ITEM4 ~~ c(NA,0)*ITEM7
F1 =~ c(0,NA)*ITEM11
ITEM9 ~~ c(0,NA)*ITEM19
'

fit_modelv3 <- cfa(modelv3, group.equal=c("loadings"), group.partial=c("F1 =~ ITEM11", "F2 =~ ITEM11"),

Measurement_Parameter_item11 <-fitMeasures(fit_modelv3, c("chisq.scaled","df.scaled", "pvalue.scaled",
Measurement_Parameter_item11
```

```
##   chisq.scaled     df.scaled pvalue.scaled    cfi.robust    tli.robust
##        969.990       420.000         0.000         0.939         0.933
##   rmsea.robust          srmr
##          0.051         0.054
```

Comparing modelv2 and modelv3

```
options(scipen=999)
compareFit(fit_modelv2, fit_modelv3, nested = FALSE)
```

```
## ####################### Model Fit Indices ###########################
##             chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust
## fit_modelv3     969.990†       420          .000      .939†      .933†
## fit_modelv2     995.433        421          .000      .937       .930
##                   aic        bic rmsea.robust  srmr
## fit_modelv3 88180.031† 88849.316†        .051† .054†
## fit_modelv2 88210.287  88874.424         .052  .057
```

```r
anova(fit_modelv2, fit_modelv3)
```

```
## Scaled Chi Square Difference Test (method = "satorra.bentler.2001")
##
##             Df   AIC   BIC  Chisq Chisq diff Df diff   Pr(>Chisq)
## fit_modelv3 420 88180 88849 1225.4
## fit_modelv2 421 88210 88874 1257.7     24.604       1 0.0000007041 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Theere is loss of 1df. The x2 is 969.990, with 420 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.939 and 0.933 respectively. The value of RMSEA and SRMR indices are 0.051 and 0.054 respectively.

Additional invariant factor loadings

```r
lavTestScore(fit_modelv3)
```

```
## Warning in lavTestScore(fit_modelv3): lavaan WARNING: se is not `standard';
## not implemented yet; falling back to ordinary score test

## $test
##
## total score test:
##
##    test     X2 df p.value
## 1 score 35.979 19   0.011
##
## $uni
##
## univariate score tests:
##
##      lhs op    rhs     X2 df p.value
## 1   .p2. ==  .p84.  0.003  1   0.958
## 2   .p3. ==  .p85.  0.071  1   0.789
## 3   .p4. ==  .p86.  1.195  1   0.274
## 4   .p5. ==  .p87.  0.386  1   0.534
## 5   .p6. ==  .p88.  0.732  1   0.392
## 6   .p7. ==  .p89.  0.048  1   0.827
## 7   .p8. ==  .p90.  1.500  1   0.221
## 8   .p9. ==  .p91.  0.034  1   0.853
## 9  .p10. ==  .p92.  1.479  1   0.224
## 10 .p12. ==  .p94.  3.577  1   0.059
## 11 .p14. ==  .p96. 10.395  1   0.001
## 12 .p15. ==  .p97.  3.305  1   0.069
## 13 .p17. ==  .p99.  8.897  1   0.003
## 14 .p18. == .p100.  0.480  1   0.488
## 15 .p19. == .p101.  0.003  1   0.960
## 16 .p20. == .p102.  4.945  1   0.026
## 17 .p21. == .p103.  0.156  1   0.693
## 18 .p22. == .p104.  0.048  1   0.827
## 19 .p23. == .p105.  0.106  1   0.745
```

The univariate score test i.e. the chi-square difference test is used to see which equality constraint should be relaxed. Here, .p14 (F2 =~ ITEM15) has the largest chi-square difference.

```r
modelv4 <- '
F1 =~ ITEM1 + ITEM2 + ITEM3 + ITEM6 + ITEM8 + ITEM13 + ITEM14 + ITEM16 + ITEM20 + ITEM12
F2 =~ ITEM5 + ITEM10 + ITEM11 + ITEM15 + ITEM22
F3 =~ ITEM4 + ITEM7 + ITEM9 + ITEM12 + ITEM17 + ITEM18 + ITEM19 + ITEM21

# Residual Covariances
ITEM1 ~~ ITEM2
ITEM6 ~~ ITEM16
ITEM10 ~~ ITEM11

# Froup specific parameters
ITEM4 ~~ c(NA,0)*ITEM7
F1 =~ c(0,NA)*ITEM11
ITEM9 ~~ c(0,NA)*ITEM19
'

fit_modelv4 <- cfa(modelv4, group.equal=c("loadings"), group.partial=c("F1 =~ ITEM11", "F2 =~ ITEM11",
              "F2 =~ ITEM15"), data = secel, estimator = "MLM", group = "group")

Measurement_Parameter_item11and15 <-fitMeasures(fit_modelv4, c("chisq.scaled","df.scaled", "pvalue.scal
Measurement_Parameter_item11and15
```

```
##  chisq.scaled     df.scaled pvalue.scaled    cfi.robust    tli.robust
##       961.653       419.000         0.000         0.940         0.934
##  rmsea.robust          srmr
##         0.051         0.054
```

The model has slightly improved as compared to the previous model. The x2 is 961.653, with 419 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.940 and 0.934 respectively. The value of RMSEA and SRMR indices are 0.051 and 0.054 respectively.

Comparing modelv3 and modelv4

```r
options(scipen=999)
compareFit(fit_modelv3, fit_modelv4, nested = FALSE)
```

```
## ####################### Model Fit Indices ###########################
##             chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust
## fit_modelv4     961.653†       419          .000      .940†      .934†
## fit_modelv3     969.990        420          .000      .939       .933
##                    aic        bic rmsea.robust  srmr
## fit_modelv4 88171.685† 88846.119†        .051† .054†
## fit_modelv3 88180.031  88849.316         .051  .054
```

```r
anova(fit_modelv3, fit_modelv4)
```

```
## Scaled Chi Square Difference Test (method = "satorra.bentler.2001")
##
##              Df   AIC   BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## fit_modelv4 419 88172 88846 1215.1
## fit_modelv3 420 88180 88849 1225.4     8.7529       1   0.003091 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Comparison of modelV4 with the con???gural model

```r
anova(fit_modelv1, fit_modelv4)
```

```
## Scaled Chi Square Difference Test (method = "satorra.bentler.2001")
##
##              Df   AIC   BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## fit_modelv1 401 88182 88950 1189.8
## fit_modelv4 419 88172 88846 1215.1     20.964      18     0.2812
```

The chi-square difference between the final and the configural model is 20.964 and is not statistically significant(0.28). And all the items in MBI operate equivalently in both teacher groups except (for items 11 and 15, both of which load on Factor2).

Residual Covariances (constrained equal)

```r
modelv5 <- '
F1 =~ ITEM1 + ITEM2 + ITEM3 + ITEM6 + ITEM8 + ITEM13 + ITEM14 + ITEM16 + ITEM20 + ITEM12
F2 =~ ITEM5 + ITEM10 + ITEM11 + ITEM15 + ITEM22
F3 =~ ITEM4 + ITEM7 + ITEM9 + ITEM12 + ITEM17 + ITEM18 + ITEM19 + ITEM21

# Residual Covariances
ITEM1 ~~ c(v1,v1)*ITEM2
ITEM6 ~~ c(v2,v2)*ITEM16
ITEM10 ~~ c(v3,v3)*ITEM11

# Group specific parameters
ITEM4 ~~ c(NA,0)*ITEM7
F1 =~ c(0,NA)*ITEM11
ITEM9 ~~ c(0,NA)*ITEM19
'

fit_modelv5 <- cfa(modelv5, group.equal=c("loadings"), group.partial=c("F1 =~ ITEM11", "F2 =~ ITEM11",
              "F2 =~ ITEM15"), data = secel, estimator = "MLM", group = "group")

Measurement_Parameter_item11and15_3rescor <-fitMeasures(fit_modelv5, c("chisq.scaled","df.scaled", "pval
Measurement_Parameter_item11and15_3rescor
```

```
##   chisq.scaled     df.scaled pvalue.scaled    cfi.robust    tli.robust
##        973.378       422.000         0.000         0.939         0.933
##   rmsea.robust          srmr
##          0.051         0.054
```

Comparing modelv4 and modelv5

```r
options(scipen=999)
compareFit(fit_modelv4, fit_modelv5, nested = FALSE)
```

```
## ####################### Model Fit Indices ###########################
##             chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust
## fit_modelv4     961.653†       419          .000      .940†      .934†
## fit_modelv5     973.378        422          .000      .939       .933
##                     aic        bic rmsea.robust  srmr
## fit_modelv4 88171.685† 88846.119         .051† .054†
## fit_modelv5 88181.753  88840.742†        .051  .054
```

```r
anova(fit_modelv4, fit_modelv5)
```

```
## Scaled Chi Square Difference Test (method = "satorra.bentler.2001")
##
```

```
##               Df   AIC   BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## fit_modelv4 419 88172 88846 1215.1
## fit_modelv5 422 88182 88841 1231.1     11.123       3    0.01108 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The statistics changed a bit as compared to the previous model. The x2 is 973.378, with 422 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.939 and 0.933 respectively. The value of RMSEA and SRMR indices are 0.051 and 0.054 respectively and similar to the previous model.

Contrary to Byrne output, the chi-square difference between the current and the previous model is 11.12 and is statistically significant(0.01). However, modelv5 will be considered as the final model with all the three residual covariances operating equivalently across the groups (according to the lecture material)

Testing the invariance of the structural parameters

```
modelv6 <- '
F1 =~ ITEM1 + ITEM2 + ITEM3 + ITEM6 + ITEM8 + ITEM13 + ITEM14 + ITEM16 + ITEM20 + ITEM12
F2 =~ ITEM5 + ITEM10 + ITEM11 + ITEM15 + ITEM22
F3 =~ ITEM4 + ITEM7 + ITEM9 + ITEM12 + ITEM17 + ITEM18 + ITEM19 + ITEM21

# Residual Covariances
ITEM1 ~~ c(v1,v1)*ITEM2
ITEM6 ~~ c(v2,v2)*ITEM16
ITEM10 ~~ c(v3,v3)*ITEM11

# Group specific parameters
ITEM4 ~~ c(NA,0)*ITEM7
F1 =~ c(0,NA)*ITEM11
ITEM9 ~~ c(0,NA)*ITEM19
'

fit_modelv6 <- cfa(modelv6, group.equal=c("loadings", "lv.variances", "lv.covariances"), group.partial=c
              "F2 =~ ITEM15"), data = secel, estimator = "MLM", group = "group")

Structural_parameter_facvar_covar <- fitMeasures(fit_modelv6, c("chisq.scaled","df.scaled", "pvalue.scal
Structural_parameter_facvar_covar
```

```
##  chisq.scaled     df.scaled pvalue.scaled    cfi.robust    tli.robust
##       986.389       428.000         0.000         0.938         0.933
##  rmsea.robust          srmr
##         0.051         0.059
```

Comparing modelv5 and modelv6

```
options(scipen=999)
compareFit(fit_modelv5, fit_modelv6, nested = FALSE)
```

```
## ####################### Model Fit Indices ###########################
##             chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust
## fit_modelv5     973.378†       422          .000      .939†       .933
## fit_modelv6     986.389        428          .000      .938        .933†
##                      aic        bic rmsea.robust  srmr
## fit_modelv5 88181.753† 88840.742         .051  .054†
## fit_modelv6 88184.837  88812.935†        .051† .059
```

```
anova(fit_modelv6, fit_modelv5)
```

```
## Scaled Chi Square Difference Test (method = "satorra.bentler.2001")
##
##               Df   AIC   BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## fit_modelv5 422 88182 88841 1231.1
## fit_modelv6 428 88185 88813 1246.2     12.941       6    0.04398 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Contrary to the lecture materials, the x2 difference is 12.94 and is statistically significant (0.04). The factor variances and covariances are not operating equivalent across the groups.

Exercise 5.3

Summarize the whole invariance

```r
options(scipen=999)

compareFit(fit_modelv1, fit_modelv2, fit_modelv3, fit_modelv4, fit_modelv5, fit_modelv6, nested = FALSE)
```

```
## ####################### Model Fit Indices ###########################
##              chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust
## fit_modelv1     939.696†       401          .000      .940†       .931
## fit_modelv4     961.653        419          .000      .940        .934†
## fit_modelv3     969.990        420          .000      .939        .933
## fit_modelv2     995.433        421          .000      .937        .930
## fit_modelv5     973.378        422          .000      .939        .933
## fit_modelv6     986.389        428          .000      .938        .933
##                    aic        bic rmsea.robust  srmr
## fit_modelv1 88182.435  88949.539         .052  .051†
## fit_modelv4 88171.685† 88846.119         .051† .054
## fit_modelv3 88180.031  88849.316         .051  .054
## fit_modelv2 88210.287  88874.424         .052  .057
## fit_modelv5 88181.753  88840.742         .051  .054
## fit_modelv6 88184.837  88812.935†        .051  .059
```

```r
final <- rbind(Configural_model, Measurement_Parameter_allfactors, Measurement_Parameter_item11, Measure

kable(final, "latex", caption = "Summarizing model fit", booktabs = T) %>%
kable_styling(latex_options = c("striped", "hold_position", "scale_down"))
```

Table 1: Summarizing model fit

	chisq.scaled	df.scaled	pvalue.scaled	cfi.robust	tli.robust	rmsea.robust	srmr
Configural_model	939.6961	401	0	0.9403789	0.9313093	0.0517150	0.0507315
Measurement_Parameter_allfactors	995.4334	421	0	0.9365608	0.9303827	0.0520626	0.0566389
Measurement_Parameter_item11	969.9898	420	0	0.9392658	0.9331924	0.0510012	0.0543186
Measurement_Parameter_item11and15	961.6527	419	0	0.9400668	0.9339161	0.0507242	0.0538569
Measurement_Parameter_item11and15_3rescor	973.3782	422	0	0.9390411	0.9332630	0.0509743	0.0543318
Structural_parameter_facvar_covar	986.3891	428	0	0.9383339	0.9334352	0.0509085	0.0590753

As per my results, all the items in MBI operate equivalently in both teacher groups except (for items 11 and 15, both of which load on Factor2). All the three residual covariances does not operate equivalently across the groups. The factor variances and covariances does not remain equivalent across elementary and secondary teachers.

Week 6 SEM Assignment

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24-02-2019

TITLE: Validating Hypothesized Causal Structure for Calibration Group Initial Baseline model (Byrne 2012, p. 264)

Exercise 6.1

Specify and establish – step by step – a well fitting and parsimonious baseline model for the calibration group.

```
data1 <- read.table("~/sem2019/ELEMIND1.txt", quote="\"", comment.char="")

data2 <- read.table("~/sem2019/ELEMIND2.txt", quote="\"", comment.char="")
```

Creating names for all the variables

```
var <-c("ROLEA1","ROLEA2","ROLEC1","ROLEC2", "WORK1","WORK2","CCLIM1","CCLIM2", "CCLIM3","CCLIM4","DEC1


colnames(data1) <- var

var1 <- c("ROLEA1","ROLEA2","ROLEC1","ROLEC2", "WORK1","WORK2","CCLIM1","CCLIM2", "CCLIM3","CCLIM4","DE


colnames(data2) <- var1
```

This is an example of the multiple-group analyses of SEM: testing the invariance (equivalence) of a causal structure using the approach of cross-validation.

The dataset has sample of Elementary School Teachers (N=1203), randomly split into the calibration group (N=602) and validation group (N=601).

The first sample serves as the calibration sample on which the initially hypothesized model is tested along with any post hoc analyses necessary for attaining a well fitting model.

The second sample is then used as the validation sample for testing the structure of the final model that was created with the calibration sample.

The aim is to to test the replicability of a full SEM across groups.

Establishing a baseline model for the calibration group

```
model1<-'
F1 =~ ROLEA1 + ROLEA2
F2 =~ ROLEC1 + ROLEC2
F3 =~ WORK1 + WORK2
F4 =~ CCLIM1 + CCLIM2 + CCLIM3 + CCLIM4
F5 =~ DEC1 + DEC2
F6 =~ SSUP1 + SSUP2
F7 =~ PSUP1 + PSUP2
F8 =~ SELF1 + SELF2 + SELF3
F9 =~ ELC1 + ELC2 + ELC3 + ELC4 + ELC5
F10 =~ EE1 + EE2 + EE3
F11 =~ DP1 + DP2
```

```
F12 =~ PA1 + PA2 + PA3

#Regressions
F8 ~ F5 + F6 + F7
F9 ~ F5
F10 ~ F2 + F3 + F4
F11 ~ F2 + F10
F12 ~ F1 + F8 + F9 + F10 + F11
'

fit1<-cfa(model1, data=data1, estimator="MLM")
```

```
## Warning in lav_object_post_check(object): lavaan WARNING: covariance matrix of latent variables
##                 is not positive definite;
##                 use lavInspect(fit, "cov.lv") to investigate.
```

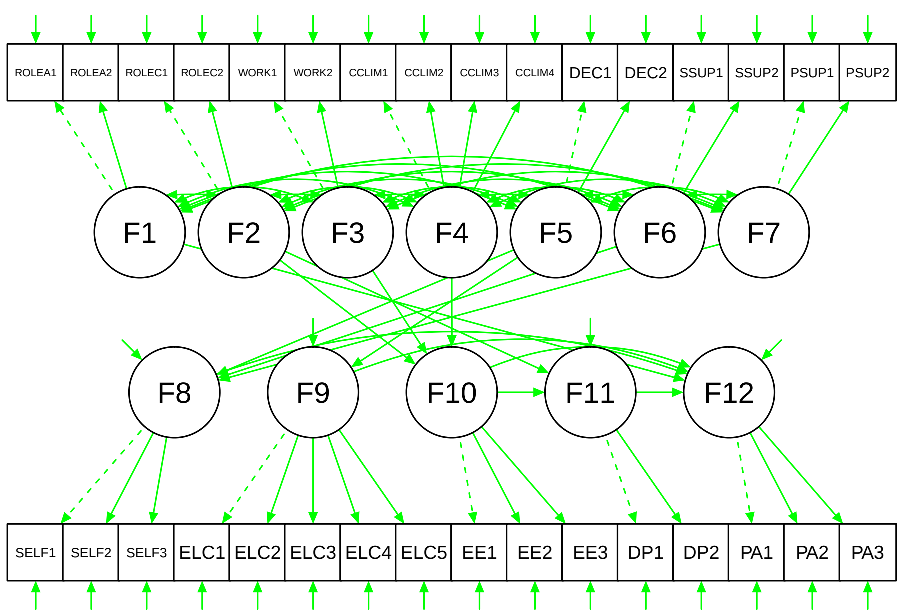
```
Model1 <- fitMeasures(fit1, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.robust",
```

Testing the hypothesized model and then modify it step by step to fit the sample data considering both parsimony and goodness-of-fit.

So, the output includes a warning that "the latent variable covariance matrix is not positive definite."

Creating the graph

```
semPaths(fit1, style = "lisrel", intercepts = FALSE, edge.label.cex=0.75, edge.color="green")
```



Model Modification indices for model 1

```
modindices(fit1, minimum = 20, sort. = TRUE)
```

```
## Warning in lav_start_check_cov(lavpartable = lavpartable, start = START): lavaan WARNING: starting va
##                     variables involved are: F2 F3

##        lhs op   rhs     mi    epc sepc.lv sepc.all sepc.nox
## 1019    F9  ~    F2 50.706  0.264   0.491    0.491    0.491
## 151     F2 =~  DEC2 47.464  0.771   0.605    0.487    0.487
## 170     F2 =~   PA2 47.097  0.773   0.606    0.696    0.696
## 1020    F9  ~    F3 47.056  0.234   0.475    0.475    0.475
## 181     F3 =~  DEC2 44.391  0.647   0.553    0.446    0.446
## 939    EE2 ~~   EE3 43.458 -0.716  -0.716   -1.911   -1.911
## 271     F6 =~  DEC2 35.370  0.979   1.068    0.860    0.860
## 1017    F9  ~    F6 34.747  0.362   0.938    0.938    0.938
## 1038   F11  ~    F4 34.215 -0.797  -0.292   -0.292   -0.292
## 1022    F9  ~    F1 32.749  0.306   0.497    0.497    0.497
## 1058    F6  ~    F9 30.179  0.395   0.153    0.153    0.153
## 986     F6 ~~    F9 30.141  0.056   0.136    0.136    0.136
## 225     F4 =~   DP1 30.030 -0.674  -0.231   -0.206   -0.206
## 196     F3 =~   EE3 29.805  0.351   0.300    0.221    0.221
## 1013    F9  ~    F8 28.735 -0.311  -0.268   -0.268   -0.268
## 751   DEC2 ~~ SSUP2 26.439  0.132   0.132    0.446    0.446
## 136     F1 =~   EE3 21.603  0.302   0.207    0.152    0.152
## 341     F8 =~   EE1 20.933  0.462   0.168    0.124    0.124
## 933    EE1 ~~   EE3 20.810 -0.336  -0.336   -0.807   -0.807
## 731   DEC1 ~~ SSUP2 20.793 -0.101  -0.101   -0.342   -0.342
## 882   ELC1 ~~  ELC2 20.631  0.048   0.048    0.225    0.225
```

The output says starting values imply a correlation larger than 1; variables involved are: F2 and F3 suggest overlapping between the factors of Role Conflict and Work Overload. So, combination these two factors into one will be involved in the next model.

Validating Causal Structure for Calibration Group Combined F2 (Role Conflict) and F3 (Work Overload)

```
model2<-
'

F1 =~ ROLEA1 + ROLEA2
F2 =~ ROLEC1 + ROLEC2
F3 =~ WORK1 + WORK2
F4 =~ CCLIM1 + CCLIM2 + CCLIM3 + CCLIM4
F5 =~ DEC1 + DEC2
F6 =~ SSUP1 + SSUP2
F7 =~ PSUP1 + PSUP2
F8 =~ SELF1 + SELF2 + SELF3
F9 =~ ELC1 + ELC2 + ELC3 + ELC4 + ELC5
F10 =~ EE1 + EE2 + EE3
F11 =~ DP1 + DP2
F12 =~ PA1 + PA2 +  PA3

# Regressions


'
fit2 <-cfa(model2, data=data1, estimator="MLM")
```

```
## Warning in lav_object_post_check(object): lavaan WARNING: covariance matrix of latent variables
##                  is not positive definite;
##                  use lavInspect(fit, "cov.lv") to investigate.
```

```
Model2 <- fitMeasures(fit2, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.robust",
```

Comparison of model 1 and 2

```
options(scipen=999)
compareFit(fit1,fit2, nested = FALSE)
```

```
## ####################### Model Fit Indices ###########################
##      chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust        aic
## fit2     717.033†       398          .000      .965†      .956† 39658.557†
## fit1     885.812        429          .000      .950       .942  39784.710
##             bic rmsea.robust  srmr
## fit2 40230.590         .038† .038†
## fit1 40220.336†        .044  .057
```

```
anova(fit1, fit2)
```

```
## Scaled Chi Square Difference Test (method = "satorra.bentler.2001")
##
##       Df   AIC   BIC  Chisq Chisq diff Df diff            Pr(>Chisq)
## fit2 398 39659 40231 792.31
## fit1 429 39785 40220 980.46     166.38      31 < 0.00000000000000022 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

For Model 1: The x2 is 885.812, with 429 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.950 and 0.942 respectively. The value of RMSEA and SRMR indices are 0.044 and 0.057 respectively.

For Model 2: The x2 is 942.192, with 436 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.944 and 0.936 respectively. The value of RMSEA and SRMR indices are 0.046 and 0.062 respectively.

The chi-square difference is significant.

The model has improved with the calibration data.

Model Modification indices for model 2

```
modindices(fit2, minimum = 20, sort. = TRUE)
```

```
## Warning in lav_start_check_cov(lavpartable = lavpartable, start = START): lavaan WARNING: starting va
##                     variables involved are: F2 F3
```

```
##      lhs op   rhs     mi    epc sepc.lv sepc.all sepc.nox
## 492  F12 =~   EE3 38.090 -0.356  -0.252   -0.186   -0.186
## 963  EE1 ~~   EE2 36.067  0.246   0.246    0.725    0.725
## 782 DEC2 ~~ SSUP2 31.564  0.149   0.149    0.560    0.560
## 490  F12 =~   EE1 27.455  0.289   0.205    0.151    0.151
## 167   F1 =~   EE3 21.861  0.298   0.204    0.150    0.150
## 913 ELC1 ~~  ELC2 21.329  0.048   0.048    0.225    0.225
## 762 DEC1 ~~ SSUP2 20.464 -0.103  -0.103   -0.368   -0.368
```

Based on the modification indices mentioned above, F8 ON F2 (External Locus of Control on Role Conflict/Work Overload) and EE1 WITH EE2 (covariance between residuals) will be taken into consideration in the next models one by one.

Validating Hypothesized Causal Structure for Calibration Group Modified Baseline model (Byrne 2012, p. 268) Combined F2 and F3, re-numbered the factors Added F8 ON F2 (External

Locus of Control on Role Conflict/Work Overload)

```
model3 <-

'
F1 =~ ROLEA1 + ROLEA2
F2 =~ ROLEC1 + ROLEC2 + WORK1 + WORK2
F3 =~ CCLIM1 + CCLIM2 + CCLIM3 + CCLIM4
F4 =~ DEC1 + DEC2
F5 =~ SSUP1 + SSUP2
F6 =~ PSUP1 + PSUP2
F7 =~ SELF1 + SELF2 + SELF3
F8 =~ ELC1 + ELC2 + ELC3 + ELC4 + ELC5
F9 =~ EE1 + EE2 + EE3
F10 =~ DP1 + DP2
F11 =~ PA1 + PA2 +  PA3

# Regressions
F7 ~ F4 + F5 + F6
F8 ~ F2 + F4
F9 ~ F2 + F3
F10 ~ F2 + F9
F11 ~ F1 + F7 + F8 + F9 + F10
'

fit3 <-cfa(model3, data=data1, estimator="MLM")

Model3 <- fitMeasures(fit3, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.robust",
```

Validating Hypothesized Causal Structure for Calibration Group Modified Baseline model (Byrne 2012, p. 268-) Combined F2 and F3, re-numbered the factors Added F8 ON F2 Added EE1 WITH EE2(covariance between residuals)

```
model4 <-

'
F1 =~ ROLEA1 + ROLEA2
F2 =~ ROLEC1 + ROLEC2 + WORK1 + WORK2
F3 =~ CCLIM1 + CCLIM2 + CCLIM3 + CCLIM4
F4 =~ DEC1 + DEC2
F5 =~ SSUP1 + SSUP2
F6 =~ PSUP1 + PSUP2
F7 =~ SELF1 + SELF2 + SELF3
F8 =~ ELC1 + ELC2 + ELC3 + ELC4 + ELC5
F9 =~ EE1 + EE2 + EE3
F10 =~ DP1 + DP2
F11 =~ PA1 + PA2 +  PA3

# Regressions
F7 ~ F4 + F5 + F6
F8 ~ F2 + F4
F9 ~ F2 + F3
F10 ~ F2 + F9
F11 ~ F1 + F7 + F8 + F9 + F10
```

```
# Covariances
EE1 ~~ EE2
'

fit4 <-cfa(model4, data=data1, estimator="MLM")
summary(fit4)
```

```
## lavaan 0.6-3 ended normally after 102 iterations
##
##   Optimization method                           NLMINB
##   Number of free parameters                         94
##
##   Number of observations                           602
##
##   Estimator                                         ML      Robust
##   Model Fit Test Statistic                     943.702     856.472
##   Degrees of freedom                               434         434
##   P-value (Chi-square)                           0.000       0.000
##   Scaling correction factor                                  1.102
##     for the Satorra-Bentler correction
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard Errors                           Robust.sem
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   F1 =~
##     ROLEA1            1.000
##     ROLEA2            1.184    0.077   15.307    0.000
##   F2 =~
##     ROLEC1            1.000
##     ROLEC2            1.334    0.080   16.638    0.000
##     WORK1             1.119    0.064   17.373    0.000
##     WORK2             1.014    0.085   11.930    0.000
##   F3 =~
##     CCLIM1            1.000
##     CCLIM2            1.342    0.105   12.794    0.000
##     CCLIM3            1.002    0.091   10.982    0.000
##     CCLIM4            1.424    0.109   13.086    0.000
##   F4 =~
##     DEC1              1.000
##     DEC2              1.300    0.069   18.767    0.000
##   F5 =~
##     SSUP1             1.000
##     SSUP2             1.064    0.029   36.593    0.000
##   F6 =~
##     PSUP1             1.000
##     PSUP2             1.039    0.061   17.026    0.000
##   F7 =~
##     SELF1             1.000
##     SELF2             1.223    0.075   16.239    0.000
```

```
##     SELF3             1.371    0.078   17.611    0.000
##   F8 =~
##     ELC1              1.000
##     ELC2              0.845    0.061   13.760    0.000
##     ELC3              1.029    0.068   15.104    0.000
##     ELC4              1.039    0.068   15.306    0.000
##     ELC5              1.288    0.080   16.054    0.000
##   F9 =~
##     EE1               1.000
##     EE2               1.033    0.028   37.081    0.000
##     EE3               1.142    0.048   23.595    0.000
##   F10 =~
##     DP1               1.000
##     DP2               0.898    0.067   13.329    0.000
##   F11 =~
##     PA1               1.000
##     PA2               0.879    0.062   14.181    0.000
##     PA3               0.848    0.074   11.434    0.000
##
## Regressions:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   F7 ~
##     F4                1.072    0.361    2.974    0.003
##     F5               -0.588    0.219   -2.684    0.007
##     F6               -0.104    0.088   -1.179    0.239
##   F8 ~
##     F2                0.276    0.039    6.997    0.000
##     F4               -0.047    0.034   -1.382    0.167
##   F9 ~
##     F2                0.838    0.078   10.787    0.000
##     F3               -0.685    0.147   -4.648    0.000
##   F10 ~
##     F2                0.081    0.085    0.944    0.345
##     F9                0.525    0.060    8.692    0.000
##   F11 ~
##     F1               -0.107    0.077   -1.386    0.166
##     F7                0.299    0.109    2.754    0.006
##     F8               -0.058    0.093   -0.620    0.535
##     F9               -0.115    0.048   -2.400    0.016
##     F10              -0.221    0.065   -3.384    0.001
##
## Covariances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##  .EE1 ~~
##    .EE2               0.268    0.050    5.344    0.000
##   F1 ~~
##     F2                0.420    0.042    9.939    0.000
##     F3               -0.088    0.015   -5.726    0.000
##     F4               -0.401    0.040   -9.970    0.000
##     F5               -0.503    0.053   -9.533    0.000
##     F6               -0.280    0.032   -8.744    0.000
##   F2 ~~
##     F3               -0.107    0.017   -6.339    0.000
##     F4               -0.398    0.043   -9.360    0.000
```

```
##     F5                -0.474    0.052   -9.092    0.000
##     F6                -0.262    0.034   -7.672    0.000
##   F3 ~~
##     F4                 0.097    0.017    5.539    0.000
##     F5                 0.108    0.023    4.702    0.000
##     F6                 0.068    0.017    4.108    0.000
##   F4 ~~
##     F5                 0.806    0.063   12.864    0.000
##     F6                 0.398    0.041    9.647    0.000
##   F5 ~~
##     F6                 0.433    0.049    8.760    0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|)
##    .ROLEA1             0.440    0.040   11.078    0.000
##    .ROLEA2             0.318    0.045    7.082    0.000
##    .ROLEC1             0.669    0.044   15.285    0.000
##    .ROLEC2             0.651    0.055   11.801    0.000
##    .WORK1              0.589    0.046   12.848    0.000
##    .WORK2              0.873    0.076   11.526    0.000
##    .CCLIM1             0.189    0.012   15.681    0.000
##    .CCLIM2             0.147    0.013   11.026    0.000
##    .CCLIM3             0.158    0.012   13.415    0.000
##    .CCLIM4             0.253    0.021   11.916    0.000
##    .DEC1               0.577    0.038   15.277    0.000
##    .DEC2               0.559    0.047   11.811    0.000
##    .SSUP1              0.316    0.037    8.574    0.000
##    .SSUP2              0.161    0.030    5.346    0.000
##    .PSUP1              0.322    0.045    7.201    0.000
##    .PSUP2              0.168    0.038    4.436    0.000
##    .SELF1              0.088    0.009    9.523    0.000
##    .SELF2              0.095    0.013    7.477    0.000
##    .SELF3              0.067    0.008    8.265    0.000
##    .ELC1               0.185    0.013   14.069    0.000
##    .ELC2               0.245    0.017   14.599    0.000
##    .ELC3               0.159    0.012   13.707    0.000
##    .ELC4               0.237    0.017   13.902    0.000
##    .ELC5               0.174    0.017   10.479    0.000
##    .EE1                0.621    0.055   11.237    0.000
##    .EE2                0.538    0.059    9.120    0.000
##    .EE3                0.253    0.045    5.594    0.000
##    .DP1                0.385    0.060    6.390    0.000
##    .DP2                0.489    0.068    7.192    0.000
##    .PA1                0.166    0.026    6.398    0.000
##    .PA2                0.374    0.041    9.204    0.000
##    .PA3                0.385    0.043    8.931    0.000
##     F1                 0.469    0.054    8.709    0.000
##     F2                 0.577    0.063    9.200    0.000
##     F3                 0.118    0.018    6.684    0.000
##     F4                 0.582    0.060    9.780    0.000
##     F5                 1.194    0.096   12.385    0.000
##     F6                 0.619    0.056   10.990    0.000
##    .F7                 0.095    0.015    6.500    0.000
##    .F8                 0.121    0.014    8.412    0.000
```

```
##    .F9                0.633    0.061   10.350    0.000
##    .F10               0.485    0.066    7.340    0.000
##    .F11               0.331    0.040    8.279    0.000
```

```r
Model4 <- fitMeasures(fit4, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.robust",
```

Comparison of model 3 and 4

```r
options(scipen=999)
compareFit(fit3,fit4, nested = FALSE)
```

```
## ####################### Model Fit Indices ###########################
##      chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust        aic
## fit4     856.472†       434          .000      .954†      .947† 39737.952†
## fit3     894.660        435          .000      .949       .942  39781.271
##             bic rmsea.robust  srmr
## fit4 40151.576†        .042† .049†
## fit3 40190.495         .044  .052
```

```r
anova(fit3, fit4)
```

```
## Scaled Chi Square Difference Test (method = "satorra.bentler.2001")
##
##       Df   AIC   BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## fit4 434 39738 40152 943.70
## fit3 435 39781 40190 989.02     16.922       1 0.00003896 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

For Model 3: The x2 is 894.660, with 435 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.949 and 0.942 respectively. The value of RMSEA and SRMR indices are 0.044 and 0.052 respectively.

For Model 4: The x2 is 856.472, with 434 degrees of freedom. The p-value is 0.000. The CFI and TLI values are 0.954 and 0.947 respectively. The value of RMSEA and SRMR indices are 0.042 and 0.049 respectively.

The chi-square difference is again significant.

Model Modification indices for model 4

```r
modindices(fit4, minimum = 20, sort. = TRUE)
```

```
##        lhs op    rhs     mi    epc sepc.lv sepc.all sepc.nox
## 976     F9  ~     F7 28.572 -0.687  -0.226   -0.226   -0.226
## 187     F3 =~    DP1 27.526 -0.658  -0.226   -0.202   -0.202
## 990    F10  ~     F3 27.471 -0.718  -0.264   -0.264   -0.264
## 978     F9  ~    F10 27.471 -1.367  -1.157   -1.157   -1.157
## 958     F9 ~~    F10 27.470 -0.664  -1.197   -1.197   -1.197
## 933     F3 ~~     F9 27.302  0.485   1.772    1.772    1.772
## 1039    F3  ~     F9 27.301  0.765   2.457    2.457    2.457
## 938     F4 ~~     F9 26.924 -0.055  -0.090   -0.090   -0.090
## 999     F4  ~     F9 26.924 -0.086  -0.125   -0.125   -0.125
## 340     F9 =~ ROLEC1 26.176 -0.264  -0.291   -0.261   -0.261
## 143     F2 =~   DEC2 24.923  0.501   0.381    0.307    0.307
## 563  WORK1 ~~    EE1 24.824  0.122   0.122    0.202    0.202
## 934     F3 ~~    F10 24.325 -0.066  -0.274   -0.274   -0.274
## 962     F7  ~     F9 23.982 -0.101  -0.306   -0.306   -0.306
## 693   DEC1 ~~  SSUP2 23.926 -0.111  -0.111   -0.363   -0.363
## 342     F9 =~  WORK1 23.703  0.248   0.274    0.239    0.239
## 952     F7 ~~     F9 23.129 -0.063  -0.257   -0.257   -0.257
```

```
## 963      F7   ~     F10 22.273 -0.097  -0.249   -0.249   -0.249
## 1009     F5   ~      F9 21.455  0.125   0.126    0.126    0.126
## 943      F5 ~~      F9 21.455  0.079   0.091    0.091    0.091
## 844    ELC1 ~~    ELC2 20.528  0.047   0.047    0.222    0.222
## 233      F5 =~    DEC2 20.101  0.944   1.031    0.830    0.830
```

As seen from the summary of model 4, there are five parameter estimates statistically non-significant. These non-significant paths will be deleted to establish baseline model for the calibration group.

Validating Hypothesized Causal Structure for Calibration Group Modified Baseline model (Byrne 2012, p. 268-) Combined F2 and F3, re-numbered the factors Added F8 ON F2 Added EE1 WITH EE2 Deleted n.s. params: F7 ON F6, F8 ON F4, F10 ON F2, F11 ON F1, F11 ON F8

```r
model5 <-

'
F1 =~ ROLEA1 + ROLEA2
F2 =~ ROLEC1 + ROLEC2 + WORK1 + WORK2
F3 =~ CCLIM1 + CCLIM2 + CCLIM3 + CCLIM4
F4 =~ DEC1 + DEC2
F5 =~ SSUP1 + SSUP2
F6 =~ PSUP1 + PSUP2
F7 =~ SELF1 + SELF2 + SELF3
F8 =~ ELC1 + ELC2 + ELC3 + ELC4 + ELC5
F9 =~ EE1 + EE2 + EE3
F10 =~ DP1 + DP2
F11 =~ PA1 + PA2 +  PA3

# Regressions
F7 ~ F4 + F5
F8 ~ F2
F9 ~ F2 + F3
F10 ~ F9
F11 ~ F1 + F7 + F10

# Covariances
EE1 ~~ EE2
'

fit5 <-cfa(model5, data=data1, estimator="MLM")
summary(fit5)
```

```
## lavaan 0.6-3 ended normally after 91 iterations
##
##   Optimization method                           NLMINB
##   Number of free parameters                         90
##
##   Number of observations                           602
##
##   Estimator                                         ML      Robust
##   Model Fit Test Statistic                     954.105     865.112
##   Degrees of freedom                               438         438
##   P-value (Chi-square)                           0.000       0.000
##   Scaling correction factor                                  1.103
##     for the Satorra-Bentler correction
```

```
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model          Structured
##   Standard Errors                           Robust.sem
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|)
##   F1 =~
##     ROLEA1            1.000
##     ROLEA2            1.183    0.077   15.310    0.000
##   F2 =~
##     ROLEC1            1.000
##     ROLEC2            1.330    0.080   16.633    0.000
##     WORK1             1.118    0.064   17.398    0.000
##     WORK2             1.011    0.085   11.895    0.000
##   F3 =~
##     CCLIM1            1.000
##     CCLIM2            1.341    0.105   12.808    0.000
##     CCLIM3            1.001    0.091   10.996    0.000
##     CCLIM4            1.422    0.109   13.098    0.000
##   F4 =~
##     DEC1              1.000
##     DEC2              1.298    0.069   18.803    0.000
##   F5 =~
##     SSUP1             1.000
##     SSUP2             1.067    0.030   36.109    0.000
##   F6 =~
##     PSUP1             1.000
##     PSUP2             1.030    0.060   17.115    0.000
##   F7 =~
##     SELF1             1.000
##     SELF2             1.221    0.075   16.241    0.000
##     SELF3             1.369    0.078   17.641    0.000
##   F8 =~
##     ELC1              1.000
##     ELC2              0.846    0.061   13.767    0.000
##     ELC3              1.028    0.068   15.094    0.000
##     ELC4              1.036    0.068   15.294    0.000
##     ELC5              1.289    0.080   16.077    0.000
##   F9 =~
##     EE1               1.000
##     EE2               1.032    0.028   36.979    0.000
##     EE3               1.128    0.047   23.855    0.000
##   F10 =~
##     DP1               1.000
##     DP2               0.918    0.068   13.560    0.000
##   F11 =~
##     PA1               1.000
##     PA2               0.892    0.064   14.014    0.000
##     PA3               0.857    0.077   11.158    0.000
##
## Regressions:
```

```
##                     Estimate  Std.Err  z-value  P(>|z|)
##   F7 ~
##     F4                 0.765    0.176    4.336    0.000
##     F5                -0.419    0.122   -3.424    0.001
##   F8 ~
##     F2                 0.312    0.030   10.299    0.000
##   F9 ~
##     F2                 0.848    0.077   11.016    0.000
##     F3                -0.694    0.147   -4.724    0.000
##   F10 ~
##     F9                 0.564    0.043   13.032    0.000
##   F11 ~
##     F1                -0.184    0.063   -2.929    0.003
##     F7                 0.317    0.109    2.905    0.004
##     F10               -0.313    0.051   -6.111    0.000
##
## Covariances:
##                     Estimate  Std.Err  z-value  P(>|z|)
##  .EE1 ~~
##    .EE2                0.254    0.050    5.114    0.000
##   F1 ~~
##     F2                 0.422    0.042    9.976    0.000
##     F3                -0.089    0.015   -5.767    0.000
##     F4                -0.409    0.040  -10.172    0.000
##     F5                -0.501    0.053   -9.482    0.000
##     F6                -0.283    0.032   -8.822    0.000
##   F2 ~~
##     F3                -0.107    0.017   -6.317    0.000
##     F4                -0.410    0.042   -9.748    0.000
##     F5                -0.477    0.052   -9.150    0.000
##     F6                -0.267    0.034   -7.795    0.000
##   F3 ~~
##     F4                 0.101    0.018    5.755    0.000
##     F5                 0.107    0.023    4.644    0.000
##     F6                 0.068    0.017    4.089    0.000
##   F4 ~~
##     F5                 0.806    0.063   12.838    0.000
##     F6                 0.389    0.040    9.659    0.000
##   F5 ~~
##     F6                 0.437    0.050    8.828    0.000
##  .F8 ~~
##    .F11               -0.012    0.012   -1.001    0.317
##
## Variances:
##                     Estimate  Std.Err  z-value  P(>|z|)
##    .ROLEA1             0.441    0.040   11.111    0.000
##    .ROLEA2             0.320    0.045    7.148    0.000
##    .ROLEC1             0.667    0.043   15.344    0.000
##    .ROLEC2             0.656    0.055   11.857    0.000
##    .WORK1              0.588    0.046   12.837    0.000
##    .WORK2              0.874    0.076   11.519    0.000
##    .CCLIM1             0.189    0.012   15.674    0.000
##    .CCLIM2             0.147    0.013   11.054    0.000
##    .CCLIM3             0.158    0.012   13.437    0.000
```

```
##    .CCLIM4            0.253    0.021   11.923    0.000
##    .DEC1              0.574    0.038   15.251    0.000
##    .DEC2              0.558    0.047   11.784    0.000
##    .SSUP1             0.318    0.037    8.491    0.000
##    .SSUP2             0.157    0.030    5.172    0.000
##    .PSUP1             0.316    0.044    7.149    0.000
##    .PSUP2             0.174    0.038    4.623    0.000
##    .SELF1             0.087    0.009    9.519    0.000
##    .SELF2             0.095    0.013    7.490    0.000
##    .SELF3             0.067    0.008    8.306    0.000
##    .ELC1              0.185    0.013   14.082    0.000
##    .ELC2              0.245    0.017   14.561    0.000
##    .ELC3              0.159    0.012   13.691    0.000
##    .ELC4              0.237    0.017   13.941    0.000
##    .ELC5              0.173    0.016   10.515    0.000
##    .EE1               0.607    0.055   10.998    0.000
##    .EE2               0.524    0.059    8.898    0.000
##    .EE3               0.275    0.044    6.225    0.000
##    .DP1               0.412    0.060    6.848    0.000
##    .DP2               0.480    0.067    7.146    0.000
##    .PA1               0.173    0.026    6.614    0.000
##    .PA2               0.368    0.040    9.107    0.000
##    .PA3               0.382    0.044    8.769    0.000
##     F1                0.468    0.054    8.702    0.000
##     F2                0.579    0.063    9.213    0.000
##     F3                0.118    0.018    6.691    0.000
##     F4                0.585    0.060    9.801    0.000
##     F5                1.193    0.097   12.355    0.000
##     F6                0.625    0.057   11.060    0.000
##    .F7                0.097    0.013    7.175    0.000
##    .F8                0.121    0.014    8.379    0.000
##    .F9                0.633    0.061   10.317    0.000
##    .F10               0.453    0.063    7.164    0.000
##    .F11               0.323    0.040    8.074    0.000
```

```
Model5 <- fitMeasures(fit5, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.robust",
```

Comparison of model 4 and 5

```
options(scipen=999)
compareFit(fit4,fit5, nested = FALSE)
```

```
## ####################### Model Fit Indices ###########################
##      chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust        aic
## fit4     856.472†       434          .000      .954†      .947† 39737.952†
## fit5     865.112        438          .000      .953       .947  39740.355
##              bic rmsea.robust  srmr
## fit4 40151.576         .042† .049†
## fit5 40136.378†        .042  .051
```

```
anova(fit4, fit5)
```

```
## Scaled Chi Square Difference Test (method = "satorra.bentler.2001")
##
##       Df   AIC   BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## fit4 434 39738 40152 943.70
```

```
## fit5 438 39740 40136 954.11      8.572       4    0.07273 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The chi-square difference is not statistically significant here with slight change in model fit as compared to the previous model.

Since there are no specified relations between either F1 or F6 and the rest of the factors, they will be deleted in the next model.

Validating Hypothesized Causal Structure for Calibration Group Modified Baseline model (Byrne 2012, p. 268-) Combined F2 and F3, re-numbered the factors Added F8 ON F2 Added EE1 WITH EE2 Deleted n.s. params: F7 ON F6, F8 ON F4, F10 ON F2, F11 ON F1, F11 ON F8 Removed factors F1 and F6 and their items (no specified relations)! (not yet renamed factors!)

```
model6 <-
  '
F2 =~ ROLEC1 + ROLEC2 + WORK1 + WORK2
F3 =~ CCLIM1 + CCLIM2 + CCLIM3 + CCLIM4
F4 =~ DEC1 + DEC2
F5 =~ SSUP1 + SSUP2
F7 =~ SELF1 + SELF2 + SELF3
F8 =~ ELC1 + ELC2 + ELC3 + ELC4 + ELC5
F9 =~ EE1 + EE2 + EE3
F10 =~ DP1 + DP2
F11 =~ PA1 + PA2 + PA3

#Regressions

F7 ~ F4 + F5
F8 ~ F2
F9 ~ F2 + F3
F10 ~ F9
F11 ~ F7 + F9 + F10

#Covariance

EE1 ~~ EE2

'


fit6 <-cfa(model6, data=data1, estimator="MLM")

Model6 <- fitMeasures(fit6, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.robust",
```

Comparison of model 5 and 6

```
anova(fit5, fit6)
```

```
## Warning in lavTestLRT(object = new("lavaan", version = "0.6.3", call =
## lavaan::lavaan(model = model5, : lavaan WARNING: some models are based on a
## different set of observed variables

## Scaled Chi Square Difference Test (method = "satorra.bentler.2001")
##
```

```
##       Df   AIC   BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## fit6 333 34447 34768 787.96
## fit5 438 39740 40136 954.11     147.05     105   0.004267 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Validating Hypothesized Causal Structure for Calibration Group Modified Baseline model (Byrne 2012, p. 268-) Combined F2 and F3, re-numbered the factors Added F8 ON F2 Added EE1 WITH EE2 Deleted n.s. params: F7 ON F6, F8 ON F4, F10 ON F2, F11 ON F1, F11 ON F8 Removed factors F1 and F6 and their items (no specified relations)! Renamed factors, deleted items from USEVARS, "revised model" (Byrne, p.275)

```
model7 <-

'
F1 =~ ROLEC1 + ROLEC2 + WORK1 + WORK2
F2 =~ CCLIM1 + CCLIM2 + CCLIM3 + CCLIM4
F3 =~ DEC1 + DEC2
F4 =~ SSUP1 + SSUP2
F5 =~ SELF1 + SELF2 + SELF3
F6 =~ ELC1 + ELC2 + ELC3 + ELC4 + ELC5
F7 =~ EE1 + EE2 + EE3
F8 =~ DP1 + DP2
F9 =~ PA1 + PA2 + PA3

#Regressions
F5 ~ F3 +  F4
F6 ~ F1
F7 ~ F1 + F2
F8 ~ F7
F9 ~ F5 + F7 + F8

#Res.covariance
EE1 ~~ EE2
'


fit7 <-cfa(model7, data=data1, estimator="MLM")

Model7 <- fitMeasures(fit7, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.robust",
```

TITLE: Validating Hypothesized Causal Structure for Calibration Group Modified Baseline model (Byrne 2012, p. 268-) Combined F2 and F3, re-numbered the factors Added F8 ON F2 Added EE1 WITH EE2 Deleted n.s. params: F7 ON F6, F8 ON F4, F10 ON F2, F11 ON F1, F11 ON F8 Removed factors F1 and F6 and their items (no specified relations)! Renamed factors, deleted items from USEVARS, "revised model" (Byrne, p.275) Fine-tuning: remove unwanted parameter F9 WITH F6 (see p.272, 278).

```
model8 <-

'
F1 =~ ROLEC1 + ROLEC2 + WORK1 + WORK2
F2 =~ CCLIM1 + CCLIM2 + CCLIM3 + CCLIM4
F3 =~ DEC1 + DEC2
F4 =~ SSUP1 + SSUP2
F5 =~ SELF1 + SELF2 + SELF3
```

```
F6 =~ ELC1 + ELC2 + ELC3 + ELC4 + ELC5
F7 =~ EE1 + EE2 + EE3
F8 =~ DP1 + DP2
F9 =~ PA1 + PA2 + PA3

#Regressions
F5 ~ F3 +  F4
F6 ~ F1
F7 ~ F1 + F2
F8 ~ F7
F9 ~ F5 + F7 + F8

#Res.covariance
EE1 ~~ EE2
F9 ~~ 0*F6
'


fit8 <-cfa(model8, data=data1, estimator="MLM")

Final_model <- fitMeasures(fit8, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.robu
```

/

```
options(scipen=999)
compareFit(fit1,fit2, fit3, fit4, fit5, fit6, fit7, fit8, nested = FALSE)
```

```
## ####################### Model Fit Indices ###########################
##      chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust        aic
## fit6     720.018        333          .000      .951       .944  34446.650
## fit7     720.018        333          .000      .951       .944  34446.650
## fit8     721.523        334          .000      .951       .944  34446.550†
## fit2     717.033†       398          .000      .965†      .956† 39658.557
## fit1     885.812        429          .000      .950       .942  39784.710
## fit4     856.472        434          .000      .954       .947  39737.952
## fit3     894.660        435          .000      .949       .942  39781.271
## fit5     865.112        438          .000      .953       .947  39740.355
##             bic rmsea.robust  srmr
## fit6 34767.869         .046  .053
## fit7 34767.869         .046  .053
## fit8 34763.368†        .046  .053
## fit2 40230.590         .038† .038†
## fit1 40220.336         .044  .057
## fit4 40151.576         .042  .049
## fit3 40190.495         .044  .052
## fit5 40136.378         .042  .051
```

```
final <- rbind(Model1, Model2, Model3, Model4, Model5, Model6, Model7, Final_model)

kable(final, "latex", caption = "Summarizing model fit", booktabs = T) %>%
kable_styling(latex_options = c("striped", "hold_position", "scale_down"))
```

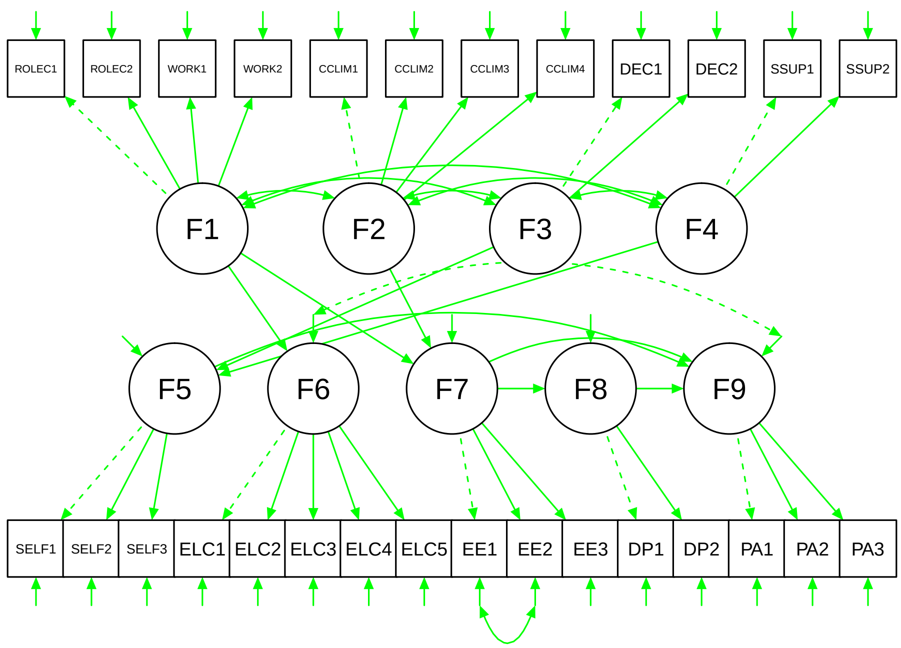
Final model seems to be parsimonious baseline model for the calibration group.

Creating the graph

Table 1: Summarizing model fit

	chisq.scaled	df.scaled	pvalue.scaled	cfi.robust	tli.robust	rmsea.robust	srmr
Model1	885.8116	429	0	0.9495947	0.9417226	0.0442472	0.0569313
Model2	717.0333	398	0	0.9648569	0.9562036	0.0383579	0.0380282
Model3	894.6600	435	0	0.9493436	0.9422401	0.0440504	0.0515388
Model4	856.4721	434	0	0.9535945	0.9469651	0.0422101	0.0492962
Model5	865.1122	438	0	0.9530414	0.9468231	0.0422666	0.0511050
Model6	720.0179	333	0	0.9510270	0.9444091	0.0459648	0.0525617
Model7	720.0179	333	0	0.9510270	0.9444091	0.0459648	0.0525617
Final_model	721.5229	334	0	0.9509475	0.9444855	0.0459332	0.0531382

```
semPaths(fit8, style = "lisrel", intercepts = FALSE, edge.label.cex=0.75, edge.color="green")
```



Exercise 6.2

** Testing for Equivalence of causal Structure Across Calibration and Validation groups Configural Model (no parameter constraints) (Byrne 2012, p. 278).**

The next step is to form and test the multigroup configural model with no parameter constraints.

```
# Combine data

cacel <- merge(data.frame(data1, group = "data1"), data.frame(data2, group = "data2"), all = TRUE, sort
```

```r
dim(cacel)
```

```
## [1] 1203   33
```

```r
fit9 <- cfa(model8, data=cacel, group="group", estimator="MLM")

Multigroup_configural_model <- fitMeasures(fit9, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.ro
```

```r
options(scipen=999)
compareFit(fit8, fit9, nested = FALSE)
```

```
## Warning in compareFit(fit8, fit9, nested = FALSE): fitMeasures() returned
## vectors of different lengths for different models, probably because
## certain options are not the same. Check lavInspect(fit, "options")
## [c("estimator","test","meanstructure")] for each model, or run
## fitMeasures() on each model to investigate.
```

```
## ####################### Model Fit Indices ###########################
##              aic        bic cfi.robust chisq.scaled df.scaled pvalue.scaled
## fit8 34446.550† 34763.368†      .951†     721.523†       334          .000
## fit9 68153.123  69171.638       .949     1484.062        668          .000
##      rmsea.robust  srmr tli.robust
## fit8        .046† .053†      .944†
## fit9        .047  .056       .942
```

```r
final <- rbind(Final_model, Multigroup_configural_model)

kable(final, "latex", caption = "Summarizing final and multigroup configural model fit", booktabs = T) %
kable_styling(latex_options = c("striped", "hold_position", "scale_down"))
```

Table 2: Summarizing final and multigroup configural model fit

	chisq.scaled	df.scaled	pvalue.scaled	cfi.robust	tli.robust	rmsea.robust	srmr
Final_model	721.5229	334	0	0.9509475	0.9444855	0.0459332	0.0531382
Multigroup_configural_model	1484.0618	668	0	0.9486303	0.9418630	0.0471248	0.0561398

Exercise 6.3

Testing for Equivalence of causal Structure Across Calibration and Validation groups Constrained Equal: factor loadings, intercepts, structural paths (Byrne 2012, p. 280)

```r
model9 <-

'
F1 =~ ROLEC1 + ROLEC2 + WORK1 + WORK2
F2 =~ CCLIM1 + CCLIM2 + CCLIM3 + CCLIM4
F3 =~ DEC1 + DEC2
F4 =~ SSUP1 + SSUP2
F5 =~ SELF1 + SELF2 + SELF3
F6 =~ ELC1 + ELC2 + ELC3 + ELC4 + ELC5
F7 =~ EE1 + EE2 + EE3
F8 =~ DP1 + DP2
F9 =~ PA1 + PA2 + PA3
```

```
#Regressions
F5 ~ F3 +  F4
F6 ~ F1
F7 ~ F1 + F2
F8 ~ F7
F9 ~ F5 + F7 + F8

#Res.covariance
EE1 ~~ EE2
F9 ~~ 0*F6
'

fit10 <- cfa(model9, data=cacel, group="group", estimator="MLM", group.equal=c("loadings"))

Model_loadings <- fitMeasures(fit10, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robust", "tli.r
```

```
model10 <-

'
F1 =~ ROLEC1 + ROLEC2 + WORK1 + WORK2
F2 =~ CCLIM1 + CCLIM2 + CCLIM3 + CCLIM4
F3 =~ DEC1 + DEC2
F4 =~ SSUP1 + SSUP2
F5 =~ SELF1 + SELF2 + SELF3
F6 =~ ELC1 + ELC2 + ELC3 + ELC4 + ELC5
F7 =~ EE1 + EE2 + EE3
F8 =~ DP1 + DP2
F9 =~ PA1 + PA2 + PA3

#Regressions
F5 ~ F3 +  F4
F6 ~ F1
F7 ~ F1 + F2
F8 ~ F7
F9 ~ F5 + F7 + F8

#Res.covariance
EE1 ~~ EE2
F9 ~~ 0*F6
'

fit11 <- cfa(model10, data=cacel, group="group", estimator="MLM", group.equal=c("loadings", "intercepts

Model_loadings_intercepts <- fitMeasures(fit11, c("chisq.scaled","df.scaled", "pvalue.scaled", "cfi.robu
```

```
model11 <-

'
F1 =~ ROLEC1 + ROLEC2 + WORK1 + WORK2
F2 =~ CCLIM1 + CCLIM2 + CCLIM3 + CCLIM4
F3 =~ DEC1 + DEC2
F4 =~ SSUP1 + SSUP2
F5 =~ SELF1 + SELF2 + SELF3
F6 =~ ELC1 + ELC2 + ELC3 + ELC4 + ELC5
```

```
F7 =~ EE1 + EE2 + EE3
F8 =~ DP1 + DP2
F9 =~ PA1 + PA2 + PA3

#Regressions
F5 ~ F3 +  F4
F6 ~ F1
F7 ~ F1 + F2
F8 ~ F7
F9 ~ F5 + F7 + F8

#Res.covariance
EE1 ~~ EE2
F9 ~~ 0*F6
'

fit12 <- cfa(model11, data=cacel, group="group", estimator="MLM", group.equal=c("loadings", "intercepts

Model_loadings_intercepts_regression <- fitMeasures(fit12, c("chisq.scaled","df.scaled", "pvalue.scaled
```

Comparison of models

```
options(scipen=999)
compareFit(fit9, fit10, fit11, fit12, nested = FALSE)
```

```
## ####################### Model Fit Indices ###########################
##       chisq.scaled df.scaled pvalue.scaled cfi.robust tli.robust
## fit9     1484.062†       668          .000      .949       .942
## fit10    1497.677        687          .000      .949†      .944
## fit11    1525.165        706          .000      .949       .945
## fit12    1533.400        715          .000      .949       .946†
##              aic        bic rmsea.robust  srmr
## fit9  68153.123  69171.638         .047  .056†
## fit10 68130.404  69052.160         .046  .057
## fit11 68115.851  68940.848         .046  .057
## fit12 68109.697† 68888.861†        .046† .058
```

```
final <- rbind(Final_model, Multigroup_configural_model, Model_loadings, Model_loadings_intercepts, Mode

kable(final, "latex", caption = "Summarizing final, multigroup configural model and testing for equival
kable_styling(latex_options = c("striped", "hold_position", "scale_down"))
```

Table 3: Summarizing final, multigroup configural model and testing for equivalence models

	chisq.scaled	df.scaled	pvalue.scaled	cfi.robust	tli.robust	rmsea.robust	srmr
Final_model	721.5229	334	0	0.9509475	0.9444855	0.0459332	0.0531382
Multigroup_configural_model	1484.0618	668	0	0.9486303	0.9418630	0.0471248	0.0561398
Model_loadings	1497.6766	687	0	0.9489570	0.9438304	0.0463206	0.0569002
Model_loadings_intercepts	1525.1651	706	0	0.9486271	0.9449888	0.0458404	0.0570396
Model_loadings_intercepts_regression	1533.3998	715	0	0.9485868	0.9456386	0.0455689	0.0580282

```
anova(fit9, fit12)
```

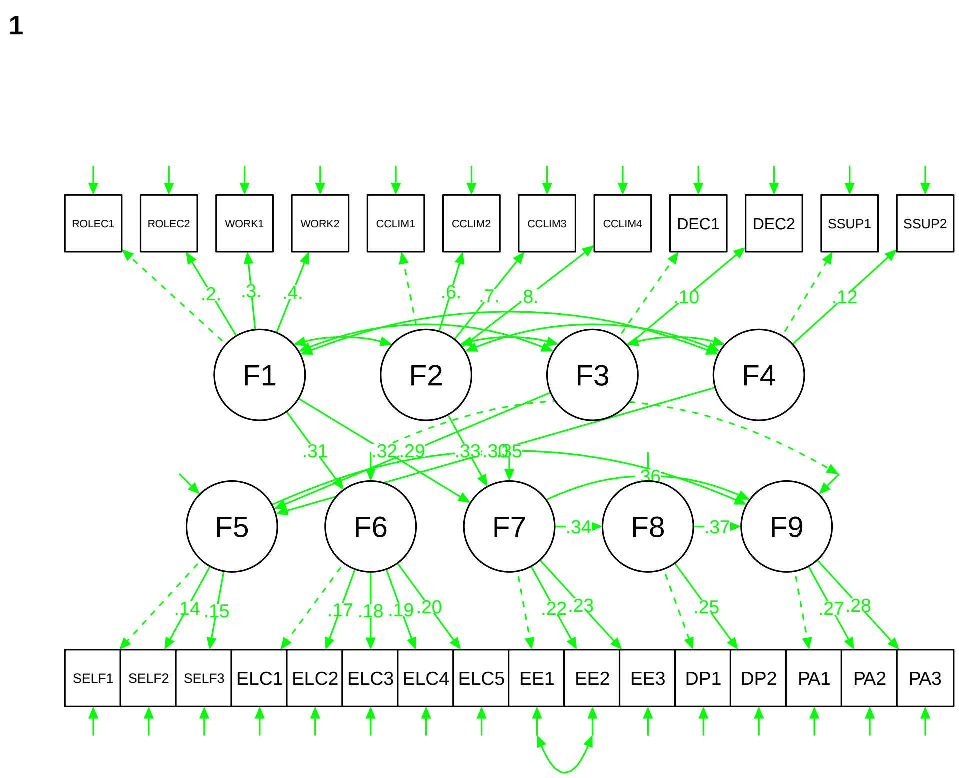
```
## Scaled Chi Square Difference Test (method = "satorra.bentler.2001")
##
```

```
##        Df   AIC   BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## fit9  668 68153 69172 1622.7
## fit12 715 68110 68889 1673.3     47.713      47     0.4436
```

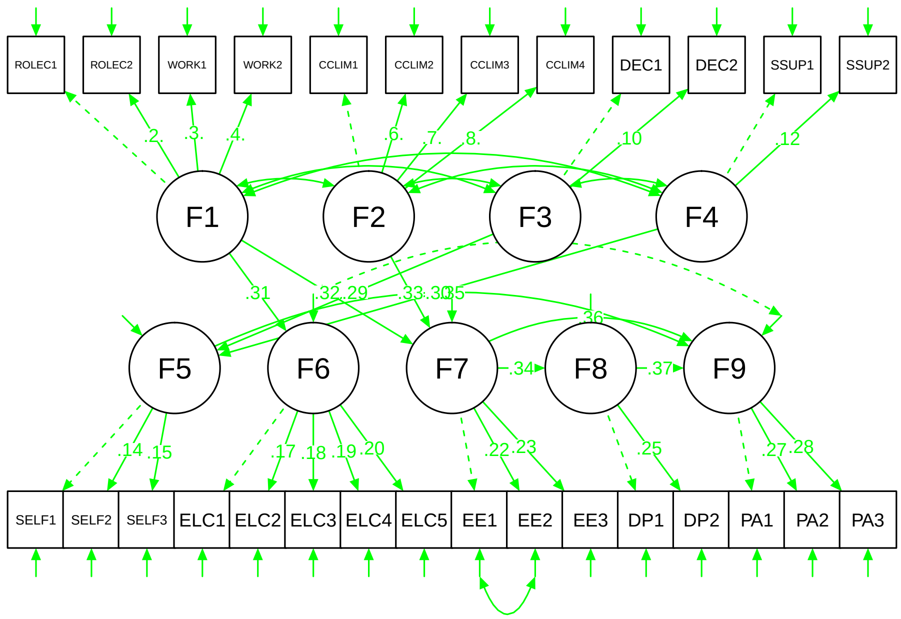
The final output shows good fit of the data. The CFI, RMSEA and SRMR has tiny changes as compared to the configural model. The chi-square difference is not statistically significant.

Creating the graph

```r
semPaths(fit12, style = "lisrel", intercepts = FALSE, edge.label.cex=0.75, edge.color="green")
```



2



ROLEC1
ROLEC2
WORK1
WORK2
CCLIM1
CCLIM2
CCLIM3
CCLIM4
DEC1
DEC2
SSUP1
SSUP2
F1
F2
F3
F4
F5
F6
F7
F8
F9
SELF1
SELF2
SELF3
ELC1
ELC2
ELC3
ELC4
ELC5
EE1
EE2
EE3
DP1
DP2
PA1
PA2
PA3