2019R2 STAT6108 Assignment 4

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```
# import data
teachers <- read.csv('hw4(2020).dat', header = FALSE, sep = '')
```

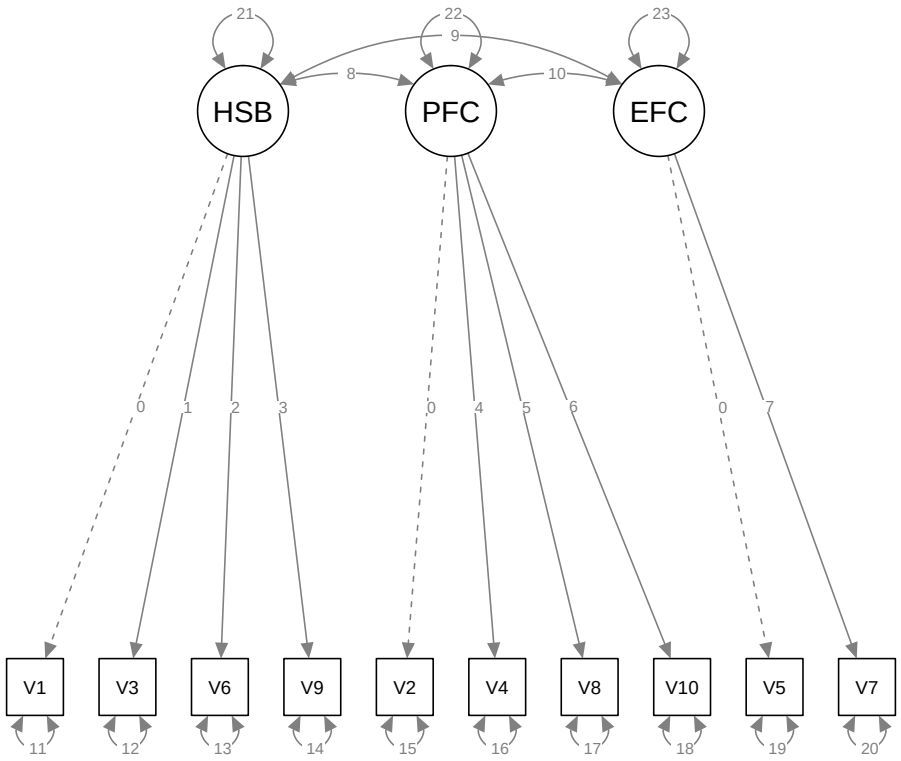
Model Setup

```
model <- 'HelpsSeekingBehavior =~ V1 + V3 + V6 + V9;
ProblemFocusedCoping =~ V2 + V4 + V8 + V10;
EmotionFocusedCoping =~ V5 + V7;
HelpsSeekingBehavior ~~ ProblemFocusedCoping;
HelpsSeekingBehavior ~~ EmotionFocusedCoping;
ProblemFocusedCoping ~~ EmotionFocusedCoping'
```

a)

Path diagram assuming unit loading identification

```
fit <- cfa(model, data = teachers)
semPlot::semPaths(object=fit, intercepts=FALSE, what="path", whatLabels="cons")
```



- Edge labeled 0 indicates the parameter is fixed, non-zero indicates free parameters.
- The factor loading of the first indicator is set to 1.0 for every latent variable to circumvent factor indeterminacy.
- The model satisfy the t-rule because the degrees of freedom is a positive integer.
- Latent factors are correlated, and degree of freedom is greater than zero. Hence the model is over-identified.

Two-indicator rule

- There are three factors
- Factor correlations are free
- At least 2 indicators per factor
- Each indicator loads on one factor
- Errors are uncorrelated

The model is identifiable.

b)

```
n_variable <- 10
n_factor <- 3

p_star <- (n_variable * (n_variable+1))/2
q <- n_variable + (n_variable - n_factor) + (n_factor * (n_factor+1))/2

df <- p_star - q
```

- There are 23.000 free parameters in the the proposed model.
- The degrees of freedom is 32.000.

c)

ULI

```
uli <- lavaan(model, data=teachers, auto.var=TRUE, auto.fix.first=TRUE, std.lv=FALSE)
uliSummary <- summary(uli, fit.measures=TRUE, standardized=TRUE, rsquare=TRUE)
```

UVI

```
uvi <- lavaan(model, data=teachers, auto.var=TRUE, auto.fix.first=FALSE, std.lv=TRUE)
uviSummary <- summary(uvi, fit.measures=TRUE, standardized=TRUE, rsquare=TRUE)
```

Prepare for comparison

```
# row numbers of fixed parameters in parameter table
uliFixedParameters <- c(1,5,9)
uviFixedParameters <- c(24,25,26)

# round numbers to 3 decimal places
uliSummary$PE[,-c(1:3)] <- round(uliSummary$PE[,-c(1:3)],3)
uviSummary$PE[,-c(1:3)] <- round(uviSummary$PE[,-c(1:3)],3)
```

Parameter estimations that are common in both methods

```
# compare all paremeters except fixed parameters
combined <- rbind(uliSummary$PE, uviSummary$PE)
intersaction <- combined[duplicated(combined), , drop = FALSE]
intersaction[,-which(names(intersaction) == "std.nox")]
```

```
##    lhs op rhs exo   est    se     z pvalue std.lv std.all
## 50  V1 ~~  V1   0 0.211 0.026 8.190  0.000  0.211   0.426
## 51  V3 ~~  V3   0 0.528 0.060 8.759  0.000  0.528   0.485
## 52  V6 ~~  V6   0 0.404 0.043 9.433  0.000  0.404   0.592
## 53  V9 ~~  V9   0 0.172 0.039 4.454  0.000  0.172   0.205
## 54  V2 ~~  V2   0 0.391 0.052 7.479  0.000  0.391   0.469
## 55  V4 ~~  V4   0 0.114 0.036 3.150  0.002  0.114   0.209
## 56  V8 ~~  V8   0 0.321 0.033 9.837  0.000  0.321   0.747
## 57 V10 ~~ V10   0 0.508 0.052 9.853  0.000  0.508   0.751
## 58  V5 ~~  V5   0 0.225 0.073 3.072  0.002  0.225   0.314
## 59  V7 ~~  V7   0 0.534 0.086 6.246  0.000  0.534   0.525
## 63  V1 r2  V1   0 0.574    NA    NA     NA     NA      NA
## 64  V3 r2  V3   0 0.515    NA    NA     NA     NA      NA
## 65  V6 r2  V6   0 0.408    NA    NA     NA     NA      NA
## 66  V9 r2  V9   0 0.795    NA    NA     NA     NA      NA
## 67  V2 r2  V2   0 0.531    NA    NA     NA     NA      NA
## 68  V4 r2  V4   0 0.791    NA    NA     NA     NA      NA
## 69  V8 r2  V8   0 0.253    NA    NA     NA     NA      NA
## 70 V10 r2 V10   0 0.249    NA    NA     NA     NA      NA
## 71  V5 r2  V5   0 0.686    NA    NA     NA     NA      NA
## 72  V7 r2  V7   0 0.475    NA    NA     NA     NA      NA
```

- Error variance and R^2 are the same across two identification methods
- All error variance are significant

Parameter estimations that are different

```
nRowTable <- dim(uviSummary$PE)[1]
tail <- tail(duplicated(combined), nRowTable)
uliSummary$PE[!tail,-which(colnames(uliSummary$PE) == "std.nox")]
```

```
##                    lhs op                  rhs exo   est    se      z pvalue std.lv std.all
## 1  HelpsSeekingBehavior =~                   V1   0 1.000 0.000     NA     NA  0.534   0.758
## 2  HelpsSeekingBehavior =~                   V3   0 1.402 0.134 10.434  0.000  0.749   0.718
## 3  HelpsSeekingBehavior =~                   V6   0 0.989 0.107  9.221  0.000  0.528   0.639
## 4  HelpsSeekingBehavior =~                   V9   0 1.533 0.126 12.196  0.000  0.818   0.892
## 5  ProblemFocusedCoping =~                   V2   0 1.000 0.000     NA     NA  0.665   0.729
## 6  ProblemFocusedCoping =~                   V4   0 0.989 0.103  9.607  0.000  0.658   0.889
## 7  ProblemFocusedCoping =~                   V8   0 0.496 0.072  6.881  0.000  0.330   0.503
## 8  ProblemFocusedCoping =~                  V10   0 0.617 0.090  6.829  0.000  0.410   0.499
## 9  EmotionFocusedCoping =~                   V5   0 1.000 0.000     NA     NA  0.702   0.828
## 10 EmotionFocusedCoping =~                   V7   0 0.991 0.157  6.318  0.000  0.695   0.689
## 11 HelpsSeekingBehavior ~~ ProblemFocusedCoping   0 0.029 0.028  1.027  0.305  0.081   0.081
## 12 HelpsSeekingBehavior ~~ EmotionFocusedCoping   0 0.144 0.034  4.204  0.000  0.384   0.384
## 13 ProblemFocusedCoping ~~ EmotionFocusedCoping   0 0.210 0.046  4.586  0.000  0.449   0.449
## 24 HelpsSeekingBehavior ~~ HelpsSeekingBehavior   0 0.285 0.046  6.250  0.000  1.000   1.000
## 25 ProblemFocusedCoping ~~ ProblemFocusedCoping   0 0.442 0.079  5.601  0.000  1.000   1.000
## 26 EmotionFocusedCoping ~~ EmotionFocusedCoping   0 0.492 0.095  5.161  0.000  1.000   1.000
```

```
uviSummary$PE[!tail,-which(names(uviSummary$PE) == "std.nox")]
```

```
##                     lhs op                  rhs exo   est    se      z pvalue std.lv std.all
## 1  HelpsSeekingBehavior =~                   V1   0 0.534 0.043 12.500  0.000  0.534   0.758
## 2  HelpsSeekingBehavior =~                   V3   0 0.749 0.064 11.636  0.000  0.749   0.718
## 3  HelpsSeekingBehavior =~                   V6   0 0.528 0.053 10.026  0.000  0.528   0.639
## 4  HelpsSeekingBehavior =~                   V9   0 0.818 0.052 15.619  0.000  0.818   0.892
## 5  ProblemFocusedCoping =~                   V2   0 0.665 0.059 11.203  0.000  0.665   0.729
## 6  ProblemFocusedCoping =~                   V4   0 0.658 0.047 14.078  0.000  0.658   0.889
## 7  ProblemFocusedCoping =~                   V8   0 0.330 0.045  7.356  0.000  0.330   0.503
## 8  ProblemFocusedCoping =~                  V10   0 0.410 0.056  7.293  0.000  0.410   0.499
## 9  EmotionFocusedCoping =~                   V5   0 0.702 0.068 10.322  0.000  0.702   0.828
## 10 EmotionFocusedCoping =~                   V7   0 0.695 0.077  9.016  0.000  0.695   0.689
## 11 HelpsSeekingBehavior ~~ ProblemFocusedCoping   0 0.081 0.078  1.040  0.298  0.081   0.081
## 12 HelpsSeekingBehavior ~~ EmotionFocusedCoping   0 0.384 0.074  5.182  0.000  0.384   0.384
## 13 ProblemFocusedCoping ~~ EmotionFocusedCoping   0 0.449 0.073  6.178  0.000  0.449   0.449
## 24 HelpsSeekingBehavior ~~ HelpsSeekingBehavior   0 1.000 0.000     NA     NA  1.000   1.000
## 25 ProblemFocusedCoping ~~ ProblemFocusedCoping   0 1.000 0.000     NA     NA  1.000   1.000
## 26 EmotionFocusedCoping ~~ EmotionFocusedCoping   0 1.000 0.000     NA     NA  1.000   1.000
```

- Since the scales are different, the estimates (and their respected standard error) produced by the two identification methods do not match.
- Parameters that are significant in uli are also significant in uvi; the result of Wald test for significance are the same.
- Standardised latent variables and complete standardised solutions are equal.

Compare goodness-of-fit

```
identical(round(uliSummary$FIT, 3), round(uviSummary$FIT, 3))
```

```
## [1] TRUE
```

- Both identification methods yields identical Chi-square goodness-of-fit test, residuals, and other goodness-of-fit indices.

d)

Goodness-of-fit evaluation

We evaluate the indicies according to Hooper, Coughlan, & Mullen (2008).

```
uliSummary$FIT
```

```
##              npar              fmin             chisq                df            pvalue
##            23.000             0.523           232.378            32.000             0.000
##    baseline.chisq       baseline.df   baseline.pvalue               cfi               tli
##           956.825            45.000             0.000             0.780             0.691
##              logl unrestricted.logl               aic               bic            ntotal
##         -2398.615         -2282.426          4843.230          4921.492           222.000
##              bic2             rmsea    rmsea.ci.lower    rmsea.ci.upper      rmsea.pvalue
##          4848.603             0.168             0.148             0.189             0.000
##              srmr
##             0.092
```

- H_0: $\Sigma = \Sigma(\theta)$
- Chi-square test statistics: 232.378; p-value: 0.000. H_0 is rejected at $\alpha = .95$.
- NNFI: $0.691 < 0.95$
- CFI: $0.780 < 0.95$
- RMSEA: $0.168 > 0.07$
- SRMR: $0.092 > 0.08$

Neither the goodness-of-fit test or the fit indices pass the acceptable threshold levels. The proposed model is of poor fit.

e)

Modification indices

```
mi1 <- modindices(uli, sort. = TRUE)
head(mi1, 2)[,-which(names(mi1) == "sepc.nox")]
```

```
##    lhs op rhs     mi   epc sepc.lv sepc.all
## 48  V1 ~~  V6 56.721 0.195   0.195    0.668
## 57  V3 ~~  V9 45.750 0.360   0.360    1.193
```

- Modification indices suggests there exist error covariance between V_1 and V_6.
- This modification is justifiable as these indicators belong to the same latent factor according to the proposed model. Hence they are likely to subject to the same type of variance.

New model

```
newModel1 <- 'HelpsSeekingBehavior =~ V1 + V3 + V6 + V9;
ProblemFocusedCoping =~ V2 + V4 + V8 + V10;
EmotionFocusedCoping =~ V5 + V7;

HelpsSeekingBehavior ~~ ProblemFocusedCoping;
HelpsSeekingBehavior ~~ EmotionFocusedCoping;
ProblemFocusedCoping ~~ EmotionFocusedCoping;

V1~~V6'

uliNew1 <- lavaan(newModel1, data=teachers, auto.var=TRUE, auto.fix.first=TRUE, std.lv=FALSE)
uliNew1Summary <- summary(uliNew1, fit.measures=TRUE, standardized=TRUE, rsquare=TRUE)
```

New model parameter fitting

```
uliNew1Summary$PE[,-which(colnames(uliNew1Summary$PE) == "std.nox")]
```

```
##                    lhs op                  rhs exo        est         se          z       pvalue
## 1  HelpsSeekingBehavior =~                   V1   0 1.00000000 0.00000000         NA           NA
## 2  HelpsSeekingBehavior =~                   V3   0 1.57245218 0.16304299  9.6444025 0.000000e+00
## 3  HelpsSeekingBehavior =~                   V6   0 0.93688873 0.08989286 10.4222821 0.000000e+00
## 4  HelpsSeekingBehavior =~                   V9   0 1.96588607 0.20307912  9.6803950 0.000000e+00
## 5  ProblemFocusedCoping =~                   V2   0 1.00000000 0.00000000         NA           NA
## 6  ProblemFocusedCoping =~                   V4   0 0.97877311 0.10125845  9.6660886 0.000000e+00
## 7  ProblemFocusedCoping =~                   V8   0 0.49272481 0.07178734  6.8636726 6.711298e-12
## 8  ProblemFocusedCoping =~                  V10   0 0.61839598 0.09003318  6.8685341 6.486589e-12
## 9  EmotionFocusedCoping =~                   V5   0 1.00000000 0.00000000         NA           NA
## 10 EmotionFocusedCoping =~                   V7   0 0.89173557 0.14562667  6.1234359 9.157870e-10
## 11 HelpsSeekingBehavior ~~ ProblemFocusedCoping   0 0.02480077 0.02304875  1.0760138 2.819211e-01
## 12 HelpsSeekingBehavior ~~ EmotionFocusedCoping   0 0.12244075 0.03015204  4.0607782 4.890942e-05
## 13 ProblemFocusedCoping ~~ EmotionFocusedCoping   0 0.22377420 0.04687993  4.7733477 1.811886e-06
## 14                   V1 ~~                   V6   0 0.19213158 0.03143827  6.1113924 9.876562e-10
## 15                   V1 ~~                   V1   0 0.28101558 0.03056538  9.1939163 0.000000e+00
## 16                   V3 ~~                   V3   0 0.55643982 0.06437812  8.6433064 0.000000e+00
## 17                   V6 ~~                   V6   0 0.49377595 0.04877951 10.1226105 0.000000e+00
## 18                   V9 ~~                   V9   0 0.01128643 0.05740288  0.1966178 8.441267e-01
## 19                   V2 ~~                   V2   0 0.38704382 0.05208436  7.4310948 1.076916e-13
## 20                   V4 ~~                   V4   0 0.11904211 0.03581781  3.3235451 8.888106e-04
## 21                   V8 ~~                   V8   0 0.32175470 0.03272460  9.8321970 0.000000e+00
## 22                  V10 ~~                  V10   0 0.50584806 0.05145592  9.8307070 0.000000e+00
## 23                   V5 ~~                   V5   0 0.17048374 0.08114393  2.1010043 3.564059e-02
## 24                   V7 ~~                   V7   0 0.58278054 0.08400991  6.9370450 4.003908e-12
## 25 HelpsSeekingBehavior ~~ HelpsSeekingBehavior   0 0.21490578 0.04155745  5.1712935 2.324791e-07
## 26 ProblemFocusedCoping ~~ ProblemFocusedCoping   0 0.44626959 0.07918072  5.6360893 1.739552e-08
## 27 EmotionFocusedCoping ~~ EmotionFocusedCoping   0 0.54723408 0.10344737  5.2899756 1.223327e-07
## 28                   V1 r2                   V1   0 0.43334649         NA         NA           NA
## 29                   V3 r2                   V3   0 0.48848036         NA         NA           NA
## 30                   V6 r2                   V6   0 0.27642519         NA         NA           NA
## 31                   V9 r2                   V9   0 0.98659306         NA         NA           NA
## 32                   V2 r2                   V2   0 0.53553631         NA         NA           NA
## 33                   V4 r2                   V4   0 0.78220032         NA         NA           NA
```

```
## 34                 V8 r2                 V8   0 0.25190553         NA         NA           NA
## 35                V10 r2                V10   0 0.25226554         NA         NA           NA
## 36                 V5 r2                 V5   0 0.76246411         NA         NA           NA
## 37                 V7 r2                 V7   0 0.42748853         NA         NA           NA
##        std.lv    std.all
## 1  0.46357931 0.65829058
## 2  0.72895630 0.69891370
## 3  0.43432223 0.52576154
## 4  0.91134411 0.99327391
## 5  0.66803413 0.73180347
## 6  0.65385384 0.88442089
## 7  0.32915699 0.50190191
## 8  0.41310962 0.50226043
## 9  0.73975272 0.87319191
## 10 0.65966381 0.65382607
## 11 0.08008340 0.08008340
## 12 0.35703875 0.35703875
## 13 0.45281916 0.45281916
## 14 0.19213158 0.51578486
## 15 0.28101558 0.56665351
## 16 0.55643982 0.51151964
## 17 0.49377595 0.72357481
## 18 0.01128643 0.01340694
## 19 0.38704382 0.46446369
## 20 0.11904211 0.21779968
## 21 0.32175470 0.74809447
## 22 0.50584806 0.74773446
## 23 0.17048374 0.23753589
## 24 0.58278054 0.57251147
## 25 1.00000000 1.00000000
## 26 1.00000000 1.00000000
## 27 1.00000000 1.00000000
## 28         NA         NA
## 29         NA         NA
## 30         NA         NA
## 31         NA         NA
## 32         NA         NA
## 33         NA         NA
## 34         NA         NA
## 35         NA         NA
## 36         NA         NA
## 37         NA         NA
```

- Result for Wald tests of significance for the parameters are the same as the old model.
- The parameter for the error covariance between V_1 and V_6 is also significant.

Likelihood ratio test

```
lavTestLRT(uli, uliNew1)
```

```
## Chi-Squared Difference Test
##
```

```
##         Df    AIC    BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## uliNew1 31 4789.9 4871.6 177.10
## uli     32 4843.2 4921.5 232.38     55.282       1  1.044e-13 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

- Likelihood ratio test reveals significant difference between models with and without error co-variance between V_1 and V_6.
- Hence the new model is a better model.

Goodness-of-fit of the new model

- H_0: $\Sigma = \Sigma(\theta)$
- Chi-square test statistics: 177.096; p-value: 0.000. H_0 is rejected at $\alpha = .95$.
- NNFI: $0.767 < 0.95$
- CFI: $0.840 < 0.95$
- RMSEA: $0.146 > 0.07$
- SRMR: $0.087 > 0.08$

The new model has better commonly used goodness-of-fit indices (closer to recommended cutoff) across all measures. However, non of which passes the recommended cutoff. Chi-square goodness-of-fit test has a lower test statistic but still rejects H_0.

Further modification indices

```
mi2 <- modindices(uliNew1, sort. = TRUE)
head(mi2, 3)[,-which(colnames(mi2) == "sepc.nox")]
```

```
##    lhs op rhs     mi    epc sepc.lv sepc.all
## 89 V10 ~~  V5 26.827  0.168   0.168    0.572
## 65  V6 ~~  V2 24.755  0.138   0.138    0.315
## 69  V6 ~~  V5 23.344 -0.128  -0.128   -0.440
```

The top expected reduction in chi-square statistic is 26.827. The current chi-square statistic is 177.096. Hence, even if another parameter is added into the model, the chi-square statistic is expected to be around: 177.096 - 26.827 = 150.269, which is still far from the required 43.773 critical value evaluated by qchisq(p=.95, df=30.000).

One could endlessly add new parameter according to the modification indices until a non-significant Chi-square test statistic is reached. This is highly data driven and defeats much the purpose of the analysis.

In summary, the proposed model may not be a good fit.