Homework 1 is based on the example in section 16.9 CFA With Reactions-to-Tests Data

1. Read the section 16.8 and 16.9 (Textbook)

2. Describe the situation given in section: 16.9 CFA With Reactions-to-Tests Data (5 points/125)

- Problem:

Confirmatory Factor Analysis (CFA) will be used to measure four factors of test anxiety. CFA tests how well the measured variables represent the number of constructs (or factors). We will assess if the model is a good fit for the data, and how well the proposed model captures the covariance between all the items. We will be using the Reactions to Tests (RTT) CFA model, developed by Sarason (1984). This model is an over-identified model that contains more nonredundant observations in the sample covariance matrix than the model parameters to estimate.

- Variables:

TEN1, TEN2, TEN3, WOR1, WOR2, WOR3, IRTHK1, IRTHK 2, IRTHK 3, BODY1, BODY2, BODY3

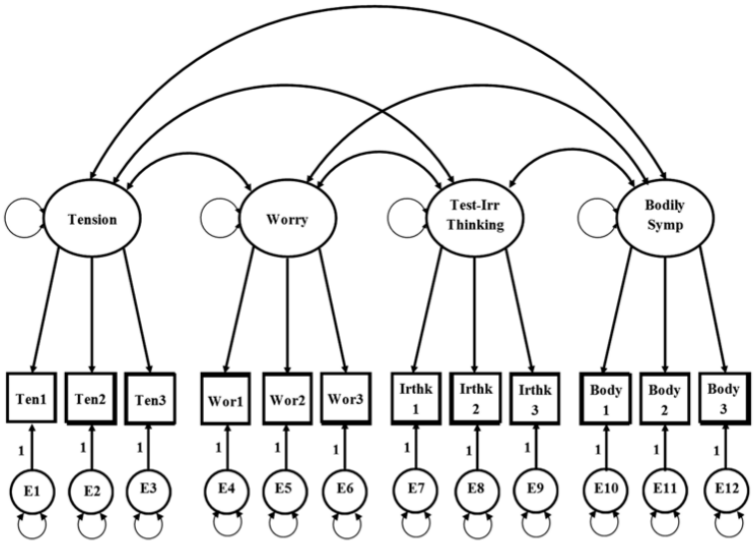
- Underlying Factors

Tension, Worry, Test-irrelevant Thinking, and Bodily Symptoms.

3. Explain why is recommended to apply the CFA (5 points/125)

Confirmatory factor analysis (CFA), or measurement models, help test the construct validity of latent variables of interest. CFA is the next step after exploratory factor analysis (EFA). CFA confirms the factor structure extracted from the EFA. It is recommended to apply CFA to confirm or reject measurement theory.

4. Present the proposal CFA model (5 points/125)



5. Run and present the code to perform the CFA in SAS (code in table 16.20 and 16.21) (10 points/125)

16.20

Code:

```
data anxiety (type=cov);
    infile cards missover;
    input _type_ $ _name_ $ ten1 ten2 ten3 wor1 wor2 wor3
                            irthk1 irthk2 irthk3 body1 body2 body3;

cards;
COV TEN1 .7821
COV TEN2 .5602 .9299
COV TEN3 .5695 .6281 .9751
COV WOR1 .1969 .2599 .2362 .6352
COV WOR2 .2289 .2835 .3079 .4575 .7943
COV WOR3 .2609 .3670 .3575 .4327 .4151 .6783
COV IRTHK1 .0556 .0740 .0981 .2094 .2306 .2503 .6855
COV IRTHK2 .0025 .0279 .0798 .2047 .2270 .2257 .4224 .6952
COV IRTHK3 .0180 .0753 .0744 .1892 .2352 .2008 .4343 .4514 .6065
COV BODY1 .1617 .1919 .2892 .1376 .1744 .1845 .0645 .0731 .0921 .4068
COV BODY2 .2628 .3047 .4043 .1742 .2066 .2547 .1356 .1336 .1283 .1958 .7015
COV BODY3 .2966 .3040 .3919 .1942 .1864 .2402 .1073 .0988 .0599 .2233 .3033 .5786
;
```

Output:

Filter: (none)

Total rows: 12 Total columns: 14

	type	_name_	ten1	ten2	ten3	wor1	wor2	wor3	irthk1	irthk2	irthk3	body1	body2	body3
1	COV	TEN1	0.7821	.	.	.	.	.	.	.	.	.	.	.
2	COV	TEN2	0.5602	0.9299	.	.	.	.	.	.	.	.	.	.
3	COV	TEN3	0.5695	0.6281	0.9751	.	.	.	.	.	.	.	.	.
4	COV	WOR1	0.1969	0.2599	0.2362	0.6352	.	.	.	.	.	.	.	.
5	COV	WOR2	0.2289	0.2835	0.3079	0.4575	0.7943	.	.	.	.	.	.	.
6	COV	WOR3	0.2609	0.367	0.3575	0.4327	0.4151	0.6783	.	.	.	.	.	.
7	COV	IRTHK1	0.0556	0.074	0.0981	0.2094	0.2306	0.2503	0.6855	.	.	.	.	.
8	COV	IRTHK2	0.0025	0.0279	0.0798	0.2047	0.227	0.2257	0.4224	0.6952	.	.	.	.
9	COV	IRTHK3	0.018	0.0753	0.0744	0.1892	0.2352	0.2008	0.4343	0.4514	0.6065	.	.	.
10	COV	BODY1	0.1617	0.1919	0.2892	0.1376	0.1744	0.1845	0.0645	0.0731	0.0921	0.4068	.	.
11	COV	BODY2	0.2628	0.3047	0.4043	0.1742	0.2066	0.2547	0.1356	0.1336	0.1283	0.1958	0.7015	.
12	COV	BODY3	0.2966	0.304	0.3919	0.1942	0.1864	0.2402	0.1073	0.0988	0.0599	0.2233	0.3033	0.5786

16.21

Code:

```
PROC CALIS DATA=ANXIETY COVARIANCE RESIDUAL MODIFICATION
NOBS=318;
LINEQS
     TEN1   = L11 F1 + E1,
     TEN2   = L21 F1 + E2,
     TEN3   = L31 F1 + E3,
     WOR1   = L12 F2 + E4,
     WOR2   = L22 F2 + E5,
     WOR3   = L32 F2 + E6,
     IRTHK1 = L13 F3 + E7,
     IRTHK2 = L23 F3 + E8,
     IRTHK3 = L33 F3 + E9,
     BODY1  = L14 F4 + E10,
     BODY2  = L24 F4 + E11,
     BODY3  = L34 F4 + E12;
  VARIANCE
    E1 - E12 = VARE1-VARE12,
    F1 = 1.0,
    F2 = 1.0,
    F3 = 1.0,
    F4 = 1.0;
  COV
    F1 F2 = COV12,
    F1 F3 = COV13,
    F1 F4 = COV14,
    F2 F3 = COV23,
    F2 F4 = COV24,
    F3 F4 = COV34;
RUN;
```

Output *(only 1 page shown because output is too long [13 pgs])* :

The CALIS Procedure
Covariance Structure Analysis: Model and Initial Values

Modeling Information	
Maximum Likelihood Estimation	
Data Set	WORK.ANXIETY
N Obs	318
Model Type	LINEQS
Analysis	Covariances

Variables in the Model		
Endogenous	Manifest	body1 body2 body3 irthk1 irthk2 irthk3 ten1 ten2 ten3 wor1 wor2 wor3
	Latent	
Exogenous	Manifest	
	Latent	F1 F2 F3 F4
	Error	E10 E11 E12 E7 E8 E9 E1 E2 E3 E4 E5 E6
Number of Endogenous Variables = 12 Number of Exogenous Variables = 16		

Initial Estimates for Linear Equations								
ten1	=		L11	(.)	F1	+	1	E1
ten2	=		L21	(.)	F1	+	1	E2
ten3	=		L31	(.)	F1	+	1	E3
wor1	=		L12	(.)	F2	+	1	E4
wor2	=		L22	(.)	F2	+	1	E5
wor3	=		L32	(.)	F2	+	1	E6
irthk1	=		L13	(.)	F3	+	1	E7
irthk2	=		L23	(.)	F3	+	1	E8
irthk3	=		L33	(.)	F3	+	1	E9
body1	=		L14	(.)	F4	+	1	E10
body2	=		L24	(.)	F4	+	1	E11
body3	=		L34	(.)	F4	+	1	E12

Initial Estimates for Variances of Exogenous Variables			
Variable Type	Variable	Parameter	Estimate
Error	E1	VARE1	.
	E2	VARE2	.
	E3	VARE3	.
	E4	VARE4	.
	E5	VARE5	.
	E6	VARE6	.
	E7	VARE7	.
	E8	VARE8	.
	E9	VARE9	.
	E10	VARE10	.
	E11	VARE11	.
	E12	VARE12	.
Latent	F1		1.00000
	F2		1.00000
	F3		1.00000
	F4		1.00000

6. Present and interpret the results given in section 16.9.2 Analysis Results: Model Fit (25 points/125)

Table 16.22: Top Half of Fit Summary Table From PROC CALIS for RTT CFA Example

Fit Summary		
Modeling Info	Number of Observations	318
	Number of Variables	12
	Number of Moments	78
	Number of Parameters	30
	Number of Active Constraints	0
	Baseline Model Function Value	5.5711
	Baseline Model Chi-Square	1766.0539
	Baseline Model Chi-Square DF	66
	Pr > Baseline Model Chi-Square	<.0001
Absolute Index	Fit Function	0.2789
	Chi-Square	88.3955
	Chi-Square DF	48
	Pr > Chi-Square	0.0003
	Z-Test of Wilson & Hilferty	3.3856
	Hoelter Critical N	234
	Root Mean Square Residual (RMR)	0.0256
	Standardized RMR (SRMR)	0.0364
	Goodness of Fit Index (GFI)	0.9565

Table 16.23: Bottom Half of Fit Summary Table From PROC CALIS for RTT CFA Example

Parsimony Index	Adjusted GFI (AGFI)	0.9294
	Parsimonious GFI	0.6957
	RMSEA Estimate	0.0515
	RMSEA Lower 90% Confidence Limit	0.0342
	RMSEA Upper 90% Confidence Limit	0.0682
	Probability of Close Fit	0.4194
	ECVI Estimate	0.4762
	ECVI Lower 90% Confidence Limit	0.4045
	ECVI Upper 90% Confidence Limit	0.5738
	Akaike Information Criterion	148.3955
	Bozdogan CAIC	291.2571
	Schwarz Bayesian Criterion	261.2571
	McDonald Centrality	0.9385
Incremental Index	Bentler Comparative Fit Index	0.9762
	Bentler-Bonett NFI	0.9499
	Bentler-Bonett Non-normed Index	0.9673
	Bollen Normed Index Rho1	0.9312
	Bollen Non-normed Index Delta2	0.9765
	James et al. Parsimonious NFI	0.6909

The results show that the model is a good fit. It shows a chi-square value of 88.3955 with a degree of freedom value of 48 (p<.0001). This means the model is statistically significant and is a good fit, since the p-value is <0.05. Other indicator values that show that this model is a good fit is: Standardized RMR (SRMR) = 0.04, RMSEA = 0.05 (90% CI: .03, .07).

7. Present and interpret the results given in section 16.9.3 Analysis Results: Parameter Estimates (25 points/125)

Table 16.26: Covariances Among Factors and Squared Multiple Correlations of Indicators in RRT CFA Example

Covariances Among Exogenous Variables					
Var1	Var2	Parameter	Estimate	Standard Error	t Value
F1	F2	COV12	0.55015	0.04996	11.01069
F1	F3	COV13	0.11423	0.06476	1.76399
F1	F4	COV14	0.77837	0.04156	18.72978
F2	F3	COV23	0.49176	0.05298	9.28262
F2	F4	COV24	0.59452	0.05458	10.89274
F3	F4	COV34	0.28632	0.06742	4.24701

Squared Multiple Correlations			
Variable	Error Variance	Total Variance	R-Square
TEN1	0.30857	0.78210	0.6055
TEN2	0.34486	0.92990	0.6291
TEN3	0.26822	0.97510	0.7249
WOR1	0.21936	0.63520	0.6547
WOR2	0.35224	0.79430	0.5565
WOR3	0.22970	0.67830	0.6614
IRTHK1	0.27009	0.68550	0.6060
IRTHK2	0.24793	0.69520	0.6434
IRTHK3	0.15688	0.60650	0.7413
BODY1	0.25957	0.40680	0.3619
BODY2	0.40523	0.70150	0.4223
BODY3	0.26669	0.57860	0.5391

Table 16.29: Standardized Variances of and Covariances Among Exogenous Variables for RTT CFA Example

Standardized Results for Variances of Exogenous Variables					
Variable Type	Variable	Parameter	Estimate	Standard Error	t Value
Error	E1	VARE1	0.39454	0.04355	9.05879
	E2	VARE2	0.37086	0.04276	8.67297
	E3	VARE3	0.27507	0.03967	6.93427
	E4	VARE4	0.34534	0.04443	7.77329
	E5	VARE5	0.44346	0.04685	9.46657
	E6	VARE6	0.33864	0.04427	7.64981
	E7	VARE7	0.39400	0.04470	8.81421
	E8	VARE8	0.35662	0.04388	8.12775
	E9	VARE9	0.25866	0.04202	6.15637
	E10	VARE10	0.63807	0.05349	11.92876
	E11	VARE11	0.57766	0.05428	10.64226
	E12	VARE12	0.46092	0.05526	8.34070
Latent	F1		1.00000		
	F2		1.00000		
	F3		1.00000		
	F4		1.00000		

(*Continued*)

Table 16.29: Continued

Standardized Results for Covariances Among Exogenous Variables					
Var1	Var2	Parameter	Estimate	Standard Error	t Value
F1	F2	COV12	0.55015	0.04996	11.01069
F1	F3	COV13	0.11423	0.06476	1.76399
F1	F4	COV14	0.77837	0.04156	18.72978
F2	F3	COV23	0.49176	0.05298	9.28262
F2	F4	COV24	0.59452	0.05458	10.89274
F3	F4	COV34	0.28632	0.06742	4.24701

Since the t statistics are greater than |1.96|, this shows that the unstandardized factor loadings are statistically significant. All covariances for the factors are significant, excluding F1 (Tension) and F3 (Test-Irrelvant Thinking) because the t= 1.76. The error variances represented by each indicator value show there is a significant amount of variance unexplained by their corresponding factor. The R^2 value ranges from 0.3619 (36%) to 0.7413 (74%). This means that a minimum of 36% of the variance is explained by their corresponding indicator.

The standardized variances estimates the exogenous variables and their correlations. All of the loading values are .60 or greater. Tension factor and Test-Irrelevant Thinking factor had the smallest correlation, and is not statistically significant based off the t-test t=1.76 (needs to be greater than |1.96|). E10 had the most unexplained variance estimate (t=11.93), which is the first bodily symptom item (BODY1).

8. Present and interpret the results given in section 16.9.4 Analysis Results: Model Modification (25 points/125)

Table 16.30: The Wald Test for the RTT CFA Example

Stepwise Multivariate Wald Test					
	Cumulative Statistics			Univariate Increment	
Parm	Chi-Square	DF	Pr > ChiSq	Chi-Square	Pr > ChiSq
COV13	3.11166	1	0.0777	3.11166	0.0777

Table 16.31: LM Tests for the RTT CFA Example

Rank Order of the 10 Largest LM Stat for Paths from Endogenous Variables				
To	From	LM Stat	Pr > ChiSq	Parm Change
WOR3	WOR2	14.16120	0.0002	-0.33957
WOR2	WOR3	14.16075	0.0002	-0.52072
WOR3	TEN2	13.25134	0.0003	0.14798
WOR2	WOR1	12.99412	0.0003	0.50217
WOR1	WOR2	12.99366	0.0003	0.31273
TEN3	BODY1	12.97464	0.0003	0.25305
WOR1	TEN3	12.60477	0.0004	-0.14216
TEN2	TEN1	10.57540	0.0011	0.33976
TEN1	TEN2	10.57540	0.0011	0.30402
TEN3	BODY2	9.14647	0.0025	0.16979

Rank Order of the 10 Largest LM Stat for Paths from Exogenous Variables				
To	From	LM Stat	Pr > ChiSq	Parm Change
TEN3	F4	18.32723	<.0001	0.45216
WOR3	F4	12.36214	0.0004	0.20495
WOR3	F1	11.94309	0.0005	0.17102
WOR1	F1	9.58317	0.0020	-0.14815
WOR1	F4	8.71089	0.0032	-0.16626
TEN1	F4	5.75662	0.0164	-0.22028
TEN2	F4	4.45498	0.0348	-0.21171
BODY3	F3	2.61711	0.1057	-0.07448
TEN1	F3	2.60138	0.1068	-0.06366
TEN2	F2	2.41395	0.1203	0.08676

Table 16.32: LM Tests for the RTT CFA Model Example

Rank Order of the 10 Largest LM Stat for Paths with New Endogenous Variables				
To	From	LM Stat	Pr > ChiSq	Parm Change
F4	TEN3	18.56890	<.0001	0.63971
F2	WOR1	14.16250	0.0002	0.78963
F2	WOR3	12.99261	0.0003	–0.74913
F1	TEN3	10.57557	0.0011	–0.62440
F4	TEN2	8.58264	0.0034	–0.32532
F1	WOR1	6.50164	0.0108	–0.32712
F1	WOR3	5.40273	0.0201	0.29429
F2	TEN2	4.58009	0.0323	0.21502
F1	TEN1	4.37550	0.0365	0.29548
F4	TEN1	2.75440	0.0970	–0.18916

Note: No LM statistic in the default test set for the covariances of exogenous variables is nonsingular. Ranking is not displayed.

Rank Order of the 10 Largest LM Stat for Error Variances and Covariances				
Var1	Var2	LM Stat	Pr > ChiSq	Parm Change
E6	E5	14.16122	0.0002	–0.11961
E5	E4	12.99369	0.0003	0.11016
E2	E1	10.57543	0.0011	0.10484
E9	E12	7.97824	0.0047	–0.04842
E3	E10	7.69945	0.0055	0.05595
E4	E3	6.54831	0.0105	–0.05123
E1	E10	5.13997	0.0234	–0.04368
E6	E2	4.99702	0.0254	0.04769
E3	E2	4.37546	0.0365	–0.08521
E3	E11	4.16317	0.0413	0.05304

The Wald test agrees with the covariance between F3 (Test-Irrelevant Thinking) and F1 (Tension). Parameter COV13 can be dropped from the model based on the Wald test, and this will not significantly increase the chi-square ($p > .05$). LM tests for paths from endogenous variables and indicate which paths may be added to the model to decrease the chi-square statistic and make the model a better fit.

Based on the LM test for endogenous variables, the top 3 suggestions would be a path from WOR2 to WOR3, a path from WOR3 to TEN2, and a path from WOR3 to TEN2. For WOR2 to WOR3, the chi-square would decrease by approximately 14.161. For WOR3 to WOR2, the chi-square would decrease by approximately 14.160. For TEN2 to WOR3, the chi-square would decrease by approximately 13.251.

Based on the LM test for exogenous variables, the top 3 suggestions would be a path from F4 to TEN3 (decrease chi-square by ~18.327), F4 to WOR3 (decrease chi-square by ~12.362), and F1 to WOR3 (decrease chi-square by ~11.943).

Based on the LM test for new endogenous variables, the top 3 suggestions would be a path from TEN3 to F4 (decrease chi-square by ~18.327), F4 to WOR3 (decrease chi-square by ~12.362), and F1 to WOR3 (decrease chi-square by ~11.943).

Based on the LM test for error variances and covariances, the top 3 suggestions would be a path from E5 to E6 (decrease chi-square by ~14.161), E4 to E5 (decrease chi-square by ~12.993), E1 to E2 (decrease chi-square by ~10.575)

9. Present and interpret the results given in section 16.9.5 Results for the Final Model (25 points/125)

Figure 16.13 CFA model for the reactions to tests scale with standardized estimates.

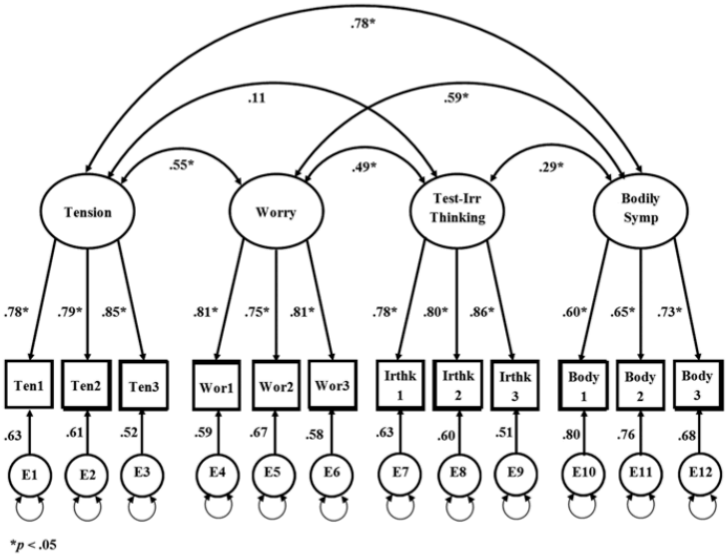


Table 16.33: Unstandardized Loadings, Standard Errors, Standardized Factors Loadings, and *R* Square Values for the RTT CFA Model

Item	Unstandardized loadings	S.E.	Standardized loadings	*R* square
Tension1	.69*	.04	.78	.61
Tension2	.76*	.05	.79	.63
Tension3	.84*	.05	.85	.72

Item	Unstandardized loadings	S.E.	Standardized loadings	*R* square
Worry1	.64*	.04	.81	.65
Worry2	.66*	.05	.75	.56
Worry3	.67*	.04	.81	.66
Test-Irrelevant Thinking1	.64*	.04	.78	.61
Test-Irrelevant Thinking1	.67*	.04	.80	.64
Test-Irrelevant Thinking1	.67*	.04	.86	.74
Bodily Symptoms1	.38*	.04	.60	.36
Bodily Sypmtoms2	.54*	.05	.65	.42
Bodily Symptoms3	.56*	.04	.73	.54

Note: *$p < .05$.

Table 16.34: Factor Intercorrelations for the RTT CFA Model

Factor	Tension	Worry	Test-Irrelevant Thinking	Bodily Symptoms
Tension	–			
Worry	.55*	–		
Test-Irrelevant Thinking	.11	.49*	–	
Bodily Symptoms	.78*	.59*	.29*	–

Note: *$p < .05$.

The results for the final model show the standardized factor loadings and the standardized paths from the errors to each respective indicator. Tension3 had the highest unstandardized loading (0.84, $p<0.05$). Test-Irrelevant Thinking1 had the highest standardized loading (0.86, $p<0.05$) and highest R-squared value (0.74). The highest factor intercorrelations value for the RTT CFA Model was with Bodily Symptoms and Tension (0.78, $p<0.05$).

10. Click on the "Week One Assignment" link above to submit your assignment