

LISREL output files for measurement models

1. Introduction

In practice, the variables of interest are often latent (unobservable) variables, such as intelligence, job satisfaction, organizational commitment, socio-economic status, ambition, alienation, verbal ability, etc. These latent variables are modeled by specifying a measurement model and a structural model. The measurement model specifies the relationships between the observed indicators and the latent variables while the structural equation model specifies the relationships amongst the latent variables.

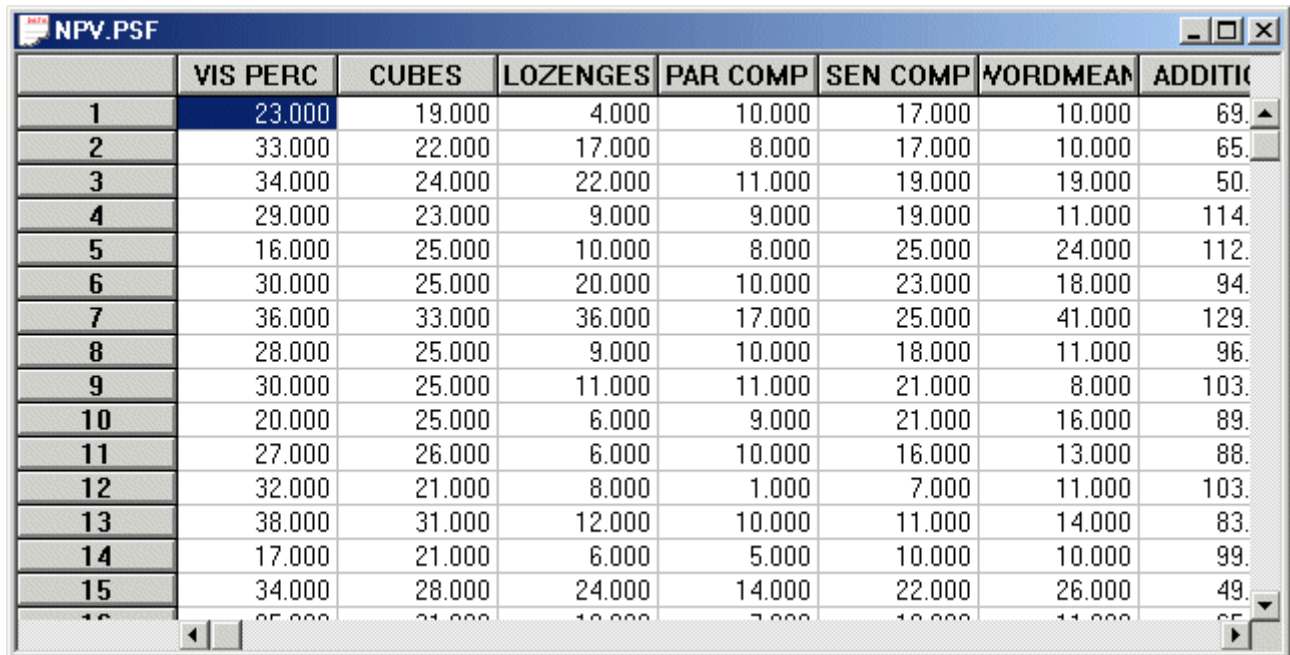
In practice, it is very convenient to refine the measurement model before the complete model is fitted to the data. In this regard, the reliability and the validity of the indicators of the latent variables are assessed even before the measurement model is fitted to the data. Thereafter, modification indices are sometimes used to refine the measurement model.

LISREL 8.80 for Windows (Jöreskog & Sörbom 2006) does not include methods to assess the reliability (internal consistency) and validity of the indicators of a measurement model. However, it does include the Maximum Likelihood (ML), Robust Maximum Likelihood (RML), Generalized Least Squares (GLS), Un-weighted Least Squares (ULS), Weighted Least Squares (WLS), Diagonally Weighted Least Squares (DWLS) and Full Information Maximum Likelihood (FIML) methods to fit measurement models to data. Each of these methods includes modification indices that may be used to refine measurement models. More information on these indices is provided in (Jöreskog & Sörbom 1999) and Du Toit & Du Toit (2001). In addition, LISREL 8.80 for Windows include methods to assess the validity of latent constructs as outlined in Steenkamp & Van Trijp (1991).

In this note, the RML method of LISREL 8.80 for Windows is used to fit and refine a measurement model to the scores of a sample of school children on nine psychological tests. This data set is described in the next section. The measurement model is described in section 3. In section 4, SIMPLIS syntax file for the measurement model is described while the results are presented in section 5. The modification indices are then used to refine the model in section 6.

2. The data

The data are the scores on nine psychological tests of 145 seventh- and eighth-grade students at the Grant-White school in Chicago. The raw data are listed in the PRELIS System File (PSF) *NPV.PSF* located in **C:\LISREL 8.8 Student Examples\WORKSHOP**. The first couple of lines of this file are shown in the following PSF window.



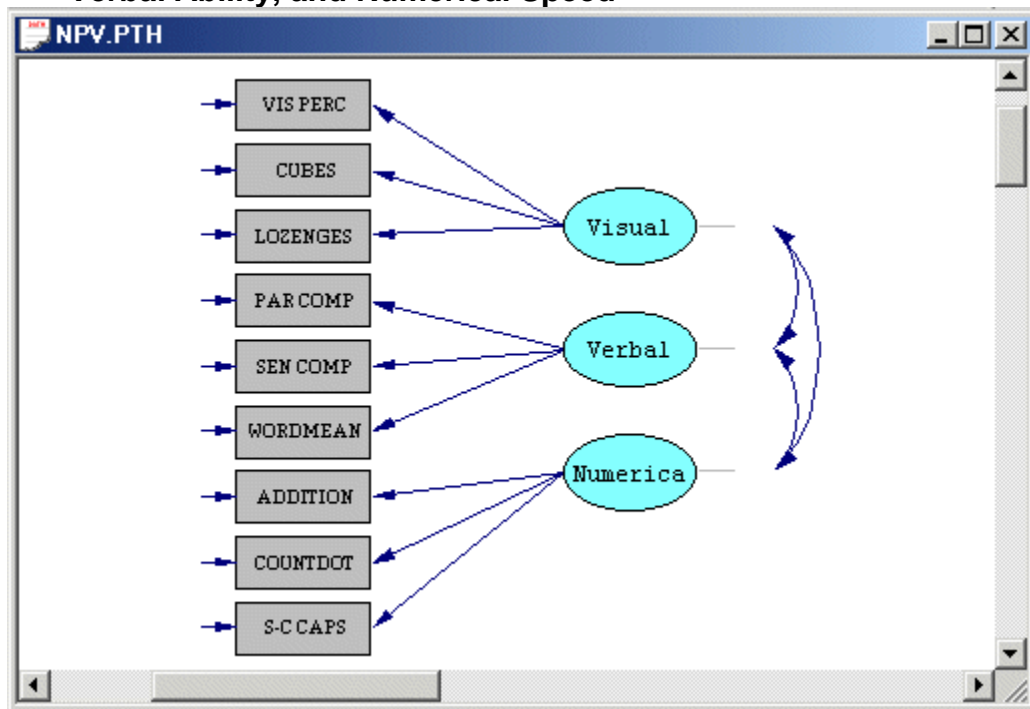
The screenshot shows a window titled "NPV.PSF" containing a table with 8 columns and 15 rows. The columns are labeled: VIS PERC, CUBES, LOZENGES, PAR COMP, SEN COMP, WORDMEAN, and ADDITIC. The rows are numbered 1 through 15. The first row (Student 1) has scores: 23.000, 19.000, 4.000, 10.000, 17.000, 10.000, and 69. The second row (Student 2) has scores: 33.000, 22.000, 17.000, 8.000, 17.000, 10.000, and 65. The table continues with rows 3 through 15, showing scores for each of the seven tests. The window includes standard Windows-style window controls (minimize, maximize, close) in the top right corner and scroll bars at the bottom.

	VIS PERC	CUBES	LOZENGES	PAR COMP	SEN COMP	WORDMEAN	ADDITIC
1	23.000	19.000	4.000	10.000	17.000	10.000	69.
2	33.000	22.000	17.000	8.000	17.000	10.000	65.
3	34.000	24.000	22.000	11.000	19.000	19.000	50.
4	29.000	23.000	9.000	9.000	19.000	11.000	114.
5	16.000	25.000	10.000	8.000	25.000	24.000	112.
6	30.000	25.000	20.000	10.000	23.000	18.000	94.
7	36.000	33.000	36.000	17.000	25.000	41.000	129.
8	28.000	25.000	9.000	10.000	18.000	11.000	96.
9	30.000	25.000	11.000	11.000	21.000	8.000	103.
10	20.000	25.000	6.000	9.000	21.000	16.000	89.
11	27.000	26.000	6.000	10.000	16.000	13.000	88.
12	32.000	21.000	8.000	1.000	7.000	11.000	103.
13	38.000	31.000	12.000	10.000	11.000	14.000	83.
14	17.000	21.000	6.000	5.000	10.000	10.000	99.
15	34.000	28.000	24.000	14.000	22.000	26.000	49.

3. The measurement model

We consider nine psychological tests that were administered to 145 seventh- and eighth-grade students. These nine psychological tests are theoretically constructed to measure the visual perception, verbal ability and numerical speed of seventh- and eighth-grade children. A path diagram for the corresponding measurement model for visual perception, verbal ability and numerical speed is shown in Figure 1.

Figure 1: A path diagram for a measurement model of Visual Perception, Verbal Ability, and Numerical Speed



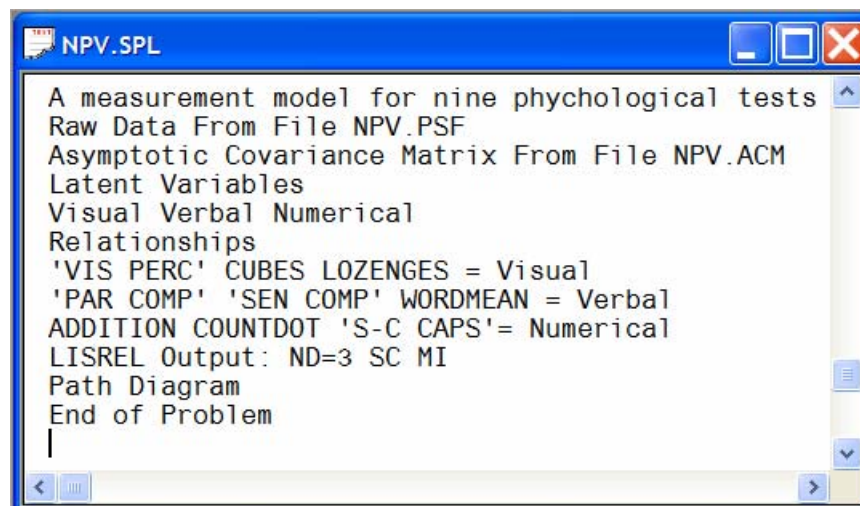
4. Fitting the measurement model to the data

Generating the estimated Asymptotic Covariance Matrix (ACM)

- Use the **Open** option on the **File** menu to load the **Open** dialog box.
- Browse for the location **C:\LISREL 8.8 Student Examples\WORKSHOP**.
- Select the **PRELIS Data (*.psf)** option from the **Files of type** dropdown list box.
- Select the file **NPV.PSF** by clicking on it.
- Click on the **Open** button to open the PSF window for **NPV.PSF**.
- Select the **Output Options** option on the **Statistics** menu to load the **Output** dialog box.
- Check the **Save to File** checkbox in the **Asymptotic Covariance Matrix** section.
- Enter the name **NPV.ACM** in the string box in the **Asymptotic Covariance Matrix** section.
- Click on the **OK** button to run PRELIS28 to generate the text editor window containing the output file **NPV.OUT**.

The SIMPLIS syntax file

- Use the **Open** option on the **File** menu to load the **Open** dialog box.
- Browse for the location **C:\LISREL 8.8 Student Examples\WORKSHOP**.
- Select the file **NPV.SPL** by clicking on it.
- Click on the **Open** button to open the following text editor window.



```
NPV.SPL
A measurement model for nine psychological tests
Raw Data From File NPV.PSF
Asymptotic Covariance Matrix From File NPV.ACM
Latent Variables
Visual Verbal Numerical
Relationships
'VIS PERC' CUBES LOZENGES = Visual
'PAR COMP' 'SEN COMP' WORDMEAN = Verbal
ADDITION COUNTDOT 'S-C CAPS'= Numerical
LISREL Output: ND=3 SC MI
Path Diagram
End of Problem
|
```

Line 1 provides a title for the analysis.

Line 2 specifies the raw data source.

Line 3 specifies the binary file containing the estimated asymptotic matrix of the sample variances and covariances.

Lines 4 and 5 specify labels for the latent variables.

Lines 6 thru 9 specify the measurement model to be fitted to the data.

Line 10 specifies that the results should be printed in terms of the LISREL model for the measurement model in Figure 1. It also requests three decimal places, the completely standardized solution and the modification indices.

Line 11 requests a path diagram of the fitted model.

Line 12 indicates no more SIMPLIS commands are to be processed.

- Click on the **Run LISREL** icon on the main toolbar to produce the PTH window for **NPV.PTH**.

5. The results

The output file, **NPV.OUT**, consists of several sections. In this section, we will review some selections of the output file. The sample covariance matrix is shown in the following text editor window.

The screenshot shows a text editor window titled "NPV.OUT" with two covariance matrices. The first matrix is a 7x7 matrix with variables: VIS PERC, CUBES, LOZENGES, PAR COMP, SEN COMP, and WORDMEAN. The second matrix is a 3x3 matrix with variables: ADDITION, COUNTDOT, and S-C CAPS.

Covariance Matrix						
	VIS PERC	CUBES	LOZENGES	PAR COMP	SEN COMP	WORDMEAN
VIS PERC	47.801					
CUBES	10.013	19.758				
LOZENGES	25.798	15.417	69.172			
PAR COMP	7.973	3.421	9.207	11.393		
SEN COMP	9.936	3.296	11.092	11.277	21.616	
WORDMEAN	17.425	6.876	22.954	19.167	25.321	63.163
ADDITION	17.132	7.015	14.763	16.766	28.069	33.768
COUNTDOT	44.651	15.675	41.659	7.357	19.311	20.213
S-C CAPS	124.657	40.803	114.763	39.309	61.230	79.993

Covariance Matrix			
	ADDITION	COUNTDOT	S-C CAPS
ADDITION	565.593		
COUNTDOT	293.126	440.792	
S-C CAPS	368.436	410.823	1371.618

The parameter specifications for the LISREL model for the model in Figure 1 are listed in the following text editor window.

LAMBDA-X						
	Visual	Verbal	Numerica			
VIS PERC	1	0	0			
CUBES	2	0	0			
LOZENGES	3	0	0			
PAR COMP	0	4	0			
SEN COMP	0	5	0			
WORDMEAN	0	6	0			
ADDITION	0	0	7			
COUNTDOT	0	0	8			
S-C CAPS	0	0	9			
PHI						
	Visual	Verbal	Numerica			
Visual	0					
Verbal	10	0				
Numerica	11	12	0			
THETA-DELTA						
	Visual	Verbal	Numerica			
VIS PERC		CUBES	LOZENGES	PAR COMP	SEN COMP	WORDMEAN
	13	14	15	16	17	18
ADDITION		COUNTDOT	S-C CAPS			
	19	20	21			

The estimated matrix of factor loadings follows.

	LAMBDA-X		
	Visual	Verbal	Numerica
VIS PERC	4.678 (0.696)	- -	- -
CUBES	6.726 2.296 (0.377)	- -	- -
LOZENGES	6.096 5.769 (0.728)	- -	- -
PAR COMP	7.925 - -	2.922 (0.251)	- -
SEN COMP	- -	11.639 3.856 (0.332)	- -
WORDMEAN	- -	11.618 6.567 (0.575)	- -
ADDITION	- -	11.425 - -	15.676 (1.836)
COUNTDOT	- -	- -	8.536 16.709 (1.781)
S-C CAPS	- -	- -	9.381 25.956 (3.088)
			8.407

The results above indicate that all the free factor loadings are statistically significant if a significance level of 1% is used. Consequently, the construct validity of the nine psychological tests as indicators of the three latent variables appears to be at an acceptable level.

The estimated correlation matrix of the three latent variables is provided in the following text editor window.

PHI			
	Visual	Verbal	Numerica
Visual	1.000		
Verbal	0.541 (0.094)	1.000	
Numerica	5.731 0.523 (0.100)	0.336 (0.115)	1.000
	5.224	2.919	

The results above indicate that all three factor correlations are statistically significant if a significance level of 1% is used. In other words, there is sufficient evidence that the three abilities are correlated.

The estimated measurement error variances are shown below.

THETA-DELTA

VIS PERC	CUBES	LOZENGES	PAR COMP	SEN COMP	WORDMEAN
25.915	14.487	35.896	2.857	6.749	20.034
(6.048)	(2.241)	(6.878)	(0.596)	(1.146)	(3.726)
4.285	6.466	5.219	4.797	5.887	5.377

THETA-DELTA

ADDITION	COUNTDOT	S-C CAPS
319.868	161.588	697.900
(42.257)	(44.819)	(109.636)
7.570	3.605	6.366

The results above indicate that all the measurement error variances are statistically significant if a significance level of 1% is used.

The estimated squared multiple correlations of the nine psychological tests are shown in the following text editor window.

Squared Multiple Correlations for X - Variables

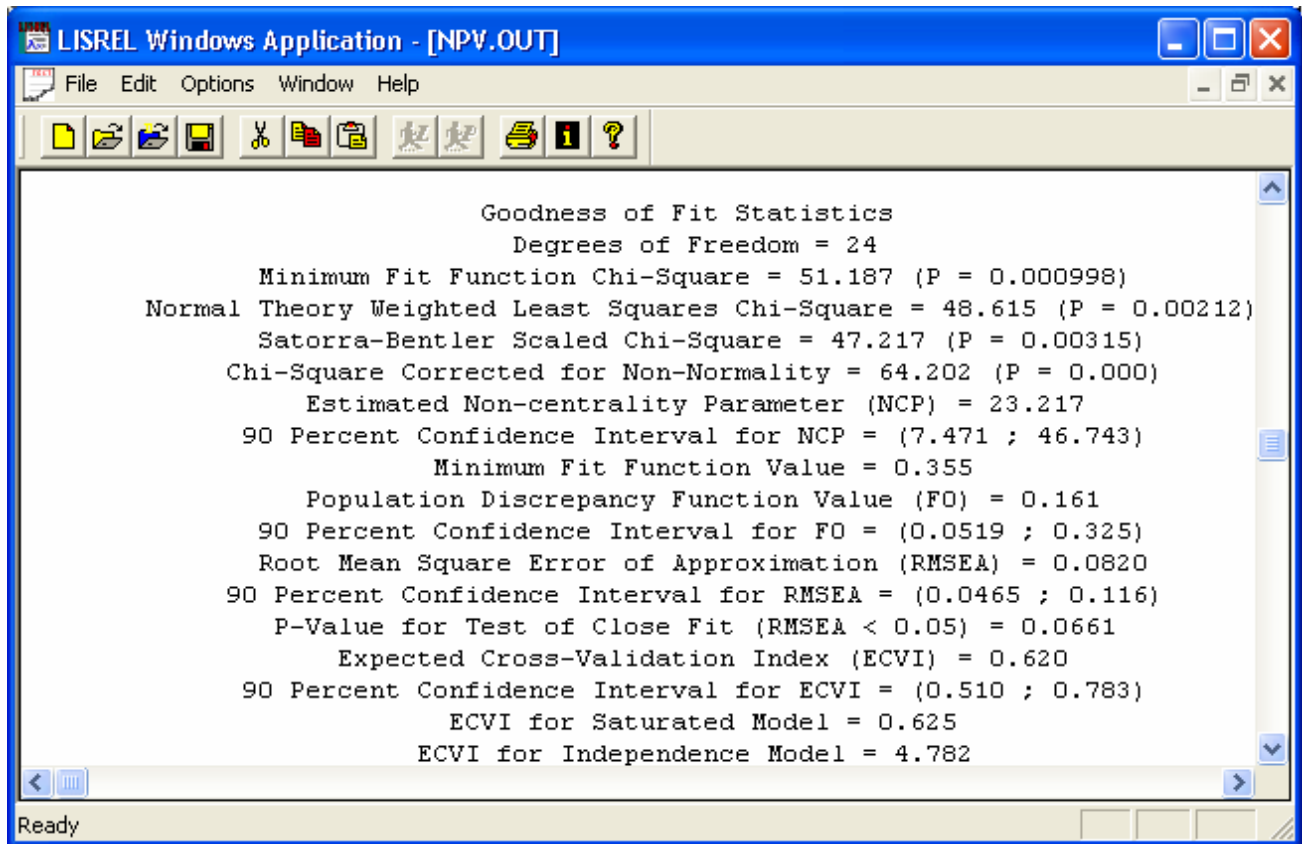
VIS PERC	CUBES	LOZENGES	PAR COMP	SEN COMP	WORDMEAN
0.458	0.267	0.481	0.749	0.688	0.683

Squared Multiple Correlations for X - Variables

ADDITION	COUNTDOT	S-C CAPS
0.434	0.633	0.491

The results above indicate that the latent variable verbal ability explain more of the variation in all three its indicators than the latent variables visual and numerical ability.

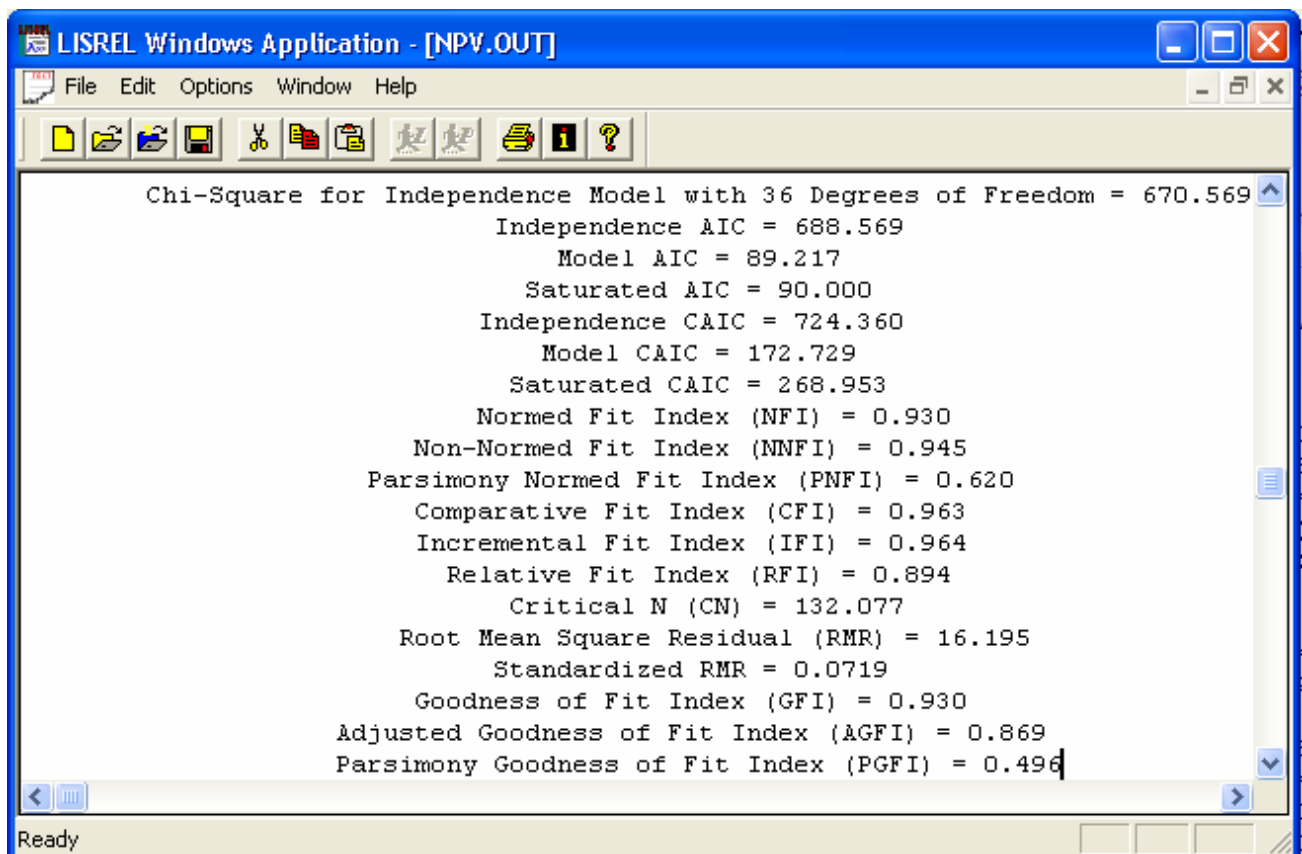
The measures of fit of the measurement model are displayed in the following two text editor windows.



The screenshot shows a window titled "LISREL Windows Application - [NPV.OUT]". The window contains a text editor with the following text:

```
Goodness of Fit Statistics
Degrees of Freedom = 24
Minimum Fit Function Chi-Square = 51.187 (P = 0.000998)
Normal Theory Weighted Least Squares Chi-Square = 48.615 (P = 0.00212)
Satorra-Bentler Scaled Chi-Square = 47.217 (P = 0.00315)
Chi-Square Corrected for Non-Normality = 64.202 (P = 0.000)
Estimated Non-centrality Parameter (NCP) = 23.217
90 Percent Confidence Interval for NCP = (7.471 ; 46.743)
Minimum Fit Function Value = 0.355
Population Discrepancy Function Value (FO) = 0.161
90 Percent Confidence Interval for FO = (0.0519 ; 0.325)
Root Mean Square Error of Approximation (RMSEA) = 0.0820
90 Percent Confidence Interval for RMSEA = (0.0465 ; 0.116)
P-Value for Test of Close Fit (RMSEA < 0.05) = 0.0661
Expected Cross-Validation Index (ECVI) = 0.620
90 Percent Confidence Interval for ECVI = (0.510 ; 0.783)
ECVI for Saturated Model = 0.625
ECVI for Independence Model = 4.782
```

The window also shows a standard menu bar (File, Edit, Options, Window, Help) and a toolbar with various icons. The status bar at the bottom left indicates "Ready".



The screenshot shows a window titled "LISREL Windows Application - [NPV.OUT]". The window contains a list of fit indices for an independence model with 36 degrees of freedom. The indices are as follows:

```
Chi-Square for Independence Model with 36 Degrees of Freedom = 670.569
Independence AIC = 688.569
Model AIC = 89.217
Saturated AIC = 90.000
Independence CAIC = 724.360
Model CAIC = 172.729
Saturated CAIC = 268.953
Normed Fit Index (NFI) = 0.930
Non-Normed Fit Index (NNFI) = 0.945
Parsimony Normed Fit Index (PNFI) = 0.620
Comparative Fit Index (CFI) = 0.963
Incremental Fit Index (IFI) = 0.964
Relative Fit Index (RFI) = 0.894
Critical N (CN) = 132.077
Root Mean Square Residual (RMR) = 16.195
Standardized RMR = 0.0719
Goodness of Fit Index (GFI) = 0.930
Adjusted Goodness of Fit Index (AGFI) = 0.869
Parsimony Goodness of Fit Index (PGFI) = 0.496
```

These measures of fit indicate that the model provides a poor fit to the data.

The next two text editor windows show the modification indices for the matrix of factor loadings and the measurement error covariance matrix.

LISREL Windows Application - [NPV.OUT]

File Edit Options Window Help

Modification Indices for LAMBDA-X

	Visual	Verbal	Numerica
	-----	-----	-----
VIS PERC	- -	0.301	2.980
CUBES	- -	0.579	0.516
LOZENGES	- -	0.035	1.434
PAR COMP	0.026	- -	0.740
SEN COMP	0.237	- -	2.894
WORDMEAN	0.112	- -	0.582
ADDITION	8.548	0.134	- -
COUNTDOT	3.908	8.329	- -
S-C CAPS	28.365	10.814	- -

Ready

LISREL Windows Application - [NPV.OUT]

File Edit Options Window Help

Modification Indices for THETA-DELTA

	VIS PERC	CUBES	LOZENGES	PAR COMP	SEN COMP	WORDMEAN
	-----	-----	-----	-----	-----	-----
VIS PERC	- -					
CUBES	0.673	- -				
LOZENGES	- -	3.527	- -			
PAR COMP	0.165	0.438	0.020	- -		
SEN COMP	0.001	1.139	0.697	0.012	- -	
WORDMEAN	0.020	0.061	1.312	0.065	- -	- -
ADDITION	5.175	0.442	3.556	0.491	0.683	0.016
COUNTDOT	0.173	0.014	0.029	4.220	0.317	0.140
S-C CAPS	9.218	0.004	1.051	0.508	0.584	0.220
	ADDITION	COUNTDOT	S-C CAPS			
	-----	-----	-----			
ADDITION	- -					
COUNTDOT	15.134	- -				
S-C CAPS	3.181	- -	- -			

Ready

The results above indicate that the largest modification index is that for the factor loading of visual ability for the indicator S-C CAPS.

The completely standardized solution is given in the following two text editor windows.

NPV.OUT

Completely Standardized Solution

LAMBDA-X

	Visual	Verbal	Numerica
VIS PERC	0.677	- -	- -
CUBES	0.517	- -	- -
LOZENGES	0.694	- -	- -
PAR COMP	- -	0.866	- -
SEN COMP	- -	0.829	- -
WORDMEAN	- -	0.826	- -
ADDITION	- -	- -	0.659
COUNTDOT	- -	- -	0.796
S-C CAPS	- -	- -	0.701

PHI

	Visual	Verbal	Numerica
Visual	1.000		
Verbal	0.541	1.000	
Numerica	0.523	0.336	1.000

NPV.OUT

THETA-DELTA

VIS PERC	CUBES	LOZENGES	PAR COMP	SEN COMP	WORDMEAN
0.542	0.733	0.519	0.251	0.312	0.317

THETA-DELTA

ADDITION	COUNTDOT	S-C CAPS
0.566	0.367	0.509

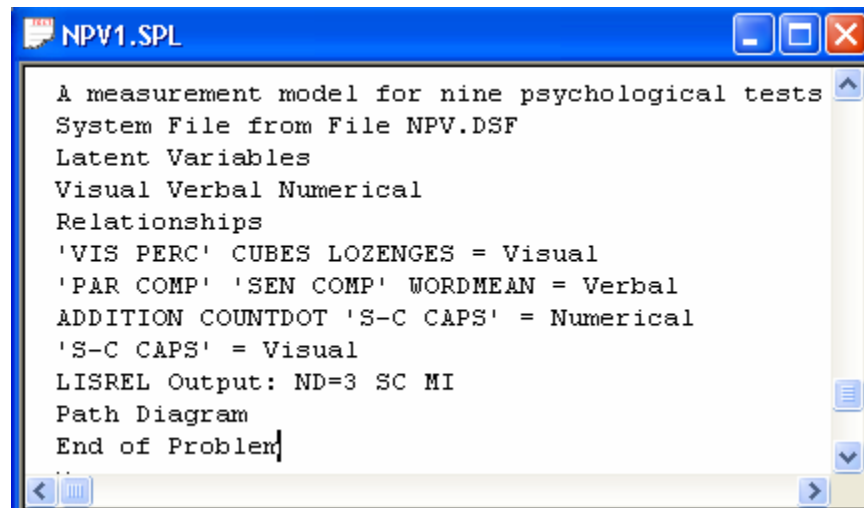
The completely standardized estimates above indicate that the solution is admissible since none of them exceeds unity in absolute value.

6. Refining the measurement model

From the results in section 5, it is evident that the largest modification index is that of the factor loading of the variable **S-C CAPS** as an indicator of latent variable **Visual**. The contents of this test support this suggestion. In other words, this factor loading makes sense from a theoretical point of view. We will now demonstrate how to modify the SIMPLIS syntax file for the measurement model to accommodate this factor loading.

The SIMPLIS syntax file

- Use the **Open** option on the **File** menu to load the **Open** dialog box.
- Browse for the location **C:\LISREL 8.8 Student Examples\WORKSHOP**.
- Select the file **NPV1.SPL** by clicking on it.
- Click on the **Open** button to open the following text editor window.



```
NPV1.SPL
A measurement model for nine psychological tests
System File from File NPV.DSF
Latent Variables
Visual Verbal Numerical
Relationships
'VIS PERC' CUBES LOZENGES = Visual
'PAR COMP' 'SEN COMP' WORDMEAN = Verbal
ADDITION COUNTDOT 'S-C CAPS' = Numerical
'S-C CAPS' = Visual
LISREL Output: ND=3 SC MI
Path Diagram
End of Problem
```

Line 1 provides a title for the analysis.

Line 2 specifies the data source.

Lines 3 to 4 specify labels for the latent variables.

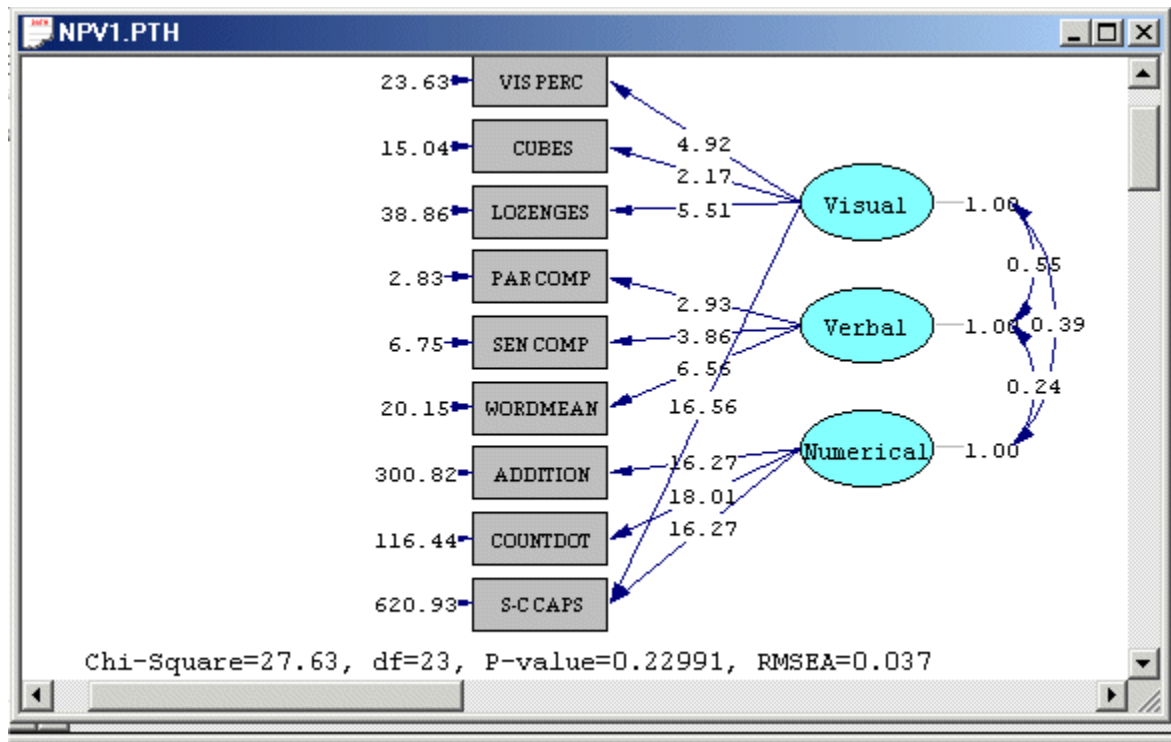
Lines 5 to 9 specify the measurement model to be fitted to the data.

Line 10 specifies that the results should be printed in terms of the LISREL model for the measurement model in Figure 1. It also requests three decimal places, the completely standardized solution and modification indices.

Line 11 requests a path diagram.

Line 12 indicates no more SIMPLIS commands are to be processed.

- Click on the **Run LISREL** icon on the main toolbar to produce the following PTH window.



The modification indices are displayed in the following two text editor windows.

Modification Indices for LAMBDA-X

	Visual	Verbal	Numerica
VIS PERC	--	0.071	1.270
CUBES	--	0.349	0.211
LOZENGES	--	0.121	0.486
PAR COMP	0.041	--	1.076
SEN COMP	0.069	--	3.224
WORDMEAN	0.001	--	0.464
ADDITION	3.111	2.446	--
COUNTDOT	4.415	2.593	--
S-C CAPS	--	0.368	--

NPV1.OUT

Modification Indices for THETA-DELTA

	VIS PERC	CUBES	LOZENGES	PAR COMP	SEN COMP	WORDMEAN
VIS PERC	--					
CUBES	0.466	--				
LOZENGES	4.725	5.203	--			
PAR COMP	0.039	0.425	0.015	--		
SEN COMP	0.090	1.192	0.752	0.000	--	
WORDMEAN	0.010	0.012	1.596	0.062	0.238	--
ADDITION	4.007	0.202	1.858	1.280	0.602	0.002
COUNTDOT	2.741	0.293	1.149	3.560	0.167	0.013
S-C CAPS	2.959	1.358	1.204	0.050	1.202	0.934
	ADDITION	COUNTDOT	S-C CAPS			
ADDITION	--					
COUNTDOT	--	--				
S-C CAPS	1.551	1.032	--			

From the results above, it is evident that none of the modification indices suggests further refining of the measurement model.

References

- Du Toit, M. & Du Toit, S.H.C. (2001).
Interactive LISREL: User's Guide.
 Lincolnwood, IL: Scientific Software International, Inc.
- Jöreskog, K.G. & Sörbom, D. (1999).
LISREL 8: User's Reference Guide.
 Lincolnwood, IL: Scientific Software International, Inc.
- Jöreskog, K.G. & Sörbom, D. (2006).
LISREL 8.80 for Windows [Computer Software].
 Lincolnwood, IL: Scientific Software International, Inc.
- Steenkamp, J.E.M. & Van Trijp, H.C.M (1991).
 The use of LISREL in validating marketing constructs.
International Journal of Research in Marketing, **8**, 283-299.