FITTING MEASUREMENT MODELS
TO
COMPLETE CONTINUOUS DATA

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 8.7 for Windows (Jöreskog & Sörbom 2004) does not include methods to assess the reliability 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 8.7 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 8.7 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, the measurement model is fitted to the data by means of the RML method. The modification indices are then used to refine the model in section 5.
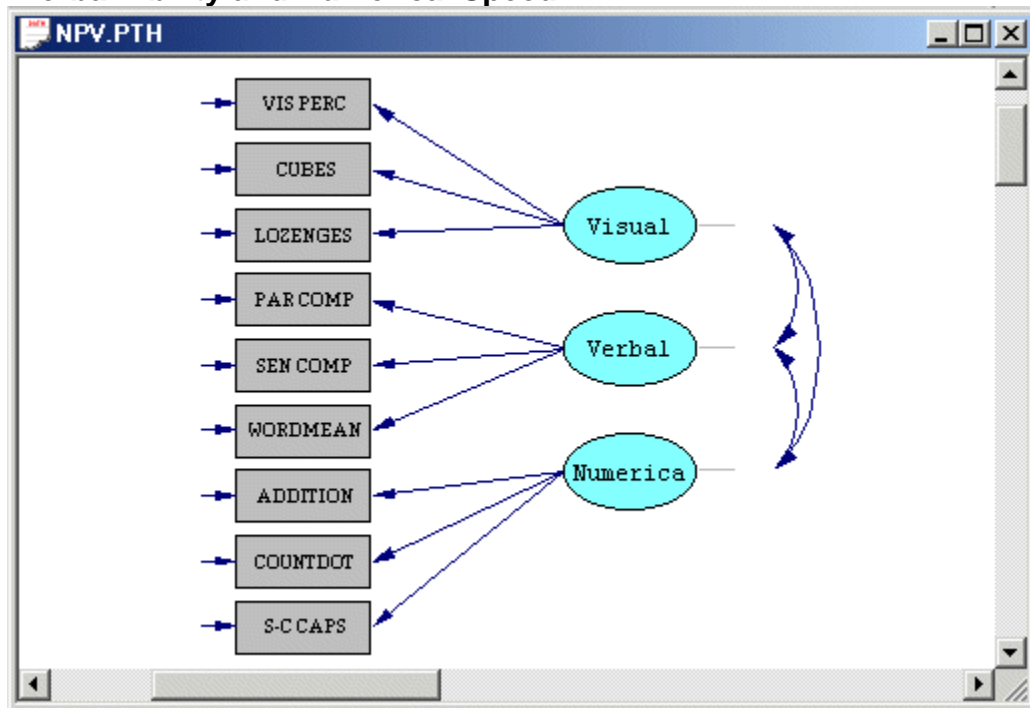
2. The Data

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** in the **TUTORIAL** subfolder of the LISREL 8.7 for Windows installation folder. The first couple of lines of this file are shown in the following PSF window.

	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. The RML Method

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Generating the Data System File (DSF)

➢ Use the *Open* option on the *File* menu to load the *Open* dialog box.
➢ Browse for the *TUTORIAL* folder of the LISREL 8.7 for Windows installation folder.
➢ Select the *PRELIS Data (*.psf)* option from the *Files of type* dropdown list box.
➢ Select the file *NPV.PSF*.
➢ Click on the *Open* push 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 field in the *Asymptotic Covariance Matrix* section.
➢ Click on the *OK* push button to run PRELIS27.EXE to generate the text editor window containing the output file *NPV.OUT*.

The RML Method

➢ Select the *Close all* option on the *Windows* menu to close all open windows.
➢ Use the *New* option on the *File* menu of the root window to load the *New* dialog box.
➢ Select the *Path Diagram* option from the list box on the *New* dialog box to load the *Save As* dialog box.
➢ Enter *NPV.PTH* in the *File name* string field.
➢ Click on the *Save* push button to open an empty path diagram window.
➢ Select the *Title and Comments* option on the *Setup* menu to load the *Title and Comments* dialog box.
➢ Enter *A measurement model for nine psychological tests* in the *Title* string field.
➢ Click on the *Next* push button to load the *Group Names* dialog box.
➢ Click on the *Next* push button to load the *Labels* dialog box.
➢ Click on the *Add/Read Variables* push button to load the *Add/Read Variables* dialog box.
➢ Select the *LISREL System File* option in the *Read from file:* dropdown list box*.*
➢ Click on the *Browse* push button to load the *Browse* dialog box.
➢ Select the file *NPV.DSF*.
➢ Click on the *Open* push button to return to the *Add/Read Variables* dialog box.
➢ Click on the *OK* push button to return to the *Labels* dialog box.
➢ Click on the *Add Latent Variables* push button to load the *Add Variables* dialog box.
➢ Enter the label *Visual* for visual perception in the string field.
➢ Click on the *OK* push button to return to the *Labels* dialog box.
➢ Click on the *Add Latent Variables* push button to load the *Add Variables* dialog box.
➢ Enter the label *Verbal* for verbal ability in the string field.
➢ Click on the *Add Latent Variables* push button to load the *Add Variables* dialog box.
➢ Enter the label *Numerical* for numerical speed in the string field.
➢ Click on the *OK* push button to produce the following *Labels* dialog box.
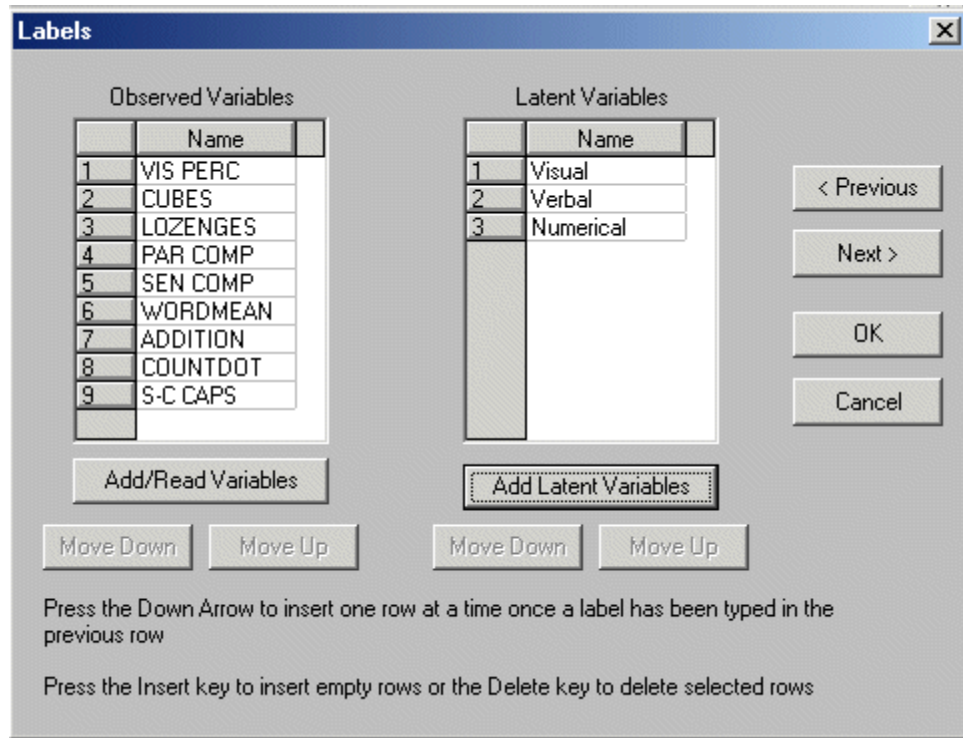
- ➢ Click on the **OK** push button to return to the PTH window for **NPV.PTH**.
- ➢ Click, drag and drop the labels of the observed variables one at a time into the PTH window.
- ➢ Click, drag and drop the labels of the latent variables one at a time into the PTH window to produce the following PTH window.
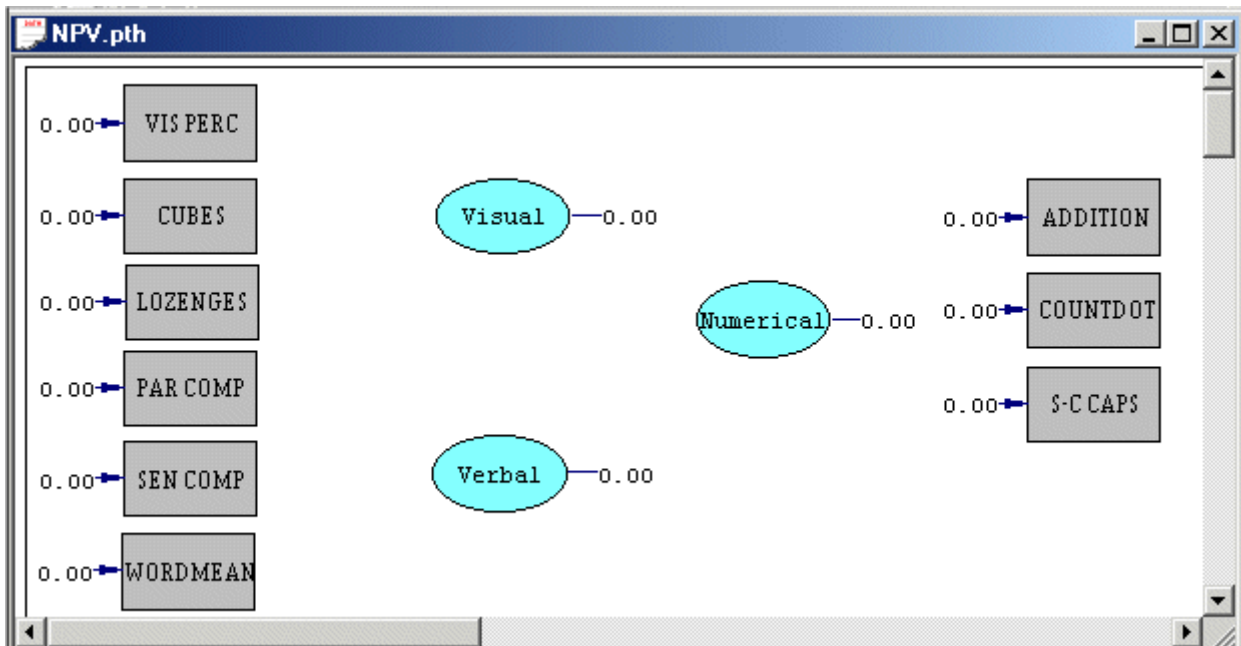
- ➢ Select the arrow icon on the drawing toolbar.
- ➢ Click and drag paths from **Visual** to **VISPERC**, **CUBES** and **LOZENGES** respectively.
- ➢ Click and drag paths from **Verbal** to **PARCOMP**, **SENCOMP** and **WORDMEAN** respectively.

➢ Click and drag paths from **Numerical** to **ADDITION**, **COUNTDOT** and **SCCAPS** respectively to produce the following PTH window.
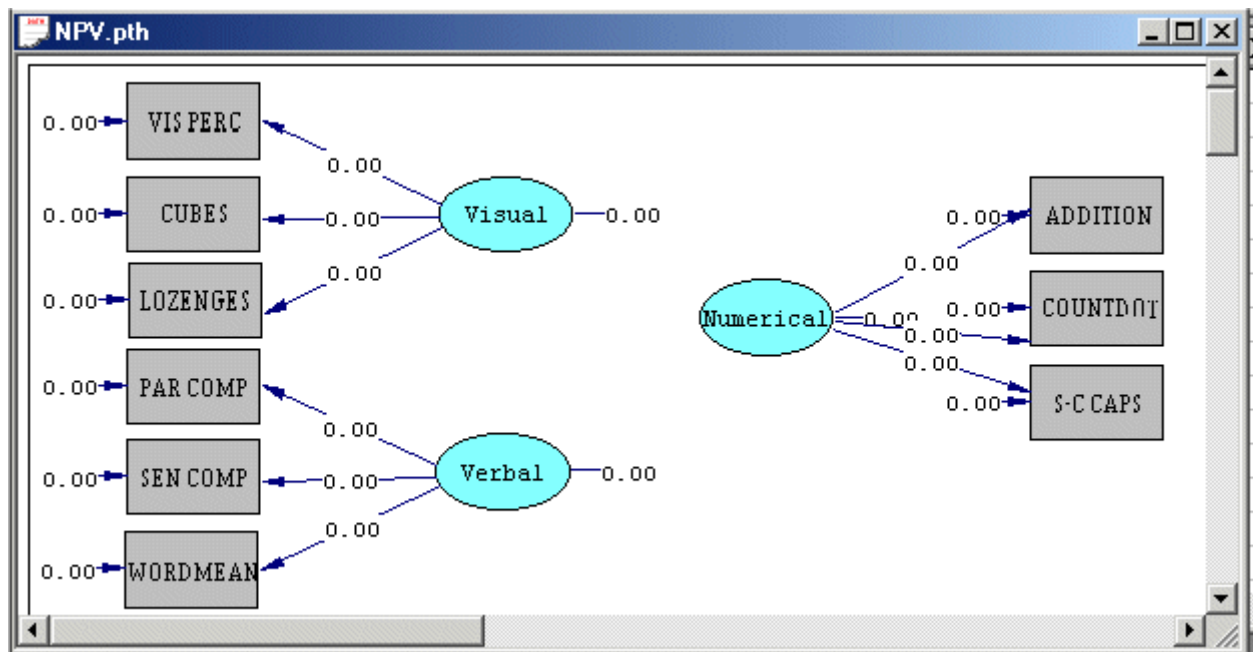
➢ Select the **Build SIMPLIS Syntax** option on the **Setup** menu to open the following SIMPLIS project window.
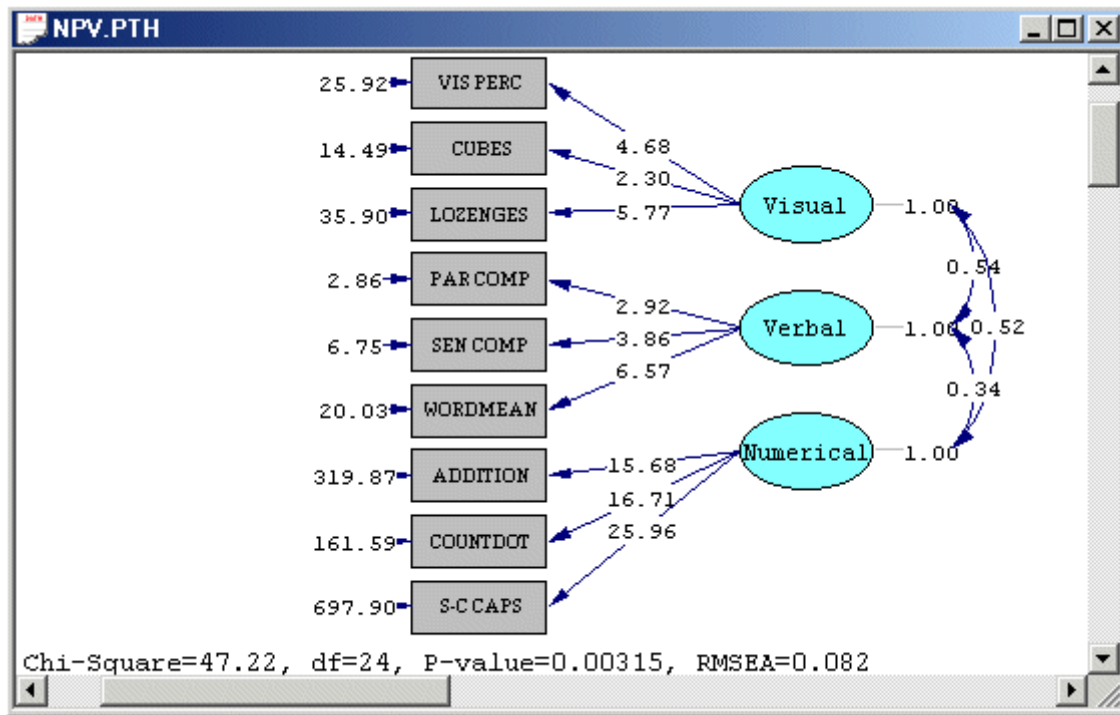

➢ Click on the **Run LISREL** icon on the main toolbar to produce the following PTH window.

```
NPV.PTH                                                    _ □ ×

        25.92━  VIS PERC
                                    4.68
        14.49━   CUBES              2.30
        35.90━  LOZENGES ━━5.77      Visual   ─1.00
                                                              0.54
         2.86━  PAR COMP
                                    2.92
         6.75━  SEN COMP ━━3.86      Verbal   ─1.00 0.52
                                    6.57
        20.03━  WORDMEAN
                                                              0.34
       319.87━  ADDITION ━━15.68   Numerical ─1.00
                          16.71
       161.59━  COUNTDOT    25.96

       697.90━   S-C CAPS

Chi-Square=47.22, df=24, P-value=0.00315, RMSEA=0.082
```

5. Refining the Measurement Model

➢ Select the **Modification Indices** option from the **Estimates** dropdown list box to open the following PTH window.


```
NPV.PTH                                                    _ □ ×

        0.00━  VIS PERC
        0.00━   CUBES
        0.00━  LOZENGES                      Visual  ─0.00
        0.00━  PAR COMP
 9.22   0.00━  SEN COMP      8.55            Verbal  ─0.00
        0.00━  WORDMEAN    28.37
                            8.33           Numerical ─0.00
        0.00━  ADDITION    10.81
       15.13
        0.00━  COUNTDOT
        0.00━   S-C CAPS

Chi-Square=47.22, df=24, P-value=0.00315, RMSEA=0.082
```
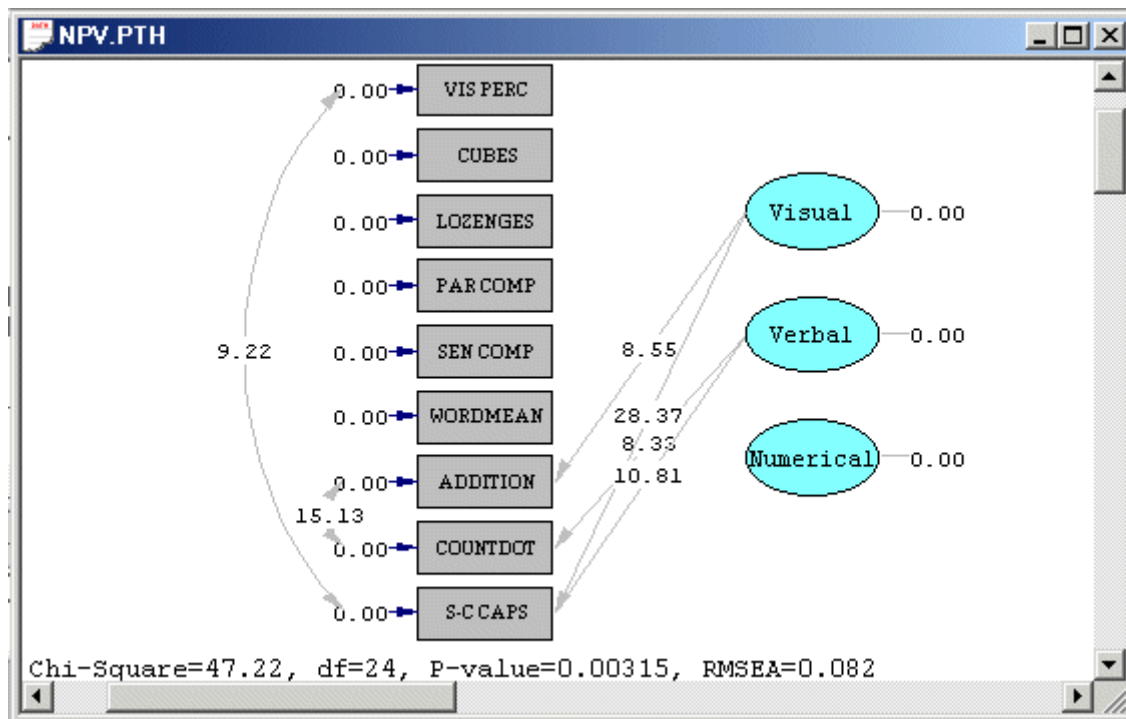
From the results above, it is evident that the largest modification index is that of the factor loading of the variable **S-C CAPS** as an indicator of latent variable **Visual**. The contents of this test support this suggestion. In other words, this factor loading makes sense from a theoretical point of view.

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- ➢ Close the PTH window for **NPV.PTH**.
- ➢ Change the line **'S-C CAPS' = Numerical** in **NPV.SPJ** to **'S-C CAPS' = Numerical Visual** in the SPJ window for **NPV.SPJ**.
- ➢ Use the **Save As** option on the **File** menu of the **SPJ** window to load the **Save As** dialog box.
- ➢ Enter the name **NPV1.SPJ** in the **File name** string field.
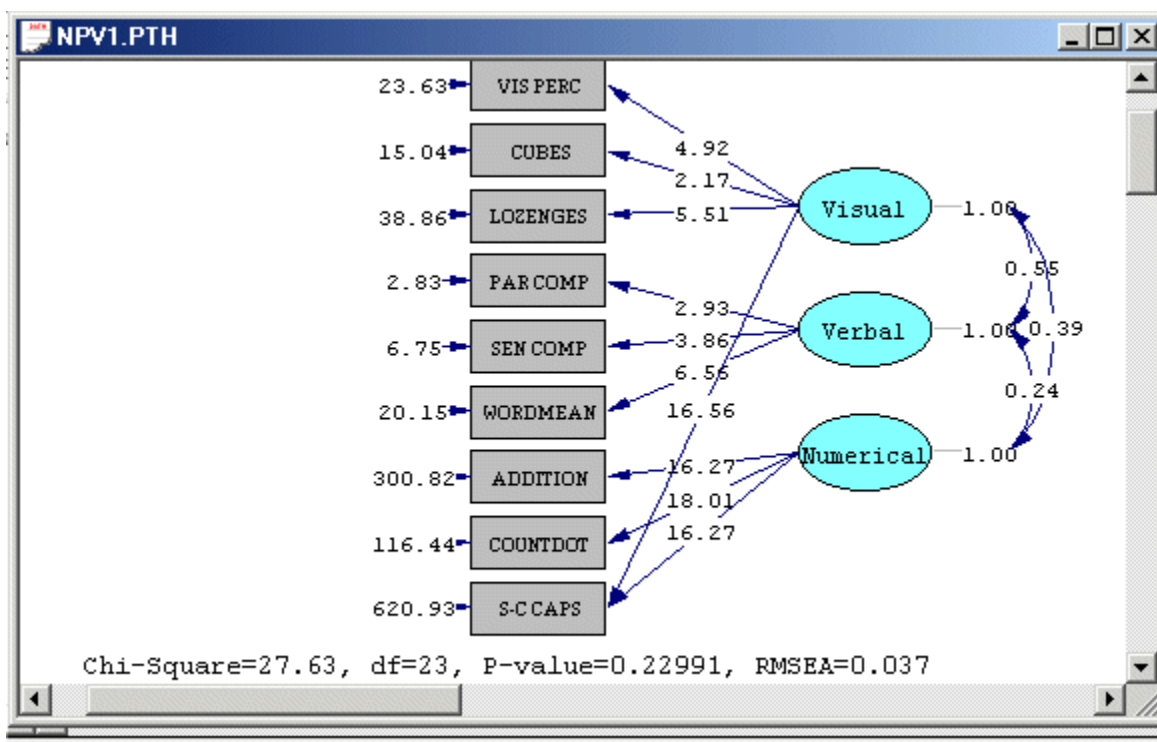- ➢ Click on the **Save** push button to produce the following SPJ window for **NPV1.SPJ**.

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

➢ Select the **Modification Indices** option from the **Estimates** dropdown list box to open the following PTH window.

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.
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