



From *A Step-by-Step Approach to Using SAS® for Factor Analysis and Structural Equation Modeling, Second Edition*. Full book available for purchase [here](#).

## Contents

<b>Chapter 1: Principal Component Analysis .....</b>	<b>1</b>
Introduction: The Basics of Principal Component Analysis .....	1
A Variable Reduction Procedure.....	2
An Illustration of Variable Redundancy .....	2
What Is a Principal Component? .....	4
Principal Component Analysis Is Not Factor Analysis .....	6
Example: Analysis of the Prosocial Orientation Inventory.....	7
Preparing a Multiple-Item Instrument .....	8
Number of Items per Component .....	9
Minimal Sample Size Requirements .....	9
SAS Program and Output.....	10
Writing the SAS Program.....	10
Results from the Output .....	13
Steps in Conducting Principal Component Analysis.....	16
Step 1: Initial Extraction of the Components.....	16
Step 2: Determining the Number of “Meaningful” Components to Retain.....	16
Step 3: Rotation to a Final Solution .....	21
Step 4: Interpreting the Rotated Solution .....	21
Step 5: Creating Factor Scores or Factor-Based Scores.....	23
Step 6: Summarizing the Results in a Table .....	30
Step 7: Preparing a Formal Description of the Results for a Paper .....	31
An Example with Three Retained Components .....	31
The Questionnaire .....	31
Writing the Program .....	32
Results of the Initial Analysis .....	33
Results of the Second Analysis.....	37
Conclusion .....	41
Appendix: Assumptions Underlying Principal Component Analysis .....	41
References.....	41
<b>Chapter 2: Exploratory Factor Analysis.....</b>	<b>43</b>
Introduction: When Is Exploratory Factor Analysis Appropriate? .....	43
Introduction to the Common Factor Model .....	44
Example: Investment Model Questionnaire.....	44
The Common Factor Model: Basic Concepts .....	45
Exploratory Factor Analysis versus Principal Component Analysis.....	50

How Factor Analysis Differs from Principal Component Analysis .....	50
How Factor Analysis Is Similar to Principal Component Analysis .....	52
Preparing and Administering the Investment Model Questionnaire .....	53
Writing the Questionnaire Items .....	53
Number of Items per Factor .....	53
Minimal Sample Size Requirements .....	54
SAS Program and Exploratory Factor Analysis Results .....	54
Writing the SAS Program .....	54
Results from the Output .....	58
Steps in Conducting Exploratory Factor Analysis .....	58
Step 1: Initial Extraction of the Factors .....	58
Step 2: Determining the Number of “Meaningful” Factors to Retain .....	61
Step 3: Rotation to a Final Solution .....	64
Step 4: Interpreting the Rotated Solution .....	66
Step 5: Creating Factor Scores or Factor-Based Scores .....	72
Step 6: Summarizing the Results in a Table .....	79
Step 7: Preparing a Formal Description of the Results for a Paper .....	80
A More Complex Example: The Job Search Skills Questionnaire .....	80
The SAS Program .....	82
Determining the Number of Factors to Retain .....	83
A Two-Factor Solution .....	87
A Four-Factor Solution .....	91
Conclusion .....	95
Appendix: Assumptions Underlying Exploratory Factor Analysis .....	95
References .....	96
<b>Chapter 3: Assessing Scale Reliability with Coefficient Alpha .....</b>	<b>97</b>
Introduction: The Basics of Response Reliability .....	97
Example of a Summated Rating Scale .....	98
True Scores and Measurement Error .....	98
Underlying Constructs versus Observed Variables .....	98
Reliability Defined .....	98
Test-Retest Reliability .....	99
Internal Consistency .....	99
Reliability as a Property of Responses to Scales .....	99
Coefficient Alpha .....	100
Formula .....	100
When Will Coefficient Alpha Be High? .....	100
Assessing Coefficient Alpha with PROC CORR .....	100
General Form .....	101
A 4-Item Scale .....	101
How Large Must a Reliability Coefficient Be to Be Considered Acceptable? .....	103
A 3-Item Scale .....	104
Summarizing the Results .....	105
Summarizing the Results in a Table .....	105

Preparing a Formal Description of the Results for a Paper.....	105
Conclusion.....	105
Note.....	106
References.....	106
<b>Chapter 4: Path Analysis .....</b>	<b>107</b>
Introduction: The Basics of Path Analysis.....	108
Some Simple Path Diagrams.....	108
Important Terms Used in Path Analysis.....	110
Why Perform Path Analysis with PROC CALIS versus PROC REG?.....	111
Necessary Conditions for Path Analysis.....	112
Overview of the Analysis.....	112
Sample Size Requirements for Path Analysis.....	113
Statistical Power and Sample Size.....	113
Effect Sizes.....	114
Estimating Sample Size Requirements.....	114
Example 1: A Path-Analytic Investigation of the Investment Model.....	115
Overview of the Rules for Performing Path Analysis.....	116
Preparing the Program Figure.....	117
Step 1: Drawing the Basic Model.....	117
Step 2: Assigning Short Variable Names to Manifest Variables.....	117
Step 3: Identifying Covariances Among Exogenous Variables.....	118
Step 4: Identifying Residual Terms for Endogenous Variables.....	119
Step 5: Identifying Variances to Be Estimated.....	119
Step 6: Identifying Covariances to Be Estimated.....	120
Step 7: Identifying the Path Coefficients to Be Estimated.....	120
Step 8: Verifying that the Model Is Overidentified.....	121
Preparing the SAS Program.....	125
Overview.....	125
The DATA Input Step.....	126
The PROC CALIS Statement.....	127
The LINEQS Statement.....	129
The VARIANCE Statement.....	134
The COV Statement.....	135
The VAR Statement.....	137
Interpreting the Results of the Analysis.....	137
Making Sure That the SAS Output File “Looks Right”.....	138
Assessing the Fit between Model and Data.....	141
Characteristics of Ideal Fit.....	149
Modifying the Model.....	150
Problems Associated with Model Modification.....	150
Recommendations for Modifying Models.....	151
Modifying the Present Model.....	152
Preparing a Formal Description of the Analysis and Results for a Paper.....	169
Preparing Figures and Tables.....	169

Preparing Text .....	171
<b>Example 2: Path Analysis of a Model Predicting Victim Reactions to Sexual Harassment.....</b>	<b>173</b>
Comparing Alternative Models .....	174
The SAS Program .....	177
Results of the Analysis.....	178
Conclusion: How to Learn More about Path Analysis.....	181
Note .....	182
References.....	182
<b>Chapter 5: Developing Measurement Models with Confirmatory Factor Analysis .....</b>	<b>185</b>
Introduction: A Two-Step Approach to Analyses with Latent Variables .....	186
A Model of the Determinants of Work Performance .....	186
The Manifest Variable Model.....	187
The Latent Variable Model.....	187
Basic Concepts in Latent Variable Analyses.....	189
Latent Variables versus Manifest Variables.....	189
Choosing Indicator Variables .....	189
The Confirmatory Factor Analytic Approach.....	190
The Measurement Model versus the Structural Model .....	190
Advantages of Covariance Structure Analyses .....	190
Necessary Conditions for Confirmatory Factor Analysis .....	192
Sample Size Requirements for Confirmatory Factor Analysis and Structural Equation Modeling .....	193
Calculation of Statistical Power.....	194
Calculation of Sample Size Requirements.....	194
Example: The Investment Model .....	196
The Theoretical Model .....	196
Research Method and Overview of the Analysis .....	196
Testing the Fit of the Measurement Model from the Investment Model Study.....	198
Preparing the Program Figure.....	198
Preparing the SAS Program .....	204
Making Sure That the SAS Log and Output Files Look Right.....	209
Assessing the Fit between Model and Data .....	219
Modifying the Measurement Model.....	225
Estimating the Revised Measurement Model.....	231
Assessing Reliability and Validity of Constructs and Indicators .....	238
Characteristics of an Ideal Fit for the Measurement Model .....	250
Conclusion: On to Structural Equation Modeling .....	251
References.....	251
<b>Chapter 6: Structural Equation Modeling .....</b>	<b>253</b>
Basic Concepts in Covariance Analyses with Latent Variables.....	253
Analysis with Manifest Variables versus Latent Variables.....	253
A Two-Step Approach to Structural Equation Modeling.....	254
The Importance of Reading Chapters 4 and 5 First.....	254

Testing the Fit of the Theoretical Model from the Investment Model Study .....	255
The Rules for Structural Equation Modeling .....	258
Preparing the Program Figure.....	259
Preparing the SAS Program .....	264
Interpreting the Results of the Analysis.....	266
Characteristics of an “Ideal Fit” for the Theoretical Model .....	281
Using Modification Indices to Modify the Present Model .....	282
Preparing a Formal Description of Results for a Paper .....	290
Figures and Tables .....	290
Preparing Text for the Results Section of the Paper .....	293
Additional Example: A SEM Predicting Victim Reactions to Sexual Harassment.....	297
Conclusion: To Learn More about Latent Variable Models .....	303
References.....	304
<b>Appendix A.1: Introduction to SAS Programs, SAS Logs, and SAS Output.....</b>	<b>305</b>
What Is SAS? .....	305
Three Types of SAS Files .....	305
The SAS Program .....	306
The SAS Log.....	307
The SAS Output File .....	309
SAS Customer Support .....	309
Conclusion .....	310
Reference.....	310
<b>Appendix A.2: Data Input.....</b>	<b>311</b>
Introduction: Inputting Questionnaire Data versus Other Types of Data .....	311
Entering Data: An Illustrative Example .....	312
Inputting Data Using the DATALINES Statement .....	316
Additional Guidelines .....	319
Inputting String Variables with the Same Prefix and Different Numeric Suffixes.....	319
Inputting Character Variables .....	320
Using Multiple Lines of Data for Each Participant.....	321
Creating Decimal Places for Numeric Variables .....	323
Inputting “Check All That Apply” Questions as Multiple Variables .....	324
Inputting a Correlation or Covariance Matrix .....	325
Inputting a Correlation Matrix.....	325
Inputting a Covariance Matrix.....	329
Inputting Data Using the INFILE Statement Rather Than the DATALINES Statement .....	329
Conclusion .....	330
References.....	330
<b>Appendix A.3: Working with Variables and Observations in SAS Datasets .....</b>	<b>331</b>
Introduction: Manipulating, Subsetting, Concatenating, and Merging Data .....	331
Placement of Data-Manipulation and Data-Subsetting Statements .....	332
Immediately Following the INPUT Statement.....	334
Immediately after Creating a New Dataset.....	334
The INFILE Statement versus the DATALINES Statement.....	335

Data Manipulation .....	336
Creating Duplicate Variables with New Variable Names.....	336
Duplicating Variables versus Renaming Variables .....	337
Creating New Variables from Existing Variables.....	337
Priority of Operators in Compound Expressions .....	338
Recoding Reversed Variables .....	340
Using IF-THEN Control Statements.....	341
Using ELSE Statements .....	342
Using the Conditional Statements AND and OR .....	343
Working with Character Variables .....	343
Using the IN Operator .....	343
Data Subsetting.....	344
Using a Simple Subsetting Statement.....	344
Using Comparison Operators .....	345
Eliminating Observations with Missing Data for Some Variables .....	345
A More Comprehensive Example .....	349
Concatenating and Merging Datasets .....	350
Concatenating Datasets .....	350
Merging Datasets .....	353
Conclusion .....	356
Reference.....	356
<b>Appendix A.4: Exploring Data with PROC MEANS, PROC FREQ, PROC PRINT, and PROC UNIVARIATE .....</b>	<b>357</b>
Introduction: Why Perform Simple Descriptive Analyses?.....	357
Example: An Abridged Volunteerism Survey.....	358
Computing Descriptive Statistics with PROC MEANS.....	360
The PROC MEANS Statement.....	360
The VAR Statement .....	361
Reviewing the Output.....	362
Creating Frequency Tables with PROC FREQ .....	362
The PROC FREQ and TABLES Statements.....	363
Reviewing the Output.....	363
Printing Raw Data with PROC PRINT .....	364
Testing for Normality with PROC UNIVARIATE .....	365
Why Test for Normality? .....	366
Departures from Normality.....	366
General Form for PROC UNIVARIATE .....	369
Results for an Approximately Normal Distribution .....	370
Results for a Distribution with an Outlier.....	373
Understanding the Stem-Leaf Plot .....	377
Results for Distributions Demonstrating Skewness.....	380
Conclusion .....	384
Reference.....	384
<b>Appendix A.5: Preparing Scattergrams and Computing Correlations .....</b>	<b>385</b>

Introduction: When Are Pearson Correlations Appropriate? ..... 385

Interpreting the Coefficient..... 386

Linear versus Nonlinear Relationships ..... 388

Producing Scattergrams with PROC SGPLOT..... 390

Computing Pearson Correlations with PROC CORR ..... 393

    Computing a Single Correlation Coefficient..... 393

    Determining Sample Size..... 395

    Computing All Possible Correlations for a Set of Variables ..... 395

    Computing Correlations between Subsets of Variables ..... 397

    Options Used with PROC CORR..... 398

Appendix: Assumptions Underlying the Pearson Correlation Coefficient..... 399

References..... 399

**Appendix A.6: Simplifying PROC CALIS Programs ..... 401**

    Introduction ..... 401

    Reviewing the Rules for Performing Path Analysis..... 401

    Simplifying the SAS Program..... 402

**Appendix B: Datasets ..... 405**

    Dataset from Chapter 1: Principal Component Analysis ..... 405

    Datasets from Chapter 2: Exploratory Factor Analysis..... 406

    Dataset from Chapter 3: Assessing Scale Reliability with Coefficient Alpha ..... 409

**Appendix C: Critical Values for the Chi-Square Distribution ..... 411**

**Index ..... 413**

From *A Step-by-Step Approach to Using SAS® for Factor Analysis and Structural Equation Modeling, Second Edition*  
 by Norm O'Rourke, Ph.D., and Larry Hatcher, Ph.D. Copyright © 2014, SAS Institute Inc., Cary, North Carolina, USA.  
 ALL RIGHTS RESERVED.