

# **SAS/STAT<sup>®</sup> 14.3**

## **User's Guide**

### **The FACTOR Procedure**

This document is an individual chapter from *SAS/STAT® 14.3 User's Guide*.

The correct bibliographic citation for this manual is as follows: SAS Institute Inc. 2017. *SAS/STAT® 14.3 User's Guide*. Cary, NC: SAS Institute Inc.

### **SAS/STAT® 14.3 User's Guide**

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September 2017

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# Chapter 39

## The FACTOR Procedure

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## Overview: FACTOR Procedure

The FACTOR procedure performs a variety of common factor and component analyses and rotations. Input can be multivariate data, a correlation matrix, a covariance matrix, a factor pattern, or a matrix of scoring coefficients. The procedure can factor either the correlation or covariance matrix, and you can save most results in an output data set.

PROC FACTOR can process output from other procedures. For example, it can rotate the canonical coefficients from multivariate analyses in the GLM procedure.

The methods for factor extraction are principal component analysis, principal factor analysis, iterated principal factor analysis, unweighted least squares factor analysis, maximum likelihood (canonical) factor analysis, alpha factor analysis, image component analysis, and Harris component analysis. A variety of methods for prior communality estimation is also available.

Specific methods for orthogonal rotation are varimax, quartimax, biquartimax, equamax, parsimax, and factor parsimax. Oblique versions of these methods are also available. In addition, quartimin, biquartimin, and covarimin methods for (direct) oblique rotation are available. General methods for orthogonal rotation are orthomax with user-specified gamma, Crawford-Ferguson family with user-specified weights on variable parsimony and factor parsimony, and generalized Crawford-Ferguson family with user-specified weights. General methods for oblique rotation are direct oblimin with user-specified tau, Crawford-Ferguson family with user-specified weights on variable parsimony and factor parsimony, generalized Crawford-Ferguson family with user-specified weights, promax with user-specified exponent, Harris-Kaiser case II with user-specified exponent, and Procrustes with a user-specified target pattern.

Output includes means, standard deviations, correlations, Kaiser's measure of sampling adequacy, eigenvalues, a scree plot, eigenvectors, prior and final communality estimates, the unrotated factor pattern, residual and partial correlations, the rotated primary factor pattern, the primary factor structure, interfactor correlations, the reference structure, reference axis correlations, the variance explained by each factor both ignoring and eliminating other factors, plots of both rotated and unrotated factors, squared multiple correlation of each factor with the variables, standard error estimates, confidence limits, coverage displays, scoring coefficients, and path diagrams.

The FACTOR procedure uses ODS Graphics to create graphs as part of its output. For general information about ODS Graphics, see Chapter 21, "Statistical Graphics Using ODS."

Any topics that are not given explicit references are discussed in Mulaik (1972) or Harman (1976).

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## Background

See Chapter 93, "The PRINCOMP Procedure," for a discussion of principal component analysis. See Chapter 29, "The CALIS Procedure," for a discussion of confirmatory factor analysis.

Common factor analysis was invented by Spearman (1904). Kim and Mueller (1978a, b) provide a very elementary discussion of the common factor model. Gorsuch (1974) presents a broad survey of factor analysis, and Gorsuch (1974) and Cattell (1978) are useful as guides to practical research methodology. Harman (1976) gives a lucid discussion of many of the more technical aspects of factor analysis, especially oblique rotation. Morrison (1976) and Mardia, Kent, and Bibby (1979) provide excellent statistical treatments of common factor analysis. Mulaik (1972) provides the most thorough and authoritative general reference on

factor analysis and is highly recommended to anyone familiar with matrix algebra. Stewart (1981) gives a nontechnical presentation of some issues to consider when deciding whether or not a factor analysis might be appropriate.

A frequent source of confusion in the field of factor analysis is the term *factor*. It sometimes refers to a hypothetical, unobservable variable, as in the phrase *common factor*. In this sense, *factor analysis* must be distinguished from component analysis since a component is an observable linear combination. *Factor* is also used in the sense of *matrix factor*, in that one matrix is a factor of a second matrix if the first matrix multiplied by its transpose equals the second matrix. In this sense, *factor analysis* refers to all methods of data analysis that use matrix factors, including component analysis and common factor analysis.

A *common factor* is an unobservable, hypothetical variable that contributes to the variance of at least two of the observed variables. The unqualified term “factor” often refers to a common factor. A *unique factor* is an unobservable, hypothetical variable that contributes to the variance of only one of the observed variables. The model for common factor analysis posits one unique factor for each observed variable.

The equation for the common factor model is

$$y_{ij} = x_{i1}b_{1j} + x_{i2}b_{2j} + \cdots + x_{iq}b_{qj} + e_{ij}$$

where

$y_{ij}$	is the value of the $i$ th observation on the $j$ th variable
$x_{ik}$	is the value of the $i$ th observation on the $k$ th common factor
$b_{kj}$	is the regression coefficient of the $k$ th common factor for predicting the $j$ th variable
$e_{ij}$	is the value of the $i$ th observation on the $j$ th unique factor
$q$	is the number of common factors

It is assumed, for convenience, that all variables have a mean of 0. In matrix terms, these equations reduce to

$$\mathbf{Y} = \mathbf{XB} + \mathbf{E}$$

In the preceding equation,  $\mathbf{X}$  is the matrix of factor scores, and  $\mathbf{B}'$  is the factor pattern.

There are two critical assumptions:

- The unique factors are uncorrelated with each other.
- The unique factors are uncorrelated with the common factors.

In principal component analysis, the residuals are generally correlated with each other. In common factor analysis, the unique factors play the role of residuals and are defined to be uncorrelated both with each other and with the common factors. Each common factor is assumed to contribute to at least two variables; otherwise, it would be a unique factor.

When the factors are initially extracted, it is also assumed, for convenience, that the common factors are uncorrelated with each other and have unit variance. In this case, the common factor model implies that the covariance  $s_{jk}$  between the  $j$ th and  $k$ th variables,  $j \neq k$ , is given by

$$s_{jk} = b_{1j}b_{1k} + b_{2j}b_{2k} + \cdots + b_{qj}b_{qk}$$

or

$$\mathbf{S} = \mathbf{B}'\mathbf{B} + \mathbf{U}^2$$

where  $\mathbf{S}$  is the covariance matrix of the observed variables, and  $\mathbf{U}^2$  is the diagonal covariance matrix of the unique factors.

If the original variables are standardized to unit variance, the preceding formula yields correlations instead of covariances. It is in this sense that common factors explain the correlations among the observed variables. When considering the diagonal elements of standardized  $\mathbf{S}$ , the variance of the  $j$ th variable is expressed as

$$s_{jj} = 1 = b_{1j}^2 + b_{2j}^2 + \cdots + b_{qj}^2 + [\mathbf{U}^2]_{jj}$$

where  $b_{1j}^2 + b_{2j}^2 + \cdots + b_{qj}^2$  and  $[\mathbf{U}^2]_{jj}$  are the communality and uniqueness, respectively, of the  $j$ th variable. The communality represents the extent of the overlap with the common factors. In other words, it is the proportion of variance accounted for by the common factors.

The difference between the correlation predicted by the common factor model and the actual correlation is the *residual correlation*. A good way to assess the goodness of fit of the common factor model is to examine the residual correlations.

The common factor model implies that the partial correlations among the variables, removing the effects of the common factors, must all be zero. When the common factors are removed, only unique factors, which are by definition uncorrelated, remain.

The assumptions of common factor analysis imply that the common factors are, in general, not linear combinations of the observed variables. In fact, even if the data contain measurements on the entire population of observations, you cannot compute the scores of the observations on the common factors. Although the common factor scores cannot be computed directly, they can be estimated in a variety of ways.

The problem of factor score indeterminacy has led several factor analysts to propose methods yielding components that can be considered approximations to common factors. Since these components are defined as linear combinations, they are computable. The methods include Harris component analysis and image component analysis. The advantage of producing determinate component scores is offset by the fact that, even if the data fit the common factor model perfectly, component methods do not generally recover the correct factor solution. You should not use any type of component analysis if you really want a common factor analysis (Dziuban and Harris 1973; Lee and Comrey 1979).

After the factors are estimated, it is necessary to interpret them. Interpretation usually means assigning to each common factor a name that reflects the *salience* of the factor in predicting each of the observed variables—that is, the coefficients in the pattern matrix corresponding to the factor. Factor interpretation is a subjective process. It can sometimes be made less subjective by *rotating* the common factors—that is, by applying a nonsingular linear transformation. A rotated pattern matrix in which all the coefficients are close to 0 or  $\pm 1$  is easier to interpret than a pattern with many intermediate elements. Therefore, most rotation methods attempt to optimize a simplicity function of the rotated pattern matrix that measures, in some sense, how close the elements are to 0 or  $\pm 1$ . Because the loading estimates are subject to sampling variability, it is useful to obtain the standard error estimates for the loadings for assessing the uncertainty due to random sampling. Notice that the *salience* of a factor loading refers to the magnitude of the loading, while statistical

*significance* refers to the statistical evidence against a particular hypothetical value. A loading significantly different from 0 does not automatically mean it must be salient. For example, if salience is defined as a magnitude larger than 0.4 while the entire 95% confidence interval for a loading lies between 0.1 and 0.3, the loading is statistically significant larger than 0 but it is not salient. Under the maximum likelihood method, you can obtain standard errors and confidence intervals for judging the salience of factor loadings.

After the initial factor extraction, the common factors are uncorrelated with each other. If the factors are rotated by an *orthogonal transformation*, the rotated factors are also uncorrelated. If the factors are rotated by an *oblique transformation*, the rotated factors become correlated. Oblique rotations often produce more useful patterns than do orthogonal rotations. However, a consequence of correlated factors is that there is no single unambiguous measure of the importance of a factor in explaining a variable. Thus, for oblique rotations, the pattern matrix does not provide all the necessary information for interpreting the factors; you must also examine the *factor structure* and the *reference structure*.

Rotating a set of factors does not change the statistical explanatory power of the factors. You cannot say that any rotation is better than any other rotation from a statistical point of view; all rotations, orthogonal or oblique, are equally good statistically. Therefore, the choice among different rotations must be based on nonstatistical grounds. For most applications, the preferred rotation is that which is most easily interpretable, or most compatible with substantive theories.

If two rotations give rise to different interpretations, those two interpretations must not be regarded as conflicting. Rather, they are two different ways of looking at the same thing, two different points of view in the common-factor space. Any conclusion that depends on one and only one rotation being correct is invalid.

## Outline of Use

### Principal Component Analysis

One important type of analysis performed by the FACTOR procedure is principal component analysis. The following statements result in a principal component analysis:

```
proc factor;
run;
```

The output includes all the eigenvalues and the pattern matrix for eigenvalues greater than one.

Most applications require additional output. For example, you might want to compute principal component scores for use in subsequent analyses or obtain a graphical aid to help decide how many components to keep. You can save the results of the analysis in a permanent SAS data library by using the `OUTSTAT=` option. For more information about permanent libraries and SAS data sets, see *SAS Language Reference: Concepts*. Assuming that your SAS data library has the libref `save` and that the data are in a SAS data set called `raw`, you could do a principal component analysis as follows:

```
proc factor data=raw method=principal scree mineigen=0 score
      outstat=save.fact_all;
run;
```

The `SCREE` option produces a plot of the eigenvalues that is helpful in deciding how many components to use. Alternatively, you can use the `PLOTS=SCREE` option to produce high-quality scree plots. The `MINEIGEN=0` option causes all components with variance greater than zero to be retained. The `SCORE` option requests that scoring coefficients be computed. The `OUTSTAT=` option saves the results in a specially

structured SAS data set. The name of the data set, in this case `fact_all`, is arbitrary. To compute principal component scores, use the SCORE procedure:

```
proc score data=raw score=save.fact_all out=save.scores;
run;
```

The SCORE procedure uses the data and the scoring coefficients that are saved in `save.fact_all` to compute principal component scores. The component scores are placed in variables named `Factor1`, `Factor2`, ..., `Factor $n$`  and are saved in the data set `save.scores`. If you know ahead of time how many principal components you want to use, you can obtain the scores directly from PROC FACTOR by specifying the `NFACTORS= $n$`  and `OUT=` options. To get scores from three principal components, specify the following:

```
proc factor data=raw method=principal
           nfactors=3 out=save.scores;
run;
```

To plot the scores for the first three components, use the SGSCATTER procedure:

```
proc sgscatter;
  matrix factor1-factor3;
run;
```

## Principal Factor Analysis

The simplest and computationally most efficient method of common factor analysis is principal factor analysis, which is obtained in the same way as principal component analysis except for the use of the `PRIORS=` option. The usual form of the initial analysis is as follows:

```
proc factor data=raw method=principal scree
           mineigen=0 priors=smc outstat=save.fact_all;
run;
```

The squared multiple correlations (SMC) of each variable with all the other variables are used as the prior communality estimates. If your correlation matrix is singular, you should specify `PRIORS=MAX` instead of `PRIORS=SMC`. The `SCREE` and `MINEIGEN=` options serve the same purpose as in the preceding principal component analysis. Saving the results with the `OUTSTAT=` option enables you to examine the eigenvalues and scree plot before deciding how many factors to rotate and to try several different rotations without re-extracting the factors. The `OUTSTAT=` data set is automatically marked `TYPE=FACTOR`, so the FACTOR procedure realizes that it contains statistics from a previous analysis instead of raw data.

After looking at the eigenvalues to estimate the number of factors, you can try some rotations. Two and three factors can be rotated with the following statements:

```
proc factor data=save.fact_all method=principal n=2
           rotate=promax reorder score outstat=save.fact_2;
run;
proc factor data=save.fact_all method=principal n=3
           rotate=promax reorder score outstat=save.fact_3;
run;
```

The output data set from the previous run is used as input for these analyses. The options `N=2` and `N=3` specify the number of factors to be rotated. The specification `ROTATE=PROMAX` requests a promax rotation, which has the advantage of providing both orthogonal and oblique rotations with only one invocation of

PROC FACTOR. The **REORDER** option causes the variables to be reordered in the output so that variables associated with the same factor appear next to each other.

You can now compute and plot factor scores for the two-factor promax-rotated solution as follows:

```
proc score data=raw score=save.fact_2 out=save.scores;
run;

proc sgplot;
  scatter y=factor2 x=factor1;
run;
```

## Maximum Likelihood Factor Analysis

Although principal factor analysis is perhaps the most commonly used method of common factor analysis, most statisticians prefer maximum likelihood (ML) factor analysis (Lawley and Maxwell 1971). The ML method of estimation has desirable asymptotic properties (Bickel and Doksum 1977) and produces better estimates than principal factor analysis in large samples. You can test hypotheses about the number of common factors by using the ML method. You can also obtain standard error and confidence interval estimates for many classes of rotated or unrotated factor loadings, factor correlations, and structure loadings under the ML theory.

The unrotated ML solution is equivalent to Rao's canonical factor solution (Rao 1955) and Howe's solution maximizing the determinant of the partial correlation matrix (Morrison 1976). Thus, as a descriptive method, ML factor analysis does not require a multivariate normal distribution. The validity of Bartlett's  $\chi^2$  test for the number of factors does require approximate normality plus additional regularity conditions that are usually satisfied in practice (Geweke and Singleton 1980). Bartlett's test of sphericity in the context of factor analysis is equivalent to Bartlett's  $\chi^2$  test for zero common factors. This test is routinely displayed in the maximum likelihood factor analysis output.

Lawley and Maxwell (1971) derive the standard error formulas for unrotated loadings, while Archer and Jennrich (1973) and Jennrich (1973, 1974) derive the standard error formulas for several classes of rotated solutions. Extended formulas for computing standard errors in various situations appear in Browne et al. (2008); Hayashi and Yung (1999); Yung and Hayashi (2001). A combination of these methods is used in PROC FACTOR to compute standard errors in an efficient manner. Confidence intervals are computed by using the asymptotic normality of the estimates. To ensure that the confidence intervals fall within the admissible parameter range, transformation methods due to Browne (1982) are used. The validity of the standard error estimates and confidence limits requires the assumptions of multivariate normality and a fixed number of factors.

The ML method is more computationally demanding than principal factor analysis for two reasons. First, the communalities are estimated iteratively, and each iteration takes about as much computer time as principal factor analysis. The number of iterations typically ranges from about five to twenty. Second, if you want to extract different numbers of factors, as is often the case, you must run the FACTOR procedure once for each number of factors. Therefore, an ML analysis can take 100 times as long as a principal factor analysis. This does not include the time for computing standard error estimates, which is even more computationally demanding. For analyses with fewer than 35 variables, the computing time for the ML method, including the computation of standard errors, usually ranges from a few seconds to well under a minute. This seems to be a reasonable performance.

You can use principal factor analysis to get a rough idea of the number of factors before doing an ML analysis. If you think that there are between one and three factors, you can use the following statements for the ML analysis:

```
proc factor data=raw method=ml n=1
    outstat=save.fact1;
run;
proc factor data=raw method=ml n=2 rotate=promax
    outstat=save.fact2;
run;
proc factor data=raw method=ml n=3 rotate=promax
    outstat=save.fact3;
run;
```

The output data sets can be used for trying different rotations, computing scoring coefficients, or restarting the procedure in case it does not converge within the allotted number of iterations.

If you can determine how many factors should be retained before an analysis, as in the following statements, you can get the standard errors and confidence limits to aid interpretations for the ML analysis:

```
proc factor data=raw method=ml n=3 rotate=quartimin se
    cover=.4;
run;
```

In this analysis, you specify the quartimin rotation in the `ROTATE=` option. The `SE` option requests the computation of standard error estimates. In the `COVER=` option, you require absolute values of 0.4 or greater in order for loadings to be salient. In the output of coverage display, loadings that are salient would have their entire confidence intervals spanning beyond the 0.4 mark (or the  $-0.4$  mark in the opposite direction). Only those salient loadings should be used for interpreting the factors. See the section “[Confidence Intervals and the Salience of Factor Loadings](#)” on page 2528 for more details.

The ML method cannot be used with a singular correlation matrix, and it is especially prone to Heywood cases. See the section “[Heywood Cases and Other Anomalies about Communality Estimates](#)” on page 2530 for a discussion of Heywood cases. If you have problems with ML, the best alternative is to use the `METHOD=ULS` option for unweighted least squares factor analysis.

## Factor Rotation

After the initial factor extraction, the factors are uncorrelated with each other. If the factors are rotated by an *orthogonal transformation*, the rotated factors are also uncorrelated. If the factors are rotated by an *oblique transformation*, the rotated factors become correlated. Oblique rotations often produce more useful patterns than orthogonal rotations do. However, a consequence of correlated factors is that there is no single unambiguous measure of the importance of a factor in explaining a variable. Thus, for oblique rotations, the pattern matrix does not provide all the necessary information for interpreting the factors; you must also examine the *factor structure* and the *reference structure*.

Nowadays, most rotations are done analytically. There are many choices for orthogonal and oblique rotations. An excellent summary of a wide class of analytic rotations is in Crawford and Ferguson (1970). The Crawford-Ferguson family of orthogonal rotations includes the orthomax rotation as a subclass and the popular varimax rotation as a special case. To illustrate these relationships, the following four specifications for orthogonal rotations with different `ROTATE=` options will give the same results for a data set with nine observed variables:

```

/* Orthogonal Crawford-Ferguson Family with
   variable parsimony weight = nvar - 1 = 8, and
   factor parsimony weight = 1 */
proc factor data=raw n=3 rotate=orthcf(8,1);
run;

/* Orthomax without the GAMMA= option */
proc factor data=raw n=3 rotate=orthomax(1);
run;

/* Orthomax with the GAMMA= option */
proc factor data=raw n=3 rotate=orthomax gamma=1;
run;

/* Varimax */
proc factor data=raw n=3 rotate=varimax;
run;

```

You can also get the oblique versions of the varimax in two equivalent ways:

```

/* Oblique Crawford-Ferguson Family with
   variable parsimony weight = nvar - 1 = 8, and
   factor parsimony weight = 1; */
proc factor data=raw n=3 rotate=oblicf(8,1);
run;

/* Oblique Varimax */
proc factor data=raw n=3 rotate=obvarimax;
run;

```

Jennrich (1973) proposes a generalized Crawford-Ferguson family that includes the Crawford-Ferguson family and the (direct) oblimin family (see Harman 1976) as subclasses. The better-known quartimin rotation is a special case of the oblimin class, and hence a special case of the generalized Crawford-Ferguson family. For example, the following four specifications of oblique rotations are equivalent:

```

/* Oblique generalized Crawford-Ferguson Family
   with weights 0, 1, 0, -1 */
proc factor data=raw n=3 rotate=obligencf(0,1,0,-1);
run;

/* Oblimin family without the TAU= option */
proc factor data=raw n=3 rotate=oblimin(0);
run;

/* Oblimin family with the TAU= option */
proc factor data=raw n=3 rotate=oblimin tau=0;
run;

/* Quartimin */
proc factor data=raw n=3 rotate=quartimin;
run;

```

In addition to the generalized Crawford-Ferguson family, the available oblique rotation methods in PROC FACTOR include Harris-Kaiser, promax, and Procrustes. See the section “Simplicity Functions for Rotations” on page 2527 for details about the definitions of various rotations. See Harman (1976) and Mulaik (1972) for further information.

---

## Getting Started: FACTOR Procedure

The following example demonstrates how you can use the FACTOR procedure to perform common factor analysis and factor rotation.

In this example, 103 police officers were rated by their supervisors on 14 scales (variables). You conduct a common factor analysis on these variables to see what latent factors are operating behind these ratings. The overall rating variable is excluded from the factor analysis.

The following DATA step creates the SAS data set jobratings:

```
options validvarname=any;
data jobratings;
  input ('Communication Skills'n
        'Problem Solving'n
        'Learning Ability'n
        'Judgment under Pressure'n
        'Observational Skills'n
        'Willingness to Confront Problems'n
        'Interest in People'n
        'Interpersonal Sensitivity'n
        'Desire for Self-Improvement'n
        'Appearance'n
        'Dependability'n
        'Physical Ability'n
        'Integrity'n
        'Overall Rating'n) (1.);
  datalines;
26838853879867
74758876857667
56757863775875
67869777988997
99997798878888
89897899888799
89999889899798
87794798468886

... more lines ...

99899899899899
76656399567486
;
```

The following statements invoke the FACTOR procedure:

```
proc factor data=jobratings(drop='Overall Rating'n) priors=smc
  rotate=varimax;
run;
```

The **DATA=** option in PROC FACTOR specifies the SAS data set jobratings as the input data set. The **DROP=** option drops the Overall Rating variable from the analysis. To conduct a common factor analysis, you need to set the prior communality estimate to less than one for each variable. Otherwise, the factor solution would simply be a recast of the principal components solution, in which “factors” are linear combinations of observed variables. However, in the common factor model you always assume that observed variables are functions of underlying factors. In this example, the **PRIORS=** option specifies that the squared multiple correlations (SMC) of each variable with all the other variables are used as the prior communality estimates. Note that squared multiple correlations are usually less than one. By default, the principal factor extraction is used if the **METHOD=** option is not specified. To facilitate interpretations, the **ROTATE=** option specifies the VARIMAX orthogonal factor rotation to be used.

The output from the factor analysis is displayed in [Figure 39.1](#) through [Figure 39.5](#).

As displayed in [Figure 39.1](#), the prior communality estimates are set to the squared multiple correlations. [Figure 39.1](#) also displays the table of eigenvalues (the variances of the principal factors) of the reduced correlation matrix. Each row of the table pertains to a single eigenvalue. Following the column of eigenvalues are three measures of each eigenvalue’s relative size and importance. The first of these displays the difference between the eigenvalue and its successor. The last two columns display the individual and cumulative proportions that the corresponding factor contributes to the total variation. The last line displayed in [Figure 39.1](#) states that three factors are retained, as determined by the PROPORTION criterion.

**Figure 39.1** Table of Eigenvalues from PROC FACTOR

The FACTOR Procedure						
Initial Factor Method: Principal Factors						
Prior Communality Estimates: SMC						
Communication Skills	Problem Solving	Learning Ability	Judgment under Pressure	Observational Skills	Willingness to Confront Problems	Interest in People
0.62981394	0.58657431	0.61009871	0.63766021	0.67187583	0.64779805	0.75641519
Interpersonal Sensitivity	Desire for Self-Improvement	Appearance	Dependability	Physical Ability	Integrity	
0.75584891	0.57460176	0.45505304	0.63449045	0.42245324	0.68195454	

Figure 39.1 continued

Eigenvalues of the Reduced Correlation Matrix: Total = 8.06463816 Average = 0.62035678				
	Eigenvalue	Difference	Proportion	Cumulative
1	6.17760549	4.71531946	0.7660	0.7660
2	1.46228602	0.90183348	0.1813	0.9473
3	0.56045254	0.28093933	0.0695	1.0168
4	0.27951322	0.04766016	0.0347	1.0515
5	0.23185305	0.16113428	0.0287	1.0802
6	0.07071877	0.07489624	0.0088	1.0890
7	-.00417747	0.03387533	-0.0005	1.0885
8	-.03805279	0.04776534	-0.0047	1.0838
9	-.08581814	0.02438060	-0.0106	1.0731
10	-.11019874	0.01452741	-0.0137	1.0595
11	-.12472615	0.02356465	-0.0155	1.0440
12	-.14829080	0.05823605	-0.0184	1.0256
13	-.20652684		-0.0256	1.0000

**3 factors will be retained by the PROPORTION criterion.**

Figure 39.2 displays the initial factor pattern matrix. The factor pattern matrix represents standardized regression coefficients for predicting the variables by using the extracted factors. Because the initial factors are uncorrelated, the pattern matrix is also equal to the correlations between variables and the common factors.

Figure 39.2 Factor Pattern Matrix from PROC FACTOR

	Factor Pattern		
	Factor1	Factor2	Factor3
Communication Skills	0.75441	0.07707	-0.25551
Problem Solving	0.68590	0.08026	-0.34788
Learning Ability	0.65904	0.34808	-0.25249
Judgment under Pressure	0.73391	-0.21405	-0.23513
Observational Skills	0.69039	0.45292	0.10298
Willingness to Confront Problems	0.66458	0.47460	0.09210
Interest in People	0.70770	-0.53427	0.10979
Interpersonal Sensitivity	0.64668	-0.61284	-0.07582
Desire for Self-Improvement	0.73820	0.12506	0.09062
Appearance	0.57188	0.20052	0.16367
Dependability	0.79475	-0.04516	0.16400
Physical Ability	0.51285	0.10251	0.34860
Integrity	0.74906	-0.35091	0.18656

The pattern matrix suggests that Factor1 represents general ability. All loadings for Factor1 in the Factor Pattern are at least 0.5. Factor2 consists of high positive loadings on certain task-related skills (Willingness to Confront Problems, Observational Skills, and Learning Ability) and high negative loadings on some interpersonal skills (Interpersonal Sensitivity, Interest in People, and Integrity). This factor measures individuals' relative strength in these skills. Theoretically, individuals with high positive scores on this factor would exhibit better task-related skills than interpersonal skills. Individuals with high negative scores would exhibit better interpersonal skills than task-related skills. Individuals with scores near zero would have those skills balanced. Factor3 does not have a cluster of very high or very low factor loadings. Therefore, interpreting this factor is difficult.

Figure 39.3 displays the proportion of variance explained by each factor and the final communality estimates, including the total communality. The final communality estimates are the proportion of variance of the variables accounted for by the common factors. When the factors are orthogonal, the final communalities are calculated by taking the sum of squares of each row of the factor pattern matrix.

**Figure 39.3** Variance Explained and Final Communality Estimates

Variance Explained by Each Factor						
	Factor1	Factor2	Factor3			
	6.1776055	1.4622860	0.5604525			
Final Communality Estimates: Total = 8.200344						
Communication Skills	Problem Solving	Learning Ability	Judgment under Pressure	Observational Skills	Willingness to Confront Problems	Interest in People
0.64036292	0.59791844	0.61924167	0.63972863	0.69237485	0.67538695	0.79833968
Interpersonal Sensitivity	Desire for Self-improvement	Appearance	Dependability	Physical Ability	Integrity	
0.79951357	0.56879171	0.39403630	0.66056907	0.39504805	0.71903222	

Figure 39.4 displays the results of the VARIMAX rotation of the three extracted factors and the corresponding orthogonal transformation matrix. The rotated factor pattern matrix is calculated by postmultiplying the original factor pattern matrix (Figure 39.4) by the transformation matrix.

**Figure 39.4** Transformation Matrix and Rotated Factor Pattern

Orthogonal Transformation Matrix			
	1	2	3
1	0.59125	0.59249	0.54715
2	-0.80080	0.51170	0.31125
3	0.09557	0.62219	-0.77701

Figure 39.4 continued

Rotated Factor Pattern			
	Factor1	Factor2	Factor3
Communication Skills	0.35991	0.32744	0.63530
Problem Solving	0.30802	0.23102	0.67058
Learning Ability	0.08679	0.41149	0.66512
Judgment under Pressure	0.58287	0.17901	0.51764
Observational Skills	0.05533	0.70488	0.43870
Willingness to Confront Problems	0.02168	0.69391	0.43978
Interest in People	0.85677	0.21422	0.13562
Interpersonal Sensitivity	0.86587	0.02239	0.22200
Desire for Self-Improvement	0.34498	0.55775	0.37242
Appearance	0.19319	0.54327	0.24814
Dependability	0.52174	0.54981	0.29337
Physical Ability	0.25445	0.57321	0.04165
Integrity	0.74172	0.38033	0.15567

The rotated factor pattern matrix is somewhat simpler to interpret. If a magnitude of at least 0.5 is required to indicate a salient variable-factor relationship, Factor1 now represents interpersonal skills (Interpersonal Sensitivity, Interest in People, Integrity, Judgment Under Pressure, and Dependability). Factor2 measures physical skills and job enthusiasm (Observational Skills, Willingness to Confront Problems, Physical Ability, Desire for Self-Improvement, Dependability, and Appearance). Factor3 measures cognitive skills (Communication Skills, Problem Solving, Learning Ability, and Judgment Under Pressure).

However, using 0.5 for determining a salient variable-factor relationship does not take sampling variability into account. If the underlying assumptions for the maximum likelihood estimation are approximately satisfied, you can output standard error estimates and the confidence intervals with `METHOD=ML`. You can then determine the salience of the variable-factor relationship by using the coverage displays. See the section “Confidence Intervals and the Salience of Factor Loadings” on page 2528 for more details.

Figure 39.5 displays the variance explained by each factor and the final communality estimates after the orthogonal rotation. Even though the variances explained by the rotated factors are different from that of the unrotated factor (compare with Figure 39.3), the cumulative variance explained by the common factors remains the same. Note also that the final communalities for variables, as well as the total communality, remain unchanged after rotation. Although rotating a factor solution will not increase or decrease the statistical quality of the factor model, it can simplify the interpretations of the factors and redistribute the variance explained by the factors.

Figure 39.5 Variance Explained and Final Communality Estimates after Rotation

Variance Explained by Each Factor		
Factor1	Factor2	Factor3
3.1024330	2.7684489	2.3294622

Figure 39.5 continued

Final Communality Estimates: Total = 8.200344						
Communication Skills	Problem Solving	Learning Ability	Judgment under Pressure	Observational Skills	Willingness to Confront Problems	Interest in People
0.64036292	0.59791844	0.61924167	0.63972863	0.69237485	0.67538695	0.79833968
Interpersonal Sensitivity	Desire for Self-Improvement	Appearance	Dependability	Physical Ability	Integrity	
0.79951357	0.56879171	0.39403630	0.66056907	0.39504805	0.71903222	

## Syntax: FACTOR Procedure

The following statements are available in the FACTOR procedure:

```

PROC FACTOR < options > ;
VAR variables ;
PRIORS communalities ;
PATHDIAGRAM < options > ;
PARTIAL variables ;
FREQ variable ;
WEIGHT variable ;
BY variables ;

```

Usually only the VAR statement is needed in addition to the PROC FACTOR statement. The descriptions of the BY, FREQ, PARTIAL, PRIORS, VAR, and WEIGHT statements follow the description of the PROC FACTOR statement in alphabetical order.

## PROC FACTOR Statement

```

PROC FACTOR < options > ;

```

The PROC FACTOR statement invokes the FACTOR procedure. The *options* listed in Table 39.1 are available in the PROC FACTOR statement.

**Table 39.1** Options Available in the PROC FACTOR Statement

Option	Description
<b>Data Set Options</b>	
DATA=	Specifies input SAS data set
OUT=	Specifies output SAS data set
OUTSTAT=	Specifies output data set containing statistical results
TARGET=	Specifies input data set containing the target pattern for rotation

Table 39.1 *continued*

Option	Description
<b>Factor Extraction and Communalities</b>	
HEYWOOD	Sets to 1 any communality greater than 1
METHOD=	Specifies the estimation method
PRIORS=	Specifies the method for computing prior communality estimates
RANDOM=	Specifies the seed for pseudo-random number generation
ULTRAHEYWOOD	Allows communalities to exceed 1
<b>Number of Factors</b>	
MINEIGEN=	Specifies the smallest eigenvalue for retaining a factor
NFACTORS=	Specifies the number of factors to retain or the factor extraction criterion to use
PROPORTION=	Specifies the proportion of common variance in extracted factors
<b>Data Analysis Options</b>	
ALPHA=	Specifies the confidence level for interval construction
COVARIANCE	Requests factoring of the covariance matrix
COVER=	Computes the confidence interval and specifies the coverage reference point
MAP	Requests a minimum average partial (MAP) correlation analysis
NOINT	Omits the intercept from computing covariances or correlations
PARALLEL	Requests a parallel analysis
SE	Requests the standard error estimates in ML estimation
VARDEF=	Specifies the divisor used in calculating covariances or correlations
WEIGHT	Factors a weighted correlation or covariance matrix
<b>Rotation Method and Properties</b>	
GAMMA=	Specifies the orthomax weight
HKPOWER=	Specifies the power in Harris-Kaiser rotation
NORM=	Specifies the method for row normalization in rotation
NOPROMAXNORM	Turns off row normalization in promax rotation
POWER=	Specifies the power to be used in promax rotation
PREROTATE=	Specifies the prerotation method in promax rotation
RCONVERGE=	Specifies the convergence criterion for rotation cycles
RITER=	Specifies the maximum number of cycles for rotation
ROTATE=	Specifies the rotation method
TAU=	Specifies the oblimin weight
<b>ODS Graphics</b>	
PLOTS=	Specifies ODS Graphics selection

Table 39.1 *continued*

Option	Description
<b>Control Display Output</b>	
ALL	Displays all optional output except plots
CORR	Displays the (partial) correlation matrix
EIGENVECTORS	Displays the eigenvectors of the reduced correlation matrix
FLAG=	Specifies the minimum absolute value to be flagged in the correlation and loading matrices
FUZZ=	Specifies the maximum absolute value to be displayed as missing in the correlation and loading matrices
MSA	Computes Kaiser's measure of sampling adequacy and the related partial correlations
NOPRINT	Suppresses the display of all output
NPLOT=	Specifies the number of factors to be plotted
PLOT	Plots the rotated factor pattern
PLOTREF	Plots the reference structure
PREPLOT	Plots the factor pattern before rotation
PRINT	Displays the input factor pattern or scoring coefficients and related statistics
REORDER	Reorders the rows (variables) of various factor matrices
RESIDUALS	Displays the residual correlation matrix and the associated partial correlation matrix
ROUND	Prints correlation and loading matrices with rounded values
SCORE	Displays the factor scoring coefficients
SCREE	Displays the scree plot of the eigenvalues
SIMPLE	Displays means, standard deviations, and number of observations
<b>Numerical Properties</b>	
CONVERGE=	Specifies the convergence criterion
MAXITER=	Specifies the maximum number of iterations
NTHREADS=	Specifies the maximum number of simultaneous computational threads available to the procedure
SINGULAR=	Specifies the singularity criterion
<b>Miscellaneous</b>	
NOCORR	Excludes the correlation matrix from the OUTSTAT= data set
NOBS=	Specifies the number of observations
PARPREFIX=	Specifies the prefix for the residual variables in the output data sets
PREFIX=	Specifies the prefix for naming factors

**ALL**

displays all optional output except plots. When the input data set is `TYPE=CORR`, `TYPE=UCORR`, `TYPE=COV`, `TYPE=UCOV`, or `TYPE=FACTOR`, simple statistics, correlations, and `MSA` are not displayed.

**ALPHA= $\rho$** 

specifies the level of confidence  $1 - \rho$  for interval construction. By default,  $\rho = 0.05$ , corresponding to  $1 - \rho = 95\%$  confidence intervals. If  $\rho$  is greater than one, it is interpreted as a percentage and divided by 100. With multiple confidence intervals to be constructed, the `ALPHA=` value is applied to each interval construction one at a time. This will not control the coverage probability of the intervals simultaneously. To control familywise coverage probability, you might consider supplying a nonconventional  $\rho$  by using methods such as Bonferroni adjustment.

**CONVERGE= $\rho$** **CONV= $\rho$** 

specifies the convergence criterion for the `METHOD=PRINIT`, `METHOD=ULS`, `METHOD=ALPHA`, or `METHOD=ML` option. Iteration stops when the maximum change in the communalities is less than the value of the `CONVERGE=` option. The default value is 0.001. Negative values are not allowed.

**CORR****C**

displays the correlation matrix or partial correlation matrix.

**COVARIANCE****COV**

requests factoring of the covariance matrix instead of the correlation matrix. The `COV` option is effective only with the `METHOD=PRINCIPAL`, `METHOD=PRINIT`, `METHOD=ULS`, or `METHOD=IMAGE` option. For other methods, PROC FACTOR produces the same results with or without the `COV` option.

**COVER <= $\rho$ >****CI <= $\rho$ >**

computes the confidence intervals and optionally specifies the value of factor loading for coverage detection. By default,  $\rho = 0$ . The specified value is represented by an asterisk (\*) in the coverage display. This is useful for determining the salience of loadings. For example, if `COVER=0.4`, a display '0\*[ ]' indicates that the entire confidence interval is above 0.4, implying strong evidence for the salience of the loading. See the section “[Confidence Intervals and the Salience of Factor Loadings](#)” on page 2528 for more details.

**DATA=SAS-data-set**

specifies the input data set, which can be an ordinary SAS data set or a specially structured SAS data set as described in the section “[Input Data Set](#)” on page 2521. If the `DATA=` option is omitted, the most recently created SAS data set is used.

**EIGENVECTORS****EV**

displays the eigenvectors of the reduced correlation matrix, of which the diagonal elements are replaced with the communality estimates. When **METHOD=ML**, the eigenvectors are for the weighted reduced correlation matrix. PROC FACTOR chooses the solution that makes the sum of the elements of each eigenvector nonnegative. If the sum of the elements is equal to zero, then the sign depends on how the number is rounded off.

**FLAG= $\rho$** 

flags absolute values larger than  $\rho$  with an asterisk in the correlation and loading matrices. Negative values are not allowed for  $\rho$ . Values printed in the matrices are multiplied by 100 and rounded to the nearest integer (see the **ROUND** option). The **FLAG=** option has no effect when standard errors or confidence intervals are also printed.

**FUZZ= $\rho$** 

prints correlations and factor loadings with absolute values less than  $\rho$  printed as missing. For partial correlations, the **FUZZ=** value is divided by 2. For residual correlations, the **FUZZ=** value is divided by 4. The exact values in any matrix can be obtained from the **OUTSTAT=** and ODS output data sets. Negative values are not allowed. The **FUZZ=** option has no effect when standard errors or confidence intervals are also printed.

**GAMMA= $\rho$** 

specifies the orthomax weight used with the option **ROTATE=ORTHOMAX** or **PRE-ROTATE=ORTHOMAX**. Alternatively, you can use **ROTATE=ORTHOMAX( $\rho$ )** with  $\rho$  representing the orthomax weight. There is no restriction on valid values for the orthomax weight, although the most common values are between zero and the number of variables. The default **GAMMA=** value is one, resulting in the varimax rotation. See the section “[Simplicity Functions for Rotations](#)” on page 2527 for more details.

**HEYWOOD****HEY**

sets to 1 any communality greater than 1, allowing iterations to proceed. See the section “[Heywood Cases and Other Anomalies about Communality Estimates](#)” on page 2530 for a discussion of Heywood cases.

**HKPOWER= $\rho$** **HKP= $\rho$** 

specifies the power of the square roots of the eigenvalues to use to rescale the eigenvectors for Harris-Kaiser rotation (**ROTATE=HK**), assuming that the factors are extracted by the principal factor method. If the principal factor method is not used for factor extraction, the eigenvectors are replaced by the normalized columns of the unrotated factor matrix and the eigenvalues are replaced by the column normalizing constants.

Values of  $\rho$  between 0.0 and 1.0 are reasonable; a value of 1.0 is equivalent to an orthogonal rotation, with the varimax rotation as the default. You can also specify this option with an orthogonal rotation, such as **ROTATE=QUARTIMAX**, **ROTATE=BIQUARTIMAX**, **ROTATE=EQUAMAX**, or **ROTATE=ORTHOMAX**, and so on. Such a combination specifies a Harris-Kaiser case II orthoblique rotation that produces an oblique factor solution in general. By default, **HKPOWER=0.0**, which yields the independent cluster solution, in which each variable tends to have a large loading on only one factor.

**MAP**

requests a minimum average partial (MAP) correlation analysis that uses squared (Velicer 1976) and fourth-powered (Velicer, Eaton, and Fava 2000) partial correlations. Although you can use MAP analysis to suggest the number of factors, this option merely performs MAP analysis and does not affect the number of factors that are extracted. To use the MAP criterion for determining the number of factors, specify **NFACTORS=MAP2** or **NFACTORS=MAP4** in the PROC FACTOR statement. To obtain a graphical summary of the MAP analysis, specify **PLOTS=MAP**, **PLOTS=MAP2**, or **PLOTS=MAP4**.

**MAXITER=*n***

specifies the maximum number of iterations for factor extraction. You can use the MAXITER= option with the PRINIT, ULS, ALPHA, or ML method. The default is 30.

**METHOD=*name*****M=*name***

specifies the method for extracting factors. The default is METHOD=PRINCIPAL unless the DATA= data set is TYPE=FACTOR, in which case the default is METHOD=PATTERN. Valid values for *name* are as follows:

<b>ALPHA   A</b>	produces alpha factor analysis.
<b>HARRIS   H</b>	yields Harris component analysis of $\mathbf{S}^{-1}\mathbf{RS}^{-1}$ (Harris 1962), a noniterative approximation to canonical component analysis.
<b>IMAGE   I</b>	yields principal component analysis of the image covariance matrix, not the image analysis of Kaiser (1963, 1970) or Kaiser and Rice (1974). A nonsingular correlation matrix is required.
<b>ML   M</b>	performs maximum likelihood factor analysis with an algorithm due, except for minor details, to Fuller (1987). The option METHOD=ML requires a nonsingular correlation matrix.
<b>PATTERN</b>	reads a factor pattern from a TYPE=FACTOR, TYPE=CORR, TYPE=UCORR, TYPE=COV, or TYPE=UCOV data set. If you create a TYPE=FACTOR data set in a DATA step, only observations containing the factor pattern ( <code>_TYPE_='PATTERN'</code> ) and, if the factors are correlated, the interfactor correlations ( <code>_TYPE_='FCORR'</code> ) are required.
<b>PRINCIPAL   PRIN   P</b>	yields principal component analysis if no PRIORS option or statement is used or if you specify <b>PRIORS=ONE</b> ; if you specify a PRIORS statement or a <b>PRIORS=</b> value other than <b>PRIORS=ONE</b> , a principal factor analysis is performed.
<b>PRINIT</b>	yields iterated principal factor analysis.
<b>SCORE</b>	reads scoring coefficients ( <code>_TYPE_='SCORE'</code> ) from a TYPE=FACTOR, TYPE=CORR, TYPE=UCORR, TYPE=COV, or TYPE=UCOV data set. The data set must also contain either a correlation or a covariance matrix. Scoring coefficients are also displayed if you specify the <b>OUT=</b> option.
<b>ULS   U</b>	produces unweighted least squares factor analysis.

**MINEIGEN=*p*****MIN=*p***

specifies the smallest eigenvalue for which to retain a factor. If you specify two or more of the **MINEIGEN=**, **NFACTORS=*n***, and **PROPORTION=** options, the number of factors retained is the minimum number that satisfies any of the criteria. The **MINEIGEN=** option cannot be used with either the **METHOD=PATTERN** option or the **METHOD=SCORE** option. Negative values of *p* are not allowed. By default, **MINEIGEN=0** unless you omit both the **NFACTORS=*n*** and the **PROPORTION=** options and one of the following conditions holds:

- If you specify the **METHOD=ALPHA** or **METHOD=HARRIS** option, then **MINEIGEN=1**.
- If you specify the **METHOD=IMAGE** option, then

$$\text{MINEIGEN} = \frac{\text{total image variance}}{\text{number of variables}}$$

- For any other **METHOD=** specification, if prior communality estimates of 1.0 are used, then

$$\text{MINEIGEN} = \frac{\text{total weighted variance}}{\text{number of variables}}$$

When an unweighted correlation matrix is factored, this value is 1.

**MSA**

produces the partial correlations between each pair of variables controlling for all other variables (the negative anti-image correlations) and Kaiser's measure of sampling adequacy (Kaiser 1970; Kaiser and Rice 1974; Cerny and Kaiser 1977).

**NFACTORS=*n* | *name*****NFACT=*n* | *name*****N=*n* | *name***

specifies either the maximum number of factors (*n*) or a *name* that represents a specific factor extraction criterion.

**NFACTORS=*n*** specifies the maximum number of factors to be extracted and determines the amount of memory to be allocated for factor matrices. This is the default option, with *n* equal to the number of variables. Specifying a number that is small relative to the number of variables can substantially decrease the amount of memory required to run PROC FACTOR, especially with oblique rotations. If you specify two or more of the **NFACTORS=*n***, **MINEIGEN=**, and **PROPORTION=** options, the retained number of factors is the minimum number that satisfies any of the criteria. If you specify the option **NFACTORS=0**, eigenvalues are computed but no factors are extracted. If you specify the option **NFACTORS=-1**, neither eigenvalues nor factors are computed. You can use the **NFACTORS=*n*** option with the **METHOD=PATTERN** or **METHOD=SCORE** option to specify a smaller number of factors than are present in the data set.

Alternatively, you can specify one of the following as the *name* for the factor extraction criterion:

**MAP | MAP2**

requests a minimum average partial (MAP) correlation analysis (Velicer 1976) to determine the number of factors to extract. All other criteria for determining the number of factors are ignored. This criterion selects the number of factors that results in the smallest average squared partial correlations among variables. This criterion cannot be used if **METHOD=PATTERN**.

To request a minimum average partial correlation analysis without using the MAP criterion for determining the number of extracted factors, use the **MAP** option in the PROC FACTOR statement.

**MAP4** requests a minimum average partial (MAP) correlation analysis similar to the **NFACTORS=MAP** option, but using the smallest average fourth-powered partial correlations among variables (Velicer, Eaton, and Fava 2000). This criterion cannot be used if **METHOD=PATTERN**.

**PARALLEL**<(suboptions)> requests a parallel analysis (Glorfeld 1995; Horn 1965) to determine the number of factors to extract. All other criteria for determining the number of factors are ignored. To request a parallel analysis without using its criterion for determining the number of extracted factors, use the **PARALLEL** option in the PROC FACTOR statement. This criterion cannot be used if **METHOD=PATTERN**.

This criterion selects the number of factors that corresponds to the first  $n$  consecutive eigenvalues of the sample correlation matrix that are significantly greater than the corresponding eigenvalues of random correlation matrices. PROC FACTOR generates these random correlation matrices by simulation from a multivariate standard normal distribution. A factor is accepted if an observed eigenvalue is greater than the critical value at a specified one-sided  $\alpha$ -level, with reference to the corresponding simulated distribution of random eigenvalues. As soon as an observed eigenvalue is less than or equal to the corresponding critical value, no more factors are counted. To obtain a graphical summary of the results of the parallel analysis, specify **PLOTS=PARALLEL**.

To fine-tune the parallel analysis, the **NFACTORS=PARALLEL** option accepts the same *suboptions* as those described for the **PARALLEL** option.

#### **NOBS= $n$**

specifies the number of observations. If the **DATA=** input data set is a raw data set, *nobs* is defined by default to be the number of observations in the raw data set. The **NOBS=** option overrides this default definition. If the **DATA=** input data set contains a covariance, correlation, or scalar product matrix, the number of observations can be specified either by using the **NOBS=** option in the PROC FACTOR statement or by including a **\_TYPE\_='N'** observation in the **DATA=** input data set.

#### **NOCORR**

prevents the correlation matrix from being transferred to the **OUTSTAT=** data set when you specify the **METHOD=PATTERN** option. The **NOCORR** option greatly reduces memory requirements when there are many variables but few factors. The **NOCORR** option is not effective if the correlation matrix is required for other requested output; for example, if the scores or the residual correlations are displayed (for example, by using the **SCORE**, **RESIDUALS**, or **ALL** option).

#### **NOINT**

omits the intercept from the analysis; covariances or correlations are not corrected for the mean.

#### **NOPRINT**

suppresses the display of all output. Note that this option temporarily disables the Output Delivery System (ODS). For more information, see Chapter 20, “Using the Output Delivery System.”

**NOPROMAXNORM****NOPMAXNORM**

turns off the default row normalization of the prerotated factor pattern, which is used in computing the promax target matrix.

**NORM=COV | KAISER | NONE | RAW | WEIGHT**

specifies the method for normalizing the rows of the factor pattern for rotation. If you specify the option **NORM=KAISER**, Kaiser's normalization is used ( $\sum_j p_{ij}^2 = 1$ ). If you specify the option **NORM=WEIGHT**, the rows are weighted by the Cureton-Mulaik technique (Cureton and Mulaik 1975). If you specify the option **NORM=COV**, the rows of the pattern matrix are rescaled to represent covariances instead of correlations. If you specify the option **NORM=NONE** or **NORM=RAW**, normalization is not performed. The default is **NORM=KAISER**.

**NPLOTS=*n*****NPLOT=*n***

specifies the number of factors to be plotted. The default is to plot all factors. The smallest allowable value is 2. If you specify the option **NPLOTS=*n***, all pairs of the first *n* factors are plotted, producing a total of  $n(n - 1)/2$  plots.

**NTHREADS=*n*****THREADS=*n***

specifies the maximum number of simultaneous computational threads available to the procedure. By default, the procedure uses the values of the **THREADS** and **CPUCOUNT** system variables to determine the number of computational threads. To explicitly request this default behavior, specify  $n < 1$ . To disable multithreading within **PROC FACTOR**, specify **NTHREADS=1**.

Multithreading is available only for parallel analysis and the generalized Crawford-Ferguson family of factor rotations. For parallel analysis, multithreading is enabled by default. For generalized Crawford-Ferguson rotations, multithreading is enabled by default only if the number of factors is 20 or greater. You can enable multithreading for rotation (for any number of factors) by specifying  $n > 1$ .

**OUT=SAS-data-set**

creates a data set containing all the data from the **DATA=** data set plus variables called Factor1, Factor2, and so on, containing estimated factor scores. The **DATA=** data set must contain multivariate data, not correlations or covariances. You must also specify the **NFACTORS=*n*** option to determine the number of factor score variables. If you specify partial variables in the **PARTIAL** statement, the **OUT=** data set will also contain the residual variables that are used for factor analysis. The output data set is described in detail in the section “**Output Data Sets**” on page 2523. If you want to create a SAS data set in a permanent library, you must specify a two-level name. For more information about permanent libraries and SAS data sets, see *SAS Language Reference: Concepts*.

**OUTSTAT=SAS-data-set**

specifies an output data set containing most of the results of the analysis. The output data set is described in detail in the section “**Output Data Sets**” on page 2523. If you want to create a SAS data set in a permanent library, you must specify a two-level name. For more information about permanent libraries and SAS data sets, see *SAS Language Reference: Concepts*.

**PARALLEL** <(suboptions)>

requests a parallel analysis as described by Glorfeld (1995) and Horn (1965). Although you can use parallel analysis to suggest the number of factors, this option merely performs the parallel analysis and does not affect the number of factors that are extracted. To use the parallel analysis criterion for determining the number of factors, specify **NFACTORS=PARALLEL** in the PROC FACTOR statement. To obtain a graphical summary of the results of the parallel analysis, specify **PLOTS=PARALLEL**. The PARALLEL option cannot be used if **METHOD=PATTERN**.

To conduct a parallel analysis, PROC FACTOR compares the eigenvalues of the sample correlation matrix to the corresponding eigenvalues of random correlation matrices. These random correlation matrices are simulated from a multivariate standard normal distribution. A factor is accepted if an observed eigenvalue is greater than the critical value at a specified one-sided  $\alpha$ -level, with reference to the corresponding simulated distribution of random eigenvalues. As soon as an observed eigenvalue is less than or equal to the corresponding critical value, no more factors are counted.

To fine-tune the parallel analysis, you can specify any of the following *suboptions*:

- ALPHA= $p$**  specifies the one-sided  $\alpha$ -level for computing the critical value at the upper-end of the simulated distribution of eigenvalues, where  $p$  must be between 0 and 1. By default, ALPHA=0.05.
- NSIMS= $n$**  specifies the number of simulations to use to construct an empirical distribution of eigenvalues for the parallel analysis, where  $n$  must be greater than 200. By default, NSIMS=1000.
- SEED= $n$**  specifies a positive integer as a starting value for the pseudorandom number generator that is used to simulate correlation matrices for the parallel analysis, where  $n$  must be an integer  $\geq 1$ . If you do not specify the SEED= suboption, the time of day is used to initialize the pseudorandom number sequence.

**PARPREFIX=***name*

specifies the prefix for the residual variables in the **OUT=** and the **OUTSTAT=** data sets when partial variables are specified in the PARTIAL statement.

**PLOT**

plots the factor pattern after rotation. This option produces printer plots. High-quality ODS graphical plots for factor patterns can be requested with the **PLOTS=LOADINGS** or **PLOTS=INITLOADINGS** option.

**PLOTREF**

plots the reference structure instead of the default factor pattern after oblique rotation.

**PLOTS** <(global-plot-options)> = *plot-request* <(options)>**PLOTS** <(global-plot-options)> = (*plot-request* <(options)> <...*plot-request* <(options)> > )

specifies one or more ODS graphical plots in PROC FACTOR. When you specify only one *plot-request*, you can omit the parentheses around the *plot-request*. Here are some examples:

```
plots=all
plots(flip)=loadings
plots=(loadings(flip) scree(unpack))
```

ODS Graphics must be enabled before plots can be requested. For example:

```
ods graphics on;
proc factor plots=all;
run;
ods graphics off;
```

For more information about enabling and disabling ODS Graphics, see the section “Enabling and Disabling ODS Graphics” on page 615 in Chapter 21, “Statistical Graphics Using ODS.”

For an example containing graphical displays of factor analysis results, see [Example 39.2](#).

The following table shows the available *plot-requests* and their available *options*:

<i>Plot-Request</i>	<b>Plot Description</b>	<b>Suboptions</b>
ALL	All available plots	All
INITLOADINGS	Unrotated factor loadings	CIRCLE=, FLIP, NPLOTS=, PLOTREF, and VECTOR
LOADINGS	Rotated factor loadings	CIRCLE=, FLIP, NPLOTS=, PLOTREF, and VECTOR
MAP	MAP2 and MAP4	
MAP2	Average squared partial correlations	
MAP4	Average fourth-powered partial correlations	
NONE	No ODS graphical plots	
PARALLEL	Parallel analysis	
PATHDIAGRAM	Path diagram	
PRELOADINGS	Prerotated factor loadings	CIRCLE=, FLIP, NPLOTS=, PLOTREF, and VECTOR
SCREE	Scree and variance explained	UNPACK

The following are the available *global-plot-options* or *options* for plots:

**CIRCLE** < = *numbers* > | **CIRCLES** < = *numbers* > draws circular reference lines in scatter plots or vector plots of factor loadings. You can specify the locations of the circular reference lines in the *numbers* list. Each number indicates the proportion or percentage of area of the unit circle that is enclosed by the specified circle. Each of the *numbers* must lie between 0 and 100, inclusively. When a number is between 0 and 1 (inclusively), it is interpreted as a proportion; otherwise, it is interpreted as a percentage. The maximum number of circles is 5.

The CIRCLE option applies to the scatter or vector plots requested by the INITLOADINGS, LOADINGS, and PRELOADINGS options. By default, a unit-circle, which represents 100% of the total area, is drawn for the vector plots. However, no circle will be drawn for scatter plots unless the CIRCLE option is specified. Two special cases for this option are: (1) With no *numbers* following the CIRCLE option, a 100% circle will be drawn. (2) With CIRCLE=0, no circle will be drawn. This special case is primarily used to turn off the default unit-circle in vector plots.

**FLIP** switches the X and Y axes. It applies to the INITLOADINGS, LOADINGS, and PRELOADINGS *plot-requests*.

**NPLOT**=*n* | **NPLOTS**=*n* specifies the number of factors *n* ( $n \geq 2$ ) to be plotted. It applies to the INITLOADINGS, LOADINGS, and PRELOADINGS *plot-requests*. Since this

option can also be specified in the PROC FACTOR statement, the final value of  $n$  is determined by the following steps. The NPLOTS= value of the PROC FACTOR is read first. If the NPLOTS= option is specified as a *global-plot-option*, the value of  $n$  will be updated. Then, if the NPLOTS= option is again specified in an individual *plot-request*, the value will be updated again for that individual *plot-request*. For example, in the following statement, four factors are extracted with the N=4 option:

```
proc factor n=4 nplots=3 plots(nplots=4)=
          (loadings preloadings(nplots=2));
```

Initially, plots of the first three factors are specified with the NPLOTS=3 option. When you are producing ODS graphical plots, the *global-plot-option* NPLOTS=4 is used. As a result, the LOADINGS *plot-request* will produce plots for all pairs of the first 4 factors. However, because the NPLOTS=2 is specified locally for the PRELOADINGS *plot-request*, it will produce a prerotated factor loading plot for the first two factors only.

The default NPLOTS= value is 5 or the total number of factors ( $m$ ), whichever is smaller. If you specify an NPLOTS= value that is greater than  $m$ , NPLOTS= $m$  will be used.

**PATHDIAGRAM** creates a path diagram for the last factor model. The last factor model refers to the initial factor solution if you do not specify any rotations. It refers to the rotated factor solution if you use the **ROTATE=** option. The path diagram shows the links between factors and variables, the factor correlations, and the error variances in the model.

The path diagram does not display all non-zero directed links between factors and variables. It displays only those directed links that have factor loading estimates at 0.3 or bigger in magnitude. PROC FACTOR uses this 0.3-criterion by default. You can set your own criterion by using the **FUZZ=** option in the PROC FACTOR statement.

If you use both the **METHOD=ML** and **SE** options in the PROC FACTOR statement, the statistical significance of the factor loading estimate is also required for displaying the corresponding directed link between a variable and a factor. The default level of significance is 0.05. You can set your own level of significance by using the **ALPHA=** option in the PROC FACTOR statement.

Alternatively, you can produce path diagrams by using the **PATHDIAGRAM Statement**, which provides many options that enables you to create highly customized path diagrams.

**PLOTREF** plots the reference structures rather than the factor pattern loadings. It applies to the INITLOADINGS, LOADINGS, and PRELOADINGS *plot-requests* when the factor solution is oblique. This option can also be set globally as an option in the PROC FACTOR statement.

**UNPACK** plots component graphs separately. It applies to the SCREE *plot-request* only.

**VECTOR** plots loadings in vector form. It applies to the INITLOADINGS, LOADINGS, and PRELOADINGS *plot-requests* when the factor solution is orthogonal. For oblique

solutions, the VECTOR option is ignored and the default scatter plots for factor loadings or reference structures are displayed.

Be aware that the PLOT option in the PROC FACTOR statement requests only the printer plots of factor loadings. The current option PLOTS= or PLOT=, however, is for ODS graphical plots.

You can specify options for the requested ODS graphical plots as *global-plot-options* or as local *options*. *Global-plot-options* apply to all appropriate individual *plot-requests* specified. For example, because the SCREE plot is not subject to axes flipping, the following two specifications are equivalent:

```
plots(flip)=(loadings preloadings scree)
plots=(loadings(flip) preloadings(flip) scree)
```

*Options* specified locally after each *plot-request* apply to that plot-request only. For example, consider the following specification:

```
plots=(scree(unpack) loadings(plotref) preloadings(flip))
```

The FLIP option applies to the PRELOADINGS *plot-request* but not the LOADINGS *plot-request*; the PLOTREF option applies to the LOADINGS *plot-request* but not the PRELOADINGS *plot-request*; and the UNPACK option applies to the SCREE *plot-request* only.

#### **POWER=*n***

specifies the power to be used in computing the target pattern for the option ROTATE=PROMAX. Valid values must be integers  $\geq 1$ . The default value is 3. You can also specify the POWER= value in the ROTATE= option—for example, ROTATE=PROMAX(4).

#### **PREFIX=*name***

specifies a prefix for naming the factors. By default, the names are Factor1, Factor2, . . . , Factor*n*. If you specify PREFIX=ABC, the factors are named ABC1, ABC2, ABC3, and so on. The number of characters in the prefix plus the number of digits required to designate the variables should not exceed the current name length defined by the VALIDVARNAME= system option.

#### **PREPLOT**

plots the factor pattern before rotation. This option produces printer plots. High-quality ODS graphical plots for factor patterns can be requested with the PLOTS=PRELOADINGS option.

#### **PREROTATE=*name***

#### **PRE=*name***

specifies the prerotation method for the option ROTATE=PROMAX. Any rotation method other than PROMAX or PROCURUSTES can be used. The default is PREROTATE=VARIMAX. If a previously rotated pattern is read using the option METHOD=PATTERN, you should specify the PREROTATE=NONE option.

#### **PRINT**

displays the input factor pattern or scoring coefficients and related statistics. In oblique cases, the reference and factor structures are computed and displayed. The PRINT option is effective only with the option METHOD=PATTERN or METHOD=SCORE.

**PRIORS=*name***

specifies a method for computing prior communality estimates. You can specify numeric values for the prior communality estimates by using the PRIORS statement. Valid values for *name* are as follows:

<b>ASMC   A</b>	sets the prior communality estimates proportional to the squared multiple correlations but adjusted so that their sum is equal to that of the maximum absolute correlations (Cureton 1968).
<b>INPUT   I</b>	reads the prior communality estimates from the first observation with either <code>_TYPE_='PRIORS'</code> or <code>_TYPE_='COMMUNAL'</code> in the <code>DATA=</code> data set (which cannot be <code>TYPE=DATA</code> ).
<b>MAX   M</b>	sets the prior communality estimate for each variable to its maximum absolute correlation with any other variable.
<b>ONE   O</b>	sets all prior communalities to 1.0.
<b>RANDOM   R</b>	sets the prior communality estimates to pseudo-random numbers uniformly distributed between 0 and 1.
<b>SMC   S</b>	sets the prior communality estimate for each variable to its squared multiple correlation with all other variables.

The default prior communality estimates are as follows:

<b>METHOD=</b>	<b>PRIORS=</b>
PRINCIPAL	ONE
PRINIT	ONE
ALPHA	SMC
ULS	SMC
ML	SMC
HARRIS	SMC
IMAGE	SMC
PATTERN	(not applicable)
SCORE	(not applicable)

Because the use of SMC as prior communalities is a defining feature of the HARRIS and IMAGE methods, you cannot set any prior communalities other than SMC for these two methods. The PRIORS= option is not applicable to the PATTERN and SCORE methods because these methods do not use any prior communalities.

By default, the options `METHOD=PRINIT`, `METHOD=ULS`, `METHOD=ALPHA`, and `METHOD=ML` stop iterating and set the number of factors to 0 if an estimated communality exceeds 1. The options `HEYWOOD` and `ULTRAHEYWOOD` allow processing to continue.

**PROPORTION=*p*****PERCENT=*p*****P=*p***

specifies the proportion of common variance to be accounted for by the retained factors. The proportion of common variance is computed using the total prior communality estimates as the basis. If the value is greater than one, it is interpreted as a percentage and divided by 100. The options **PROPORTION=0.75** and **PERCENT=75** are equivalent. The default value is 1.0 or 100%. You cannot specify the **PROPORTION=** option with the **METHOD=PATTERN** or **METHOD=SCORE** option. If you specify two or more of the **PROPORTION=**, **NFACTORS=*n***, and **MINEIGEN=** options, the number of factors retained is the minimum number satisfying any of the criteria.

**RANDOM=*n***

specifies a positive integer as a starting value for the pseudo-random number generator for use with the option **PRIORS=RANDOM**. If you do not specify the **RANDOM=** option, the time of day is used to initialize the pseudo-random number sequence. Valid values must be integers  $\geq 1$ .

**RCONVERGE=*p*****RCONV=*p***

specifies the convergence criterion value  $p$  ( $p > 0$ ) for rotation cycles. Rotation stops when the scaled change of the simplicity function value is less than  $p$ . Mathematically, the convergence criterion is

$$|f_{new} - f_{old}|/K < p$$

where  $f_{new}$  and  $f_{old}$  are simplicity function values of the current cycle and the previous cycle, respectively,  $K = \max(1, |f_{old}|)$  is a scaling factor, and  $p$  is 1E-9 by default.

**REORDER****RE**

causes the rows (variables) of various factor matrices to be reordered on the output. Variables with their highest absolute loading (reference structure loading for oblique rotations) on the first factor are displayed first, from largest to smallest loading, followed by variables with their highest absolute loading on the second factor, and so on. The order of the variables in the output data set is not affected. The factors are not reordered.

**RESIDUALS****RES**

displays the residual correlation matrix and the associated partial correlation matrix. The diagonal elements of the residual correlation matrix are the unique variances.

**RITER=*n***

specifies the maximum number of cycles  $n$  for factor rotation. Except for promax and Procrustes, you can use the **RITER=** option with all rotation methods. The default  $n$  is the maximum between 10 times the number of variables and 100.

**ROTATE=*name*****R=*name***

specifies the rotation method. The default is **ROTATE=NONE**.

Valid *names* for orthogonal rotations are as follows:

- BIQUARTIMAX** | **BIQMAX** specifies orthogonal biquartimax rotation. This corresponds to the specification `ROTATE=ORTHOMAX(.5)`.
- EQUAMAX** | **E** specifies orthogonal equamax rotation. This corresponds to the specification `ROTATE=ORTHOMAX` with `GAMMA=number of factors/2`.
- FACTORPARSIMAX** | **FPA** specifies orthogonal factor parsimax rotation. This corresponds to the specification `ROTATE=ORTHOMAX` with `GAMMA=number of variables`.
- NONE** | **N** specifies that no rotation be performed, leaving the original orthogonal solution.
- ORTHCF**(*p1,p2*) | **ORCF**(*p1,p2*) specifies the orthogonal Crawford-Ferguson rotation with the weights *p1* and *p2* for variable parsimony and factor parsimony, respectively. See the definitions of weights in the section “Simplicity Functions for Rotations” on page 2527.
- ORTHGENCF**(*p1,p2,p3,p4*) | **ORGENCF**(*p1,p2,p3,p4*) specifies the orthogonal generalized Crawford-Ferguson rotation with the four weights *p1*, *p2*, *p3*, and *p4*. See the definitions of weights in the section “Simplicity Functions for Rotations” on page 2527.
- ORTHOMAX**<*p*> | **ORMAX**<*p*> specifies the orthomax rotation with orthomax weight *p*. If `ROTATE=ORTHOMAX` is used, the default *p* value is 1 unless specified otherwise in the `GAMMA=` option. Alternatively, `ROTATE=ORTHOMAX(p)` specifies *p* as the orthomax weight or the `GAMMA=` value. See the definition of the orthomax weight in the section “Simplicity Functions for Rotations” on page 2527.
- PARSIMAX** | **PA** specifies orthogonal parsimax rotation. This corresponds to the specification `ROTATE=ORTHOMAX` with
- $$\text{GAMMA} = \frac{nvar \times (nfact - 1)}{nvar + nfact - 2}$$
- where *nvar* is the number of variables and *nfact* is the number of factors.
- QUARTIMAX** | **QMAX** | **Q** specifies orthogonal quartimax rotation. This corresponds to the specification `ROTATE=ORTHOMAX(0)`.
- VARIMAX** | **V** specifies orthogonal varimax rotation. This corresponds to the specification `ROTATE=ORTHOMAX` with `GAMMA=1`.

Valid *names* for oblique rotations are as follows:

- BIQUARTIMIN** | **BIQMIN** specifies biquartimin rotation. It corresponds to the specification `ROTATE=OBLIMIN(.5)` or `ROTATE=OBLIMIN` with `TAU=0.5`.
- COVARIMIN** | **CVMIN** specifies covarimin rotation. It corresponds to the specification `ROTATE=OBLIMIN(1)` or `ROTATE=OBLIMIN` with `TAU=1`.
- HK**<*p*> | **H**<*p*> specifies Harris-Kaiser case II orthoblique rotation. The Harris-Kaiser rotation makes use of the orthogonal rotation algorithm to produce factor solutions that are, in general, oblique. When specifying this option, you can use the `HKPOWER=` option to specify the power of the square roots of the eigenvalues by which the eigenvectors are scaled, assuming that the factors are extracted by the principal factor method. For other extraction methods, the unrotated factor pattern is column normalized. The power is then applied to the column normalizing constants, instead

of the eigenvalues. You can also use `ROTATE=HK( $p$ )`, with  $p$  representing the `HKPOWER=` value. The default associated orthogonal rotation with `ROTATE=HK` is the varimax rotation without Kaiser normalization. You might associate the Harris-Kaiser with other orthogonal rotations by using the `ROTATE=` option together with the `HKPOWER=` option.

**OBBIQUARTIMAX** | **OBIQMAX** specifies oblique biquartimax rotation.

**OBEQUAMAX** | **OE** specifies oblique equamax rotation.

**OBFACORPARSIMAX** | **OFPA** specifies oblique factor parsimax rotation.

**OBLICF**( $p1,p2$ ) | **OBCF**( $p1,p2$ ) specifies the oblique Crawford-Ferguson rotation with the weights  $p1$  and  $p2$  for variable parsimony and factor parsimony, respectively. See the definitions of weights in the section “Simplicity Functions for Rotations” on page 2527.

**OBLIGENCF**( $p1,p2,p3,p4$ ) | **OBGENCF**( $p1,p2,p3,p4$ ) specifies the oblique generalized Crawford-Ferguson rotation with the four weights  $p1$ ,  $p2$ ,  $p3$ , and  $p4$ . See the definitions of weights in the section “Simplicity Functions for Rotations” on page 2527.

**OBLIMIN**<( $p$ )> | **OBMIN**<( $p$ )> specifies the oblimin rotation with oblimin weight  $p$ . If `ROTATE=OBLIMIN` is used, the default  $p$  value is zero unless specified otherwise in the `TAU=` option. Alternatively, `ROTATE=OBLIMIN( $p$ )` specifies  $p$  as the oblimin weight or the `TAU=` value. See the definition of the oblimin weight in the section “Simplicity Functions for Rotations” on page 2527.

**OBPARSIMAX** | **OPA** specifies oblique parsimax rotation.

**OBQUARTIMAX** | **OQMAX** specifies oblique quartimax rotation. This is the same as the `QUARTIMIN` method.

**OBVARIMAX** | **OV** specifies oblique varimax rotation.

**PROCRUSTES** specifies oblique Procrustes rotation with the target pattern provided by the `TARGET=` data set. The unrestricted least squares method is used with factors scaled to unit variance after rotation.

**PROMAX**<( $p$ )> | **P**<( $p$ )> specifies oblique promax rotation. You can use the `PREROTATE=` option to set the desirable prerotation method, orthogonal or oblique. When used with `ROTATE=PROMAX`, the `POWER=` option lets you specify the power for forming the target. You can also use `ROTATE=PROMAX( $p$ )`, where  $p$  represents the `POWER=` value.

**QUARTIMIN** | **QMIN** specifies quartimin rotation. It is the same as the oblique quartimax method. It also corresponds to the specification `ROTATE=OBLIMIN(0)` or `ROTATE=OBLIMIN` with `TAU=0`.

## ROUND

prints correlation and loading matrices with entries multiplied by 100 and rounded to the nearest integer. The exact values can be obtained from the `OUTSTAT=` and ODS output data sets. The `ROUND` option also flags absolute values larger than the `FLAG=` value with an asterisk in correlation and loading matrices (see the `FLAG=` option). If the `FLAG=` option is not specified, the root mean square of all the values in the matrix printed is used as the default `FLAG=` value. The `ROUND` option has no effect when standard errors or confidence intervals are also printed.

**SCORE**

displays the factor scoring coefficients. The squared multiple correlation of each factor with the variables is also displayed except in the case of unrotated principal components. The SCORE option also outputs the factor scoring coefficients in the `_TYPE_=SCORE` or `_TYPE_=USCORE` observations in the `OUTSTAT=` data set. Unless you specify the **NOINT** option in PROC FACTOR, the scoring coefficients should be applied to standardized variables—variables that are centered by subtracting the original variable means and then divided by the original variable standard deviations. With the **NOINT** option, the scoring coefficients should be applied to data without centering.

**SCREE**

displays a scree plot of the eigenvalues (Cattell 1966, 1978; Cattell and Vogelman 1977; Horn and Engstrom 1979). This option produces printer plots. High-quality scree plots can be requested with the `PLOTS=SCREE` option.

**SE****STDERR**

computes standard errors for various classes of unrotated and rotated solutions under the maximum likelihood estimation.

**SIMPLE****S**

displays means, standard deviations, and the number of observations.

**SINGULAR= $p$** **SING= $p$** 

specifies the singularity criterion, where  $0 < p < 1$ . The default value is  $1E-8$ .

**TARGET=*SAS-data-set***

specifies an input data set containing the target pattern for Procrustes rotation (see the description of the `ROTATE=` option). The `TARGET=` data set must contain variables with the same names as those being factored. Each observation in the `TARGET=` data set becomes one column of the target factor pattern. Missing values are treated as zeros. The `_NAME_` and `_TYPE_` variables are not required and are ignored if present.

**TAU= $p$** 

specifies the oblimin weight used with the option `ROTATE=OBLIMIN` or `PREROTATE=OBLIMIN`. Alternatively, you can use `ROTATE=OBLIMIN( $p$ )` with  $p$  representing the oblimin weight. There is no restriction on valid values for the oblimin weight, although for practical purposes a negative or zero value is recommended. The default `TAU=` value is 0, resulting in the quartimin rotation. See the section “Simplicity Functions for Rotations” on page 2527 for more details.

**ULTRAHEYWOOD****ULTRA**

allows communalities to exceed 1. The **ULTRAHEYWOOD** option can cause convergence problems because communalities can become extremely large, and ill-conditioned Hessians might occur. See the section “Heywood Cases and Other Anomalies about Communality Estimates” on page 2530 for a discussion of Heywood cases.

**VARDEF=DF | N | WDF | WEIGHT | WGT**

specifies the divisor used in the calculation of variances and covariances. The default value is VARDEF=DF. The values and associated divisors are displayed in the following table where  $i=0$  if the NOINT option is used and  $i=1$  otherwise, and where  $k$  is the number of partial variables specified in the PARTIAL statement.

Value	Description	Divisor
DF	degrees of freedom	$n - k - i$
N	number of observations	$n - k$
WDF	sum of weights DF	$\sum_i w_i - k - i$
WEIGHT   WGT	sum of weights	$\sum_i w_i - k$

**WEIGHT**

factors a weighted correlation or covariance matrix. The WEIGHT option can be used only with the METHOD=PRINCIPAL, METHOD=PRINIT, METHOD=ULS, or METHOD=IMAGE option. The input data set must be of type CORR, UCORR, COV, UCOV, or FACTOR, and the variable weights are obtained from an observation with `_TYPE_='WEIGHT'`.

---

## BY Statement

**BY** *variables* ;

You can specify a BY statement with PROC FACTOR to obtain separate analyses of observations in groups that are defined by the BY variables. When a BY statement appears, the procedure expects the input data set to be sorted in order of the BY variables. If you specify more than one BY statement, only the last one specified is used.

If your input data set is not sorted in ascending order, use one of the following alternatives:

- Sort the data by using the SORT procedure with a similar BY statement.
- Specify the NOTSORTED or DESCENDING option in the BY statement for the FACTOR procedure. The NOTSORTED option does not mean that the data are unsorted but rather that the data are arranged in groups (according to values of the BY variables) and that these groups are not necessarily in alphabetical or increasing numeric order.
- Create an index on the BY variables by using the DATASETS procedure (in Base SAS software).

If you specify the TARGET= option and the TARGET= data set does not contain any of the BY variables, then the entire TARGET= data set is used as a Procrustean target for each BY group in the DATA= data set.

If the TARGET= data set contains some but not all of the BY variables, or if some BY variables do not have the same type or length in the TARGET= data set as in the DATA= data set, then PROC FACTOR displays an error message and stops.

If all the BY variables appear in the TARGET= data set with the same type and length as in the DATA= data set, then each BY group in the TARGET= data set is used as a Procrustean target for the corresponding BY

group in the **DATA=** data set. The BY groups in the **TARGET=** data set must be in the same order as in the **DATA=** data set. If you specify the **NOTSORTED** option in the BY statement, there must be identical BY groups in the same order in both data sets. If you do not specify the **NOTSORTED** option, some BY groups can appear in one data set but not in the other.

For more information about BY-group processing, see the discussion in *SAS Language Reference: Concepts*. For more information about the DATASETS procedure, see the discussion in the *SAS Visual Data Management and Utility Procedures Guide*.

---

## FREQ Statement

**FREQ** *variable* ;

If a variable in the data set represents the frequency of occurrence for the other values in the observation, include the variable's name in a FREQ statement. The procedure then treats the data set as if each observation appears  $n$  times, where  $n$  is the value of the FREQ variable for the observation. The total number of observations is considered to be equal to the sum of the FREQ variable when the procedure determines degrees of freedom for significance probabilities.

If the value of the FREQ variable is missing or is less than one, the observation is not used in the analysis. If the value is not an integer, the value is truncated to an integer.

The WEIGHT and FREQ statements have a similar effect, except in determining the number of observations for significance tests.

---

## PARTIAL Statement

**PARTIAL** *variables* ;

If you want the analysis to be based on a partial correlation or covariance matrix, use the PARTIAL statement to list the variables that are used to partial out the variables in the analysis.

---

## PATHDIAGRAM Statement

**PATHDIAGRAM** *< options >* ;

You can use the PATHDIAGRAM statement to specify and modify the layout algorithm, to control the formatting of estimates, and to fine-tune many graphical and nongraphical features of path diagrams. You can use multiple PATHDIAGRAM statements to produce path diagrams that have different styles and graphical features.

Specifying a PATHDIAGRAM statement without any *options* has the same effect as specifying the **PLOTS=PATHDIAGRAM** option in the PROC FACTOR statement. Both produce a default path diagram for the last factor solution in a PROC FACTOR run. The default path diagrams show the links between factors and variables, the factor correlations, and the error variances in the model. For more information about the default path diagram, see the **PLOTS=PATHDIAGRAM** option.

The *options* in the PATHDIAGRAM statement can be classified into three categories, which are summarized in Table 39.2 through Table 39.4. The following three tables summarize these *options*. An alphabetical listing of these *options* that includes more details follows the tables.

Table 39.2 shows the *options* that you can use to specify the path diagram layout algorithm, to set the criteria for displaying the directed paths between variables and factors, and to specify the size of factors relative to the observed variables.

**Table 39.2** Options for Controlling the Layout

Option	Description
ALPHA=	Specifies the significance level of the loading estimate that is required in order to display the corresponding link between a variable and a factor
ARRANGE=	Specifies the algorithm for laying out variables in the path diagram
COVER=	Specifies the salience criterion on the loading estimate
FACTORSIZE=	Specifies the size of latent factors relative to observed variables
FUZZ=	Specifies the magnitude of the loading estimate that is required in order to display the corresponding link between a variable and a factor
SCALE=	Specifies the scale factor for the node size

Table 39.3 shows the *options* that you can use to control the display of parameter estimates in output path diagrams.

**Table 39.3** Options for Displaying Parameter Estimates

Option	Description
DECP=	Specifies the number of decimal places in the estimates
NOESTIM	Disables the display of all numerical estimates
NOERRVAR	Disables the display of error variances
NOFACTORVAR	Disables the display of factor variances
NOVARIANCE	Disables the display of all variances

Table 39.4 shows the *options* that you can use to specify the title, the path diagram label, and the variable labels.

**Table 39.4** Options for Specifying Titles and Labels

Option	Description
DESIGNHEIGHT=	Sets the height, in pixels, of the output path diagram
DESIGNWIDTH=	Sets the width, in pixels, of the output path diagram
DIAGRAMLABEL=	Specifies the label of the diagram in the ODS
LABEL=	Specifies labels of the nodes that are shown in the path diagram
NODELABEL=	Specifies whether the variable names or labels are used to label nodes
NOTITLE	Suppresses the display of the title
TITLE=	Specifies the title to display in the output path diagram

**ALPHA= $\alpha$** **ALPHALOAD= $\alpha$** 

specifies the significance level ( $\alpha$ -level) of the loading estimate that is required in order to display the corresponding directed link (path) between a variable and a factor. If  $\alpha$  is greater than 1, it is interpreted as a percentage and divided by 100. If the  $p$ -value of a loading estimate is greater than  $\alpha$ , the loading estimate is insignificant and PROC FACTOR does not display the corresponding link in the path diagram. By default,  $\alpha = 0.05$ .

The ALPHA= option applies only when you specify the **METHOD=ML** option in the PROC FACTOR statement and when standard errors are computed in the analysis (for example, by specifying the **SE** option in the PROC FACTOR statement).

If you specify the **ALPHA=** option in the PROC FACTOR statement, all PATHDIAGRAM statements use the same  $\alpha$  value that is specified in the ALPHA= option in the PROC FACTOR statement unless you respecify the ALPHA= option in individual PATHDIAGRAM statements.

**NOTE:** The  $p$ -value of a loading estimate is computed by using a reference sampling distribution that has a specific mean value. This mean value reflects the criterion for determining the salience of loading estimates. You can use the **COVER=** option or the **SALIENCE=** option to specify the salience criterion. By default, **COVER=0**; so PROC FACTOR displays all directed links between variables and factors that are significantly greater than 0.

**ARRANGE=*name*****ARRANGEMENT=*name*****METHOD=*name***

specifies the algorithm for laying out the variables in the path diagram. You can specify the following *names*:

**FLOW** specifies the process-flow algorithm.

**GRIP** specifies the GRIP (graph drawing with intelligent placement) algorithm.

**GROUPEDFLOW** specifies the grouped-flow algorithm.

By default, **ARRANGE=FLOW** if the number of observed variables is less than 15; otherwise, the default is **ARRANGE=GRIP**. The reason for switching the default layout algorithm is that when the number of observed variables becomes large, the process-flow algorithm might run out of vertical space for aligning all observed variables in a vertical line. In that case, the GRIP algorithm might be a better choice because the observed variables tend to scatter around the space rather than being aligned vertically. See [Example 39.6](#) for the use of the **ARRANGE=** option. For more information and for general uses of these layout algorithms, see the section “[The Process-Flow, Grouped-Flow, and GRIP Layout Algorithms](#)” on page 1500 in Chapter 29, “[The CALIS Procedure](#).”

**COVER= $p$** **SALIENCE= $p$** 

specifies the salience criterion,  $p$ , for the loading estimate. In order to display a loading estimate and its corresponding link between a variable and a factor in the path diagram, the magnitude of the loading estimate must be significantly greater than  $p$ . By default,  $p = 0$  and the significance level ( $\alpha$ -level) is 0.05. You can specify the significance level in the **ALPHA=** option.

The COVER= option applies only when you specify METHOD=ML in the PROC FACTOR statement and when standard errors are computed in the analysis (for example, by specifying the SE option in the PROC FACTOR statement).

If you specify the COVER= option in the PROC FACTOR statement, any PATHDIAGRAM statement that does not include a COVER= option uses the value that is specified in the PROC FACTOR statement.

**DECP=*i***

sets the number of decimal places in the estimates that are displayed in the path diagram, where *i* is between 0 and 4. The displayed estimates are at most seven digits long, including the decimal point for the nonzero value of *i*. By default, DECP=2.

**DESIGNHEIGHT | DH=*i***

sets the height of the path diagram, in number of pixels, where *i* is between 100 and 32,767. The default heights are 800, 500, and 600 for ARRANGE=FLOW, GROUPEDFLOW, and GRIP, respectively. Typically, you might want to set a larger design height and width when your path diagram contains more nodes or variables.

**DESIGNWIDTH | DW=*i***

sets the width of the path diagram, in number of pixels, where *i* is between 100 and 32,767. The default widths are 450, 720, and 600 for ARRANGE=FLOW, GROUPEDFLOW, and GRIP, respectively. Typically, you might want to set a larger design width and height when your path diagram contains more nodes or variables.

**DIAGRAMLABEL=*name***

**DLABEL=*name***

specifies the label of the path diagram. You can use any valid SAS name or quoted string of up to 256 characters for *name*. However, only up to 40 characters of the label are used by ODS. The following statements show two example label specifications:

```
pathdiagram diagramlabel=MyFactorModel;
pathdiagram diagramlabel="Varimax-Rotated Factor Solution";
```

If you do not specify this option, PROC FACTOR uses the *name* that is provided in the TITLE= option. If you specify neither the DIAGRAMLABEL= option nor the TITLE= option, PROC FACTOR uses “Path Diagram” for the label when there is only one path diagram. When there is more than one path diagram, a unique number is appended to the label of each path diagram. For example, “Path Diagram 3” is the third path diagram in the output.

**FACTORSIZE=*size***

**FACTSIZE=*size***

specifies the size of latent factors relative to the size of observed variables, where *size* is between 0.2 and 5. By default, FACTSIZE=1.5, which means that the size ratio of factors to observed variables is about 3 to 2.

**FUZZ=*p***

specifies the magnitude,  $p > 0$ , of the factor loading estimate that is required in order to display the corresponding directed link between a variable and a factor. If the magnitude of a loading estimate is

less than  $p$ , then PROC FACTOR does not display the corresponding directed link in the path diagram. By default, FUZZ=0.3.

If you specify the FUZZ= option in the PROC FACTOR statement, any PATHDIAGRAM statement that does not include a FUZZ= option uses the value that is specified in the PROC FACTOR statement.

If you specify METHOD=ML and standard errors are computed, PROC FACTOR displays only those directed links (paths) between variables and factors that are statistically significant in the path diagram. In this situation, only the criteria that are specified by the ALPHA= and COVER= options are used and the FUZZ= option is irrelevant. When METHOD=ML is not specified or standard errors are not computed, PROC FACTOR uses the criterion that is specified by the FUZZ= option.

**LABEL=** [*varlabel* <, *varlabel* ... >] | {*varlabel* <, *varlabel* ... >}

specifies the labels of variables to be displayed in path diagrams, where each *varlabel* has the following form:

*variable*=*label*

You can use any valid SAS names or quoted strings of up to 256 characters for *labels*. The *labels* identify the corresponding variables or factors in output path diagrams. For example, instead of using original variable names such as x1 and Factor1 in the path diagram, the following statement specifies the use of more meaningful labels:

```
pathdiagram label=[x1="Simple Math" Factor1="Math Ability"];
```

This option is not the only way that you can provide labels for variables. For example, you can also use the LABEL statement to specify labels for observed variables. PROC FACTOR uses the following rules to determine the label for a node (variable) in the path diagram:

1. If you specify the label for a variable or a factor by using the LABEL= option in the PATHDIAGRAM statement, the associated node (variable) uses this label in the output path diagram. Proceed to the next rule if the label of a node is not resolved.
2. If the NODELABEL=VARNAME option is specified, the associated node uses the original variable name as its label in the output path diagram. Otherwise, proceed to the next rule.
3. If the label of a variable is specified in a LABEL statement, the associated node uses this label in the output path diagram. Otherwise, proceed to the next rule.
4. The associated node uses the original variable name as its label in the output path diagram.

#### **NODELABEL=VARNAME | VARLABEL**

specifies whether the variables (nodes) in path diagrams are labeled by the original variable names (VARNAME) or their variable labels (VARLABEL), which are provided by specifying the LABEL statement. If you provide variable labels (applicable only to observed variables) in the LABEL statement, PROC FACTOR uses those provided labels unless you specify this option.

This option is not the only determinant of the final labels of nodes in the path diagram. The specifications in the LABEL= option of the PATHDIAGRAM statement are also considered. For the rules that PROC FACTOR uses to determine the node labels, see the LABEL= option.

**NOERRVAR****NOERRORVARIANCE**

suppresses the default display of error variances, which are represented as double-headed paths that are attached to observed variables.

**NOESTIM****NOEST**

suppresses the default display of all numerical estimates in path diagrams.

**NOFACTORVAR****NOFACTORVARIANCE**

suppresses the default display of factor variances, which are represented as double-headed paths that are attached to factors.

**NOTITLE**

suppresses the display of the default title. You can use the **TITLE=** option to provide your own title.

**NOVARIANCE**

suppresses the default display of all variances. This option has the same effect as specifying both the **NOFACTORVAR** and **NOERRVAR** options.

**SCALE=*n*****DIAGRAMSCALE=*n***

specifies the scaling factor, *n*, for the node size relative to the dimensions of the path diagram. Valid values of *n* are between 0 and 6. This option applies to the **ARRANGE=GRIP** layout only.

PROC FACTOR uses certain default pixel dimensions for the nodes in path diagrams that have default design dimensions (see the **DESIGNHEIGHT=** and **DESIGNWIDTH=** options for the default design dimensions). The ratio of this node dimension to the design dimension defines the point at which **SCALE=1**. **SCALE=** option values greater than 1 enlarge the nodes (relative to the design dimensions). **SCALE=** option values less than 1 shrink the nodes (relative to the design dimensions). Hence, you can accommodate more nodes (variables) in your path diagram by setting smaller **SCALE=** option values.

If you use the GRIP layout algorithm, PROC FACTOR automatically adjusts the **SCALE=** value according to the number of nodes in the path diagram, as shown in the following table:

Number of Nodes	SCALE=
14 or less	1.00
15–19	0.95
20–24	0.90
25–29	0.85
30–34	0.80
35–39	0.75
40–44	0.70
45–49	0.65
50–59	0.60
60–69	0.55
70 or more	0.50

Although these values yield reasonable relative node sizes in different situations, you can always adjust the relative node size by setting the `SCALE=` option value manually. For example, if you have 33 nodes in your path diagram and some nodes appear to be overlapping, then you can consider setting a `SCALE=` option value that is less than 0.8. When you are satisfied with the `SCALE=` option value, you can then improve the resolution of the path diagram by using the `DESIGNHEIGHT=` and `DESIGNWIDTH=` options.

**TITLE=***name*

specifies the title of the path diagram. You can use any valid SAS name or a quoted string of up to 256 characters for *name*. If you do not specify this option, PROC FACTOR uses “Path Diagram” for the title when there is only one path diagram. A unique number (for example, “Path Diagram 3”) is appended to the title of each path diagram when there is more than one path diagram.

## PRIORS Statement

**PRIORS** *communalities* ;

The PRIORS statement specifies numeric values between 0.0 and 1.0 for the prior communality estimates for each variable. The first numeric value corresponds to the first variable in the VAR statement, the second value to the second variable, and so on. The number of numeric values must equal the number of variables. For example:

```
proc factor;
  var      x  y  z;
  priors .7 .8 .9;
run;
```

You can specify various methods for computing prior communality estimates with the `PRIORS=` option in the PROC FACTOR statement. See the description of that option for more information about the default prior communality estimates.

## VAR Statement

**VAR** *variables* ;

The VAR statement specifies the numeric variables to be analyzed. If the VAR statement is omitted, all numeric variables not specified in other statements are analyzed.

## WEIGHT Statement

**WEIGHT** *variable* ;

If you want to use relative weights for each observation in the input data set, specify a variable containing weights in a WEIGHT statement. This is often done when the variance associated with each observation is different and the values of the weight variable are proportional to the reciprocals of the variances. If a variable value is negative or is missing, it is excluded from the analysis.

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## Details: FACTOR Procedure

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### Input Data Set

The FACTOR procedure can read an ordinary SAS data set containing raw data or a special data set specified as a TYPE=CORR, TYPE=UCORR, TYPE=SSCP, TYPE=COV, TYPE=UCOV, or TYPE=FACTOR data set containing previously computed statistics. A TYPE=CORR data set can be created by the CORR procedure or various other procedures such as the PRINCOMP procedure. It contains means, standard deviations, the sample size, the correlation matrix, and possibly other statistics if it is created by some procedure other than PROC CORR. A TYPE=COV data set is similar to a TYPE=CORR data set but contains a covariance matrix. A TYPE=UCORR or TYPE=UCOV data set contains a correlation or covariance matrix that is not corrected for the mean. The default VAR variable list does not include Intercept if the DATA= data set is TYPE=SSCP. If the Intercept variable is explicitly specified in the VAR statement with a TYPE=SSCP data set, the NOINT option is activated. A TYPE=FACTOR data set can be created by the FACTOR procedure and is described in the section “Output Data Sets” on page 2523.

If your data set has many observations and you plan to run FACTOR several times, you can save computer time by first creating a TYPE=CORR data set and using it as input to PROC FACTOR, as in the following statements:

```
proc corr data=raw out=correl;      /* create TYPE=CORR data set */
proc factor data=correl method=ml; /* maximum likelihood      */
proc factor data=correl;           /* principal components    */
```

The data set created by the CORR procedure is automatically given the TYPE=CORR data set option, so you do not have to specify TYPE=CORR. However, if you use a DATA step with a SET statement to modify the correlation data set, you must use the TYPE=CORR attribute in the new data set. You can use a VAR statement with PROC FACTOR when reading a TYPE=CORR data set to select a subset of the variables or change the order of the variables.

Problems can arise from using the CORR procedure when there are missing data. By default, PROC CORR computes each correlation from all observations that have values present for the pair of variables involved (pairwise deletion). The resulting correlation matrix might have negative eigenvalues. If you specify the NOMISS option with the CORR procedure, observations with any missing values are completely omitted from the calculations (listwise deletion), and there is no danger of negative eigenvalues.

PROC FACTOR can also create a TYPE=FACTOR data set, which includes all the information in a TYPE=CORR data set, and use it for repeated analyses. For a TYPE=FACTOR data set, the default value of the METHOD= option is PATTERN. The following PROC FACTOR statements produce the same results as the previous example:

```
proc factor data=raw method=ml outstat=fact; /* max. likelihood */
proc factor data=fact method=prin;         /* principal components */
```

You can use a TYPE=FACTOR data set to try several different rotation methods on the same data without repeatedly extracting the factors. In the following example, the second and third PROC FACTOR statements use the data set fact created by the first PROC FACTOR statement:

```
proc factor data=raw outstat=fact; /* principal components */
proc factor rotate=varimax;      /* varimax rotation      */
proc factor rotate=quartimax;    /* quartimax rotation  */
```

You can create a TYPE=CORR, TYPE=UCORR, or TYPE=FACTOR data set in a DATA step for PROC FACTOR to read as input. For example, in the following a TYPE=CORR data set is created and is read as input data set by the subsequent PROC FACTOR statement:

```
data correl(type=corr);
  _TYPE_='CORR';
  input _NAME_ $ x y z;
  datalines;
x 1.0 . .
y .7 1.0 .
z .5 .4 1.0
;
proc factor;
run;
```

Be sure to specify the TYPE= option in parentheses after the data set name in the DATA statement and include the \_TYPE\_ and \_NAME\_ variables. In a TYPE=CORR data set, only the correlation matrix (\_TYPE\_='CORR') is necessary. It can contain missing values as long as every pair of variables has at least one nonmissing value.

You can also create a TYPE=FACTOR data set containing only a factor pattern (\_TYPE\_='PATTERN') and use the FACTOR procedure to rotate it, as these statements show:

```
data pat(type=factor);
  _TYPE_='PATTERN';
  input _NAME_ $ x y z;
  datalines;
factor1 .5 .7 .3
factor2 .8 .2 .8
;
proc factor rotate=promax prerotate=none;
run;
```

If the input factors are oblique, you must also include the interfactor correlation matrix with \_TYPE\_='FCORR', as shown here:

```
data pat(type=factor);
  input _TYPE_ $ _NAME_ $ x y z;
  datalines;
pattern factor1 .5 .7 .3
pattern factor2 .8 .2 .8
fcorr factor1 1.0 .2 .
fcorr factor2 .2 1.0 .
;
proc factor rotate=promax prerotate=none;
run;
```

Some procedures, such as the PRINCOMP and CANDISC procedures, produce TYPE=CORR or TYPE=UCORR data sets containing scoring coefficients (\_TYPE\_='SCORE' or \_TYPE\_='USCORE'). These coefficients can be input to PROC FACTOR and rotated by using the METHOD=SCORE option, as in

the following statements:

```
proc princomp data=raw n=2 outstat=prin;
run;
proc factor data=prin method=score rotate=varimax;
run;
```

Notice that the input data set prin must contain the correlation matrix as well as the scoring coefficients.

## Output Data Sets

### The OUT= Data Set

The **OUT=** data set contains all the data in the **DATA=** data set plus new variables called Factor1, Factor2, and so on, containing estimated factor scores. Each estimated factor score is computed as a linear combination of the standardized values of the variables that are factored. The coefficients are always displayed if the **OUT=** option is specified, and they are labeled “Standardized Scoring Coefficients.”

If partial variables are specified in the **PARTIAL** statement, the factor analysis is on the residuals of the variables, which are regressed on the partial variables. In this case, the **OUT=** data set also contains the (unstandardized) residuals, which are prefixed by **R\_** by default. For example, the residual of variable **X** is named **R\_X** in the **OUT=** data set. You might also assign the prefix by the **PARPREFIX=** option. Because the residuals are factor-analyzed, the estimated factor scores are computed as linear combinations of the standardized values of the residuals, but not the original variables.

### The OUTSTAT= Data Set

The **OUTSTAT=** data set is similar to the **TYPE=CORR** or **TYPE=UCORR** data set produced by the **CORR** procedure, but it is a **TYPE=FACTOR** data set and it contains many results in addition to those produced by **PROC CORR**. The **OUTSTAT=** data set contains observations with **\_TYPE\_='UCORR'** and **\_TYPE\_='USTD'** if you specify the **NOINT** option.

The output data set contains the following variables:

- the **BY** variables, if any
- two new character variables, **\_TYPE\_** and **\_NAME\_**
- the variables analyzed—those in the **VAR** statement, or, if there is no **VAR** statement, all numeric variables not listed in any other statement. If partial variables are specified in the **PARTIAL** statement, the residuals are included instead. By default, the residual variable names are prefixed by **R\_**, unless you specify something different in the **PARPREFIX=** option.

Each observation in the output data set contains some type of statistic as indicated by the **\_TYPE\_** variable. The **\_NAME\_** variable is blank except where otherwise indicated. The values of the **\_TYPE\_** variable are as follows:

MEAN	means
STD	standard deviations

USTD	uncorrected standard deviations
N	sample size
CORR	correlations. The <code>_NAME_</code> variable contains the name of the variable corresponding to each row of the correlation matrix.
UCORR	uncorrected correlations. The <code>_NAME_</code> variable contains the name of the variable corresponding to each row of the uncorrected correlation matrix.
IMAGE	image coefficients. The <code>_NAME_</code> variable contains the name of the variable corresponding to each row of the image coefficient matrix.
IMAGECOV	image covariance matrix. The <code>_NAME_</code> variable contains the name of the variable corresponding to each row of the image covariance matrix.
COMMUNAL	final communality estimates
PRIORS	prior communality estimates, or estimates from the last iteration for iterative methods
WEIGHT	variable weights
SUMWGT	sum of the variable weights
EIGENVAL	eigenvalues
UNROTATE	unrotated factor pattern. The <code>_NAME_</code> variable contains the name of the factor.
SE_UNROT	standard error estimates for the unrotated loadings. The <code>_NAME_</code> variable contains the name of the factor.
RESIDUAL	residual correlations. The <code>_NAME_</code> variable contains the name of the variable corresponding to each row of the residual correlation matrix.
PRETRANS	transformation matrix from prerotation. The <code>_NAME_</code> variable contains the name of the factor.
PREFCORR	prerotated interfactor correlations. The <code>_NAME_</code> variable contains the name of the factor.
SE_PREFC	standard error estimates for prerotated interfactor correlations. The <code>_NAME_</code> variable contains the name of the factor.
PREROTAT	prerotated factor pattern. The <code>_NAME_</code> variable contains the name of the factor.
SE_PREPA	standard error estimates for the prerotated loadings. The <code>_NAME_</code> variable contains the name of the factor.
PRERCORR	prerotated reference axis correlations. The <code>_NAME_</code> variable contains the name of the factor.
PREREFER	prerotated reference structure. The <code>_NAME_</code> variable contains the name of the factor.
PRESTRUC	prerotated factor structure. The <code>_NAME_</code> variable contains the name of the factor.
SE_PREST	standard error estimates for prerotated structure loadings. The <code>_NAME_</code> variable contains the name of the factor.
PRESCORE	prerotated scoring coefficients. The <code>_NAME_</code> variable contains the name of the factor.
TRANSFOR	transformation matrix from rotation. The <code>_NAME_</code> variable contains the name of the factor.
FCORR	interfactor correlations. The <code>_NAME_</code> variable contains the name of the factor.

SE_FCORR	standard error estimates for interfactor correlations. The <code>_NAME_</code> variable contains the name of the factor.
PATTERN	factor pattern. The <code>_NAME_</code> variable contains the name of the factor.
SE_PAT	standard error estimates for the rotated loadings. The <code>_NAME_</code> variable contains the name of the factor.
RCORR	reference axis correlations. The <code>_NAME_</code> variable contains the name of the factor.
REFERENC	reference structure. The <code>_NAME_</code> variable contains the name of the factor.
STRUCTUR	factor structure. The <code>_NAME_</code> variable contains the name of the factor.
SE_STRUC	standard error estimates for structure loadings. The <code>_NAME_</code> variable contains the name of the factor.
SCORE	scoring coefficients to be applied to standardized variables if the <code>SCORE</code> option is specified on the <code>PROC FACTOR</code> statement. The <code>_NAME_</code> variable contains the name of the factor.
USCORE	scoring coefficients to be applied without subtracting the mean from the raw variables if the <code>SCORE</code> option is specified on the <code>PROC FACTOR</code> statement. The <code>_NAME_</code> variable contains the name of the factor.

---

## Number of Factors to Retain

`PROC FACTOR` provides a variety of factor extraction methods, which you can specify by using the `METHOD=` option. Typically, the maximum number of factors that can be extracted is the same as the number of variables that are being factor-analyzed. Because factor analysis can be viewed as a data-reduction technique, the actual number of factors that researchers want to retain after the extraction is usually much smaller.

`PROC FACTOR` provides the following three options to enable you to control the number of factors to retain in factor solutions: `MINEIGEN=`, `NFACTORS=`, and `PROPORTION=`. Although each of the `MINEIGEN=` and `PROPORTION=` options specifies a criterion value to determine the number of factors, the `NFACTORS=n` option specifies an explicit number *n* for the maximum number of factors to retain. In addition, you can use the `NFACTORS=name` option to request that either the minimum average partial correlation (MAP) analysis or parallel analysis criterion be used for determining the number of factors. The MAP and parallel analysis criteria are explained at the end of this section.

If you do not specify any of these options, `PROC FACTOR` essentially sets default criterion values for the `MINEIGEN=` and `PROPORTION=` options and retains the minimum number of factors that can satisfy either one of these criteria. See the `MINEIGEN=` and `PROPORTION=` options for the default criterion values, which depend on the factor extraction method that you use.

If you specify two or more options among the `MINEIGEN=`, `NFACTORS=n`, and `PROPORTION=` options, the number of factors retained is the minimum number that satisfies any of the criteria. However, if you specify one of the options `NFACTORS=MAP`, `NFACTORS=MAP2`, `NFACTORS=MAP4`, or `NFACTORS=PARALLEL`, the retained number of factors is determined by the specified option (MAP, MAP2, MAP4, or PARALLEL, respectively) and all other criteria are ignored. The following explains the MAP and parallel analysis criteria.

A minimum average partial correlation analysis first performs a principal components analysis on the sample correlation matrix. Next, averages of the squared (for MAP2) or fourth-powered (for MAP4) partial correlations between the variables are computed after recursively controlling for one, two, and so on, components (Velicer 1976). The selected number of factors is the number of the controlled components that corresponds to the smallest average squared or fourth-powered partial correlation. If you want to conduct a minimum average partial correlation analysis without using its criterion to determine the number of factors to extract, use the **MAP** option instead of the **NFACTORS=** option.

As first proposed by Horn (1965), a parallel analysis selects the number of factors by comparing the eigenvalues in the sample correlation matrix with the eigenvalues of random correlation matrices that are generated from a multivariate standard normal distribution. PROC FACTOR simulates a large number of random correlation matrices and constructs an empirical distribution for each positional eigenvalue: largest, second-largest, and so on (Glorfeld 1995). A factor is suggested if an observed eigenvalue is greater than the critical value at a specified one-sided  $\alpha$ -level, with reference to the corresponding simulated distribution of random eigenvalues. As soon as an observed eigenvalue is less than or equal to the corresponding critical value, no more factors are counted. In other words, only the first  $n$  consecutive significant eigenvalues are counted for the number of factors.

If you want to conduct a parallel analysis without using its criterion to determine the number of factors being extracted, use the **PARALLEL** option instead of the **NFACTORS=PARALLEL** option.

---

## Variable Weights and Variance Explained

A principal component analysis of a correlation matrix treats all variables as equally important. A principal component analysis of a covariance matrix gives more weight to variables with larger variances. A principal component analysis of a covariance matrix is equivalent to an analysis of a weighted correlation matrix, where the weight of each variable is equal to its variance. Variables with large weights tend to have larger loadings on the first component and smaller residual correlations than variables with small weights.

You might want to give weights to variables by using values other than their variances. Mulaik (1972) explains how to obtain a maximally reliable component by means of a weighted principal component analysis. With the FACTOR procedure, you can indirectly give arbitrary weights to the variables by using the **COV** option and rescaling the variables to have variance equal to the desired weight, or you can give arbitrary weights directly by using the **WEIGHT** option and including the weights in a **TYPE=CORR** data set.

Arbitrary variable weights can be used with the **METHOD=PRINCIPAL**, **METHOD=PRINIT**, **METHOD=ULS**, or **METHOD=IMAGE** option. Alpha and ML factor analyses compute variable weights based on the communalities (Harman 1976, pp. 217–218). For alpha factor analysis, the weight of a variable is the reciprocal of its communality. In ML factor analysis, the weight is the reciprocal of the uniqueness. Harris component analysis uses weights equal to the reciprocal of one minus the squared multiple correlation of each variable with the other variables.

For uncorrelated factors, the variance explained by a factor can be computed with or without taking the weights into account. The usual method for computing variance accounted for by a factor is to take the sum of squares of the corresponding column of the factor pattern, yielding an unweighted result. If the square of each loading is multiplied by the weight of the variable before the sum is taken, the result is the weighted variance explained, which is equal to the corresponding eigenvalue except in image analysis. Whether the weighted or unweighted result is more important depends on the purpose of the analysis.

In the case of correlated factors, the variance explained by a factor can be computed with or without taking the other factors into account. If you want to ignore the other factors, the variance explained is given by the weighted or unweighted sum of squares of the appropriate column of the factor structure since the factor structure contains simple correlations. If you want to subtract the variance explained by the other factors from the amount explained by the factor in question (the Type II variance explained), you can take the weighted or unweighted sum of squares of the appropriate column of the reference structure because the reference structure contains semipartial correlations. There are other ways of measuring the variance explained. For example, given a prior ordering of the factors, you can eliminate from each factor the variance explained by previous factors and compute a Type I variance explained. Harman (1976, pp. 268–270) provides another method, which is based on direct and joint contributions.

---

## Simplicity Functions for Rotations

To rotate a factor pattern is to apply a nonsingular linear transformation to the unrotated factor pattern matrix. An optimal transformation is usually defined as a minimum or maximum point of a simplicity function. Different rotation methods are based on different simplicity functions employed.

For the promax or the Procrustes rotation, the simplicity function used is the sum of squared differences between the rotated factor pattern and the target matrix. The optimal transformation is obtained by minimizing this simplicity function with respect to the choices of all possible transformation.

For the class of the generalized Crawford-Ferguson family (Jennrich 1973), the simplicity function being optimized is

$$f = k_1 Z + k_2 H + k_3 V + k_4 Q$$

where

$$Z = \left( \sum_j \sum_i b_{ij}^2 \right)^2, \quad H = \sum_i \left( \sum_j b_{ij}^2 \right)^2$$

$$V = \sum_j \left( \sum_i b_{ij}^2 \right)^2, \quad Q = \sum_j \sum_i b_{ij}^4$$

$k_1, k_2, k_3$ , and  $k_4$  are constants, and  $b_{ij}$  represents an element of the rotated pattern matrix. Except for specialized research purposes, it is uncommon in practice to use this simplicity function directly for rotation. However, this simplicity function reduces to many well-known classes of rotations. One of these is the Crawford-Ferguson family (Crawford and Ferguson 1970), which minimizes

$$f_{cf} = c_1(H - Q) + c_2(V - Q)$$

where  $c_1$  and  $c_2$  are constants,  $(H - Q)$  represents variable (row) parsimony, and  $(V - Q)$  represents factor (column) parsimony. Therefore, the relative importance of both the variable parsimony and of the factor parsimony is adjusted using the constants  $c_1$  and  $c_2$ . The orthomax class (see Harman 1976) maximizes the function

$$f_{or} = pQ - \gamma V$$

where  $\gamma$  is the orthomax weight and is usually between 0 and the number of variables  $p$ . The oblimin class minimizes the function

$$f_{ob} = p(H - Q) - \tau(Z - V)$$

where  $\tau$  is the oblimin weight. For practical purposes, a negative or zero value for  $\tau$  is recommended.

All of the preceding definitions are for rotations without row normalization. For rotations with Kaiser normalization, the definition of  $b_{ij}$  is replaced by  $b_{ij}/h_i$ , where  $h_i$  is the communality estimate of variable  $i$ .

## Confidence Intervals and the Saliency of Factor Loadings

The traditional approach to determining salient loadings (loadings that are considered large in absolute values) employs rules of thumb such as 0.3 or 0.4. However, this does not use the statistical evidence efficiently. The asymptotic normality of the distribution of factor loadings enables you to construct confidence intervals to gauge the saliency of factor loadings. To guarantee the range-respecting properties of confidence intervals, a transformation procedure such as in CEFA (Browne et al. 2008) is used. For example, because the orthogonal rotated factor loading  $\theta$  must be bounded between  $-1$  and  $+1$ , the Fisher transformation

$$\varphi = \frac{1}{2} \log\left(\frac{1 + \theta}{1 - \theta}\right)$$

is employed so that  $\varphi$  is an unbounded parameter. Assuming the asymptotic normality of  $\hat{\varphi}$ , a symmetric confidence interval for  $\varphi$  is constructed. Then, a back-transformation on the confidence limits yields an asymmetric confidence interval for  $\theta$ . Applying the results of Browne (1982), a  $(1-\alpha)100\%$  confidence interval for the orthogonal factor loading  $\theta$  is

$$(\hat{\theta}_l = \frac{a/b - 1}{a/b + 1}, \hat{\theta}_u = \frac{a \times b - 1}{a \times b + 1})$$

where

$$a = \frac{1 + \hat{\theta}}{1 - \hat{\theta}}, \quad b = \exp(z_{\alpha/2} \times \frac{2\hat{\sigma}}{1 - \hat{\theta}^2})$$

and  $\hat{\theta}$  is the estimated factor loading,  $\hat{\sigma}$  is the standard error estimate of the factor loading, and  $z_{\alpha/2}$  is the  $100(1 - \alpha/2)$ th percentile point of a standard normal distribution.

Once the confidence limits are constructed, you can use the corresponding coverage displays for determining the saliency of the variable-factor relationship. In a coverage display, the **COVER=** value is represented by an asterisk (\*). The following table summarizes various displays and their interpretations.

**Table 39.5** Interpretations of the Coverage Displays

Positive Estimate	Negative Estimate	COVER=0 Specified	Interpretation
[0]*	*[0]		The estimate is not significantly different from zero, and the CI covers a region of values that are smaller in magnitude than the COVER= value. This is strong statistical evidence for the nonsaliency of the variable-factor relationship.
0[ ]*	*[ ]0		The estimate is significantly different from zero, but the CI covers a region of values that are smaller in magnitude than the COVER= value. This is strong statistical evidence for the nonsaliency of the variable-factor relationship.

Table 39.5 *continued*

Positive Estimate	Negative Estimate	COVER=0 Specified	Interpretation
[0*]	[*0]	[0]	The estimate is not significantly different from zero or the COVER= value. The population value might have been larger or smaller in magnitude than the COVER= value. There is no statistical evidence for the salience of the variable-factor relationship.
0[*]	[*]0		The estimate is significantly different from zero but not from the COVER= value. This is marginal statistical evidence for the salience of the variable-factor relationship.
0*[ ]	[ ]*0	0[ ] or [ ]0	The estimate is significantly different from zero, and the CI covers a region of values that are larger in magnitude than the COVER= value. This is strong statistical evidence for the salience of the variable-factor relationship.

See [Example 39.5](#) for an illustration of the use of confidence intervals for interpreting factors.

## Factor Scores

The FACTOR procedure can compute estimated factor scores directly if you specify the `NFACTORS=n` and `OUT=` options, or indirectly using the SCORE procedure. The latter method is preferable if you use the FACTOR procedure interactively to determine the number of factors, the rotation method, or various other aspects of the analysis. To compute factor scores for each observation by using the SCORE procedure, do the following:

- Use the `SCORE` option in the PROC FACTOR statement.
- Create a `TYPE=FACTOR` output data set with the `OUTSTAT=` option.
- Use the SCORE procedure with both the raw data and the `TYPE=FACTOR` data set.
- Do not use the `TYPE=` option in the PROC SCORE statement.

For example, the following statements could be used:

```
proc factor data=raw score outstat=fact;
run;
proc score data=raw score=fact out=scores;
run;
```

or

```
proc corr data=raw out=correl;
run;
proc factor data=correl score outstat=fact;
run;
proc score data=raw score=fact out=scores;
run;
```

For a more detailed example, see [Example 103.1](#) in Chapter 103, “The SCORE Procedure.”

A component analysis (principal, image, or Harris) produces scores with mean zero and variance one. If you have done a common factor analysis, the true factor scores have mean zero and variance one, but the computed factor scores are only estimates of the true factor scores. These estimates have mean zero but variance equal to the squared multiple correlation of the factor with the variables. The estimated factor scores might have small nonzero correlations even if the true factors are uncorrelated.

---

## Heywood Cases and Other Anomalies about Communality Estimates

Since communalities are squared correlations, you would expect them always to lie between 0 and 1. It is a mathematical peculiarity of the common factor model, however, that final communality estimates might exceed 1. If a communality equals 1, the situation is referred to as a Heywood case, and if a communality exceeds 1, it is an ultra-Heywood case. An ultra-Heywood case implies that some unique factor has negative variance, a clear indication that something is wrong. Possible causes include the following:

- bad prior communality estimates
- too many common factors
- too few common factors
- not enough data to provide stable estimates
- the common factor model is not an appropriate model for the data

An ultra-Heywood case renders a factor solution invalid. Factor analysts disagree about whether or not a factor solution with a Heywood case can be considered legitimate.

With `METHOD=PRINIT`, `METHOD=ULS`, `METHOD=ALPHA`, or `METHOD=ML`, the FACTOR procedure, by default, stops iterating and sets the number of factors to 0 if an estimated communality exceeds 1. To enable processing to continue with a Heywood or ultra-Heywood case, you can use the `HEYWOOD` or `ULTRAHEYWOOD` option in the PROC FACTOR statement. The `HEYWOOD` option sets the upper bound of any communality to 1, while the `ULTRAHEYWOOD` option allows communalities to exceed 1.

Theoretically, the communality of a variable should not exceed its reliability. Violation of this condition is called a quasi-Heywood case and should be regarded with the same suspicion as an ultra-Heywood case.

Elements of the factor structure and reference structure matrices can exceed 1 only in the presence of an ultra-Heywood case. On the other hand, an element of the factor pattern might exceed 1 in an oblique rotation.

The maximum likelihood method is especially susceptible to quasi- or ultra-Heywood cases. During the iteration process, a variable with high communality is given a high weight; this tends to increase its communality, which increases its weight, and so on.

It is often stated that the squared multiple correlation of a variable with the other variables is a lower bound to its communality. This is true if the common factor model fits the data perfectly, but it is not generally the case with real data. A final communality estimate that is less than the squared multiple correlation can, therefore, indicate poor fit, possibly due to not enough factors. It is by no means as serious a problem as an ultra-Heywood case. Factor methods that use the Newton-Raphson method can actually produce communalities less than 0, a result even more disastrous than an ultra-Heywood case.

The squared multiple correlation of a factor with the variables might exceed 1, even in the absence of ultra-Heywood cases. This situation is also cause for alarm. Alpha factor analysis seems to be especially prone to this problem, but it does not occur with maximum likelihood. If a squared multiple correlation is negative, there are too many factors retained.

With data that do not fit the common factor model perfectly, you can expect some of the eigenvalues to be negative. If an iterative factor method converges properly, the sum of the eigenvalues corresponding to rejected factors should be 0; hence, some eigenvalues are positive and some negative. If a principal factor analysis fails to yield any negative eigenvalues, the prior communality estimates are probably too large. Negative eigenvalues cause the cumulative proportion of variance explained to exceed 1 for a sufficiently large number of factors. The cumulative proportion of variance explained by the retained factors should be approximately 1 for principal factor analysis and should converge to 1 for iterative methods. Occasionally, a single factor can explain more than 100 percent of the common variance in a principal factor analysis, indicating that the prior communality estimates are too low.

If a squared canonical correlation or a coefficient alpha is negative, there are too many factors retained.

Principal component analysis, unlike common factor analysis, has none of these problems if the covariance or correlation matrix is computed correctly from a data set with no missing values. Various methods for missing value correlation or severe rounding of the correlations can produce negative eigenvalues in principal components.

## Missing Values

If the `DATA=` data set contains data (rather than a matrix or factor pattern), then observations with missing values for any variables in the analysis are omitted from the computations. If a correlation or covariance matrix is read, it can contain missing values as long as every pair of variables has at least one nonmissing entry. Missing values in a pattern or scoring coefficient matrix are treated as zeros.

## Cautions

- The amount of time that FACTOR takes is roughly proportional to the cube of the number of variables. Factoring 100 variables, therefore, takes about 1,000 times as long as factoring 10 variables. Iterative methods (PRINIT, ALPHA, ULS, ML) can also take 100 times as long as noniterative methods (PRINCIPAL, IMAGE, HARRIS).

- No computer program is capable of reliably determining the optimal number of factors, since the decision is ultimately subjective. You should not blindly accept the number of factors obtained by default; instead, use your own judgment to make a decision.
- Singular correlation matrices cause problems with the options `PRIORS=SMC` and `METHOD=ML`. Singularities can result from using a variable that is the sum of other variables, coding too many dummy variables from a classification variable, or having more variables than observations.
- If you use the `CORR` procedure to compute the correlation matrix and there are missing data and the `NOMISS` option is not specified, then the correlation matrix might have negative eigenvalues.
- If a `TYPE=CORR`, `TYPE=UCORR`, or `TYPE=FACTOR` data set is copied or modified using a `DATA` step, the new data set does not automatically have the same `TYPE` as the old data set. You must specify the `TYPE=` data set option in the `DATA` statement. If you try to analyze a data set that has lost its `TYPE=CORR` attribute, `PROC FACTOR` displays a warning message saying that the data set contains `_NAME_` and `_TYPE_` variables but analyzes the data set as an ordinary SAS data set.
- For a `TYPE=FACTOR` data set, the default is `METHOD=PATTERN`, not `METHOD=PRIN`.

---

## Time Requirements

- $n$  = number of observations  
 $v$  = number of variables  
 $f$  = number of factors  
 $i$  = number of iterations during factor extraction  
 $r$  = length of iterations during factor rotation

The time required to compute. . .	is roughly proportional to
an overall factor analysis	$iv^3$
the correlation matrix	$nv^2$
<code>PRIORS=SMC</code> or <code>ASMC</code>	$v^3$
<code>PRIORS=MAX</code>	$v^2$
eigenvalues	$v^3$
final eigenvectors	$fv^2$
generalized Crawford-Ferguson family of rotations, <code>PROMAX</code> , or <code>HK</code>	$rvf^2$
<code>ROTATE=PROCRUSTES</code>	$vf^2$

Each iteration in the `PRINIT` or `ALPHA` method requires computation of eigenvalues and  $f$  eigenvectors.

Each iteration in the ML or ULS method requires computation of eigenvalues and  $v - f$  eigenvectors.

The amount of time that PROC FACTOR takes is roughly proportional to the cube of the number of variables. Factoring 100 variables, therefore, takes about 1000 times as long as factoring 10 variables. Iterative methods (PRINIT, ALPHA, ULS, ML) can also take 100 times as long as noniterative methods (PRINCIPAL, IMAGE, HARRIS).

---

## Displayed Output

PROC FACTOR output includes the following:

- Input data type, numbers of records read and used for raw data input, the number of observations that is specified in the **NOBS=** option in the PROC FACTOR statement, and the number of observations used in significance tests
- Mean and Std Dev (standard deviation) of each variable and the number of observations, if you specify the **SIMPLE** option
- Correlations, if you specify the **CORR** option
- Inverse Correlation Matrix, if you specify the **ALL** option
- Partial Correlations Controlling all other Variables (negative anti-image correlations), if you specify the **MSA** option. If the data are appropriate for the common factor model, the partial correlations should be small.
- Kaiser's Measure of Sampling Adequacy (Kaiser 1970; Kaiser and Rice 1974; Cerny and Kaiser 1977), both overall and for each variable, if you specify the **MSA** option. The **MSA** is a summary of how small the partial correlations are relative to the ordinary correlations. Values greater than 0.8 can be considered good. Values less than 0.5 require remedial action, either by deleting the offending variables or by including other variables related to the offenders.
- Prior Communalities Estimates, unless 1.0s are used or unless you specify the **METHOD=IMAGE**, **METHOD=HARRIS**, **METHOD=PATTERN**, or **METHOD=SCORE** option
- Squared Multiple Correlations of each variable with all the other variables, if you specify the **METHOD=IMAGE** or **METHOD=HARRIS** option
- Image Coefficients, if you specify the **METHOD=IMAGE** option
- Image Covariance Matrix, if you specify the **METHOD=IMAGE** option
- Preliminary Eigenvalues based on the prior communalities, if you specify the **METHOD=PRINIT**, **METHOD=ALPHA**, **METHOD=ML**, or **METHOD=ULS** option. The table produced includes the Total and the Average of the eigenvalues, the Difference between successive eigenvalues, the Proportion of variation represented, and the Cumulative proportion of variation.
- Parallel Analysis, if you specify the **PARALLEL** or **NFACTORS=PARALLEL** option. This includes the eigenvalues of the proper correlation matrix, the simulated critical values from the parallel analysis, the simulated average eigenvalues from the parallel analysis, and the number of threads used to construct the parallel analysis. (By default, the simulated average eigenvalues and the number of threads are not printed.)

- Average Partial Correlations (squared and fourth-powered) after controlling for different numbers of principal components, if you specify the `MAP`, `NFACTORS=MAP2`, or `NFACTORS=MAP4` option.
- the number of factors that are retained, unless you specify the `METHOD=PATTERN` or `METHOD=SCORE` option
- the Scree Plot of Eigenvalues, if you specify the `SCREE` option. The preliminary eigenvalues are used if you specify the `METHOD=PRINIT`, `METHOD=ALPHA`, `METHOD=ML`, or `METHOD=ULS` option. You can request the corresponding high-quality graphical plot by using the `PLOTS=` option.
- the iteration history, if you specify the `METHOD=PRINIT`, `METHOD=ALPHA`, `METHOD=ML`, or `METHOD=ULS` option. The table produced contains the iteration number (Iter); the Criterion being optimized (Jöreskog 1977); the Ridge value for the iteration if you specify the `METHOD=ML` or `METHOD=ULS` option; the maximum Change in any communality estimate; and the Communalities.
- Significance tests, if you specify the option `METHOD=ML`, including Bartlett's chi-square, df, and  $\text{Prob} > \chi^2$  for  $H_0$ : No common factors and  $H_0$ : Factors retained are sufficient to explain the correlations. The  $H_0$  test for no common factors is equivalent to Bartlett's test of sphericity. The variables should have an approximate multivariate normal distribution for the probability levels to be valid. Lawley and Maxwell (1971) suggest that the number of observations should exceed the number of variables by 50 or more, although Geweke and Singleton (1980) claim that as few as 10 observations are adequate with five variables and one common factor. Certain regularity conditions must also be satisfied for Bartlett's  $\chi^2$  test to be valid (Geweke and Singleton 1980), but in practice these conditions are usually satisfied. The notation  $\text{Prob} > \chi^2$  means "the probability under the null hypothesis of obtaining a greater  $\chi^2$  statistic than that observed." The chi-square value is displayed with and without Bartlett's correction.
- Akaike's Information Criterion, if you specify the `METHOD=ML` option. Akaike's information criterion (AIC) (Akaike 1973, 1974, 1987) is a general criterion for estimating the best number of parameters to include in a model when maximum likelihood estimation is used. The number of factors that yields the smallest value of AIC is considered best. Like the chi-square test, AIC tends to include factors that are statistically significant but inconsequential for practical purposes.
- Schwarz's Bayesian Criterion, if you specify the `METHOD=ML` option. Schwarz's Bayesian Criterion (SBC) (Schwarz 1978) is another criterion, similar to AIC, for determining the best number of parameters. The number of factors that yields the smallest value of SBC is considered best; SBC seems to be less inclined to include trivial factors than either AIC or the chi-square test.
- Tucker and Lewis's reliability coefficient, if you specify the `METHOD=ML` option (Tucker and Lewis 1973)
- Squared Canonical Correlations, if you specify the `METHOD=ML` option. These are the same as the squared multiple correlations for predicting each factor from the variables.
- Coefficient Alpha for Each Factor, if you specify the `METHOD=ALPHA` option
- Eigenvectors, if you specify the `EIGENVECTORS` or `ALL` option, unless you also specify the `METHOD=PATTERN` or `METHOD=SCORE` option
- Eigenvalues of the (Weighted) (Reduced) (Image) Correlation or Covariance Matrix, unless you specify the `METHOD=PATTERN` or `METHOD=SCORE` option. Included are the Total and the Average of the eigenvalues, the Difference between successive eigenvalues, the Proportion of variation represented, and the Cumulative proportion of variation.

- the Factor Pattern, which is equal to both the matrix of standardized regression coefficients for predicting variables from common factors and the matrix of correlations between variables and common factors since the extracted factors are uncorrelated. Standard error estimates are included if the **SE** option is specified with **METHOD=ML**. Confidence limits and coverage displays are included if **COVER=** option is specified with **METHOD=ML**.
- Variance explained by each factor, both Weighted and Unweighted, if variable weights are used
- Final Community Estimates, including the Total communality; or Final Community Estimates and Variable Weights, including the Total communality, both Weighted and Unweighted, if variable weights are used. Final communality estimates are the squared multiple correlations for predicting the variables from the estimated factors, and they can be obtained by taking the sum of squares of each row of the factor pattern, or a weighted sum of squares if variable weights are used.
- Residual Correlations with Uniqueness on the Diagonal, if you specify the **RESIDUAL** or **ALL** option
- Root Mean Square Off-Diagonal Residuals, both Over-all and for each variable, if you specify the **RESIDUAL** or **ALL** option
- Partial Correlations Controlling Factors, if you specify the **RESIDUAL** or **ALL** option
- Root Mean Square Off-Diagonal Partial, both Over-all and for each variable, if you specify the **RESIDUAL** or **ALL** option
- Plots of Factor Pattern for unrotated factors, if you specify the **PREPLOT** option. The number of plots is determined by the **NPLOT=** option. You can request the corresponding high-quality graphical plots by using the **PLOTS=** option.
- Variable Weights for Rotation, if you specify the **NORM=WEIGHT** option
- Factor Weights for Rotation, if you specify the **HKPOWER=** option
- Orthogonal Transformation Matrix, if you request an orthogonal rotation
- Rotated Factor Pattern, if you request an orthogonal rotation. Standard error estimates are included if the **SE** option is specified with **METHOD=ML**. Confidence limits and coverage displays are included if **COVER=** option is specified with **METHOD=ML**.
- Variance explained by each factor after rotation. If you request an orthogonal rotation and if variable weights are used, both weighted and unweighted values are produced.
- Target Matrix for Procrustean Transformation, if you specify the **ROTATE=PROMAX** or **ROTATE=PROCRUSTES** option
- the Procrustean Transformation Matrix, if you specify the **ROTATE=PROMAX** or **ROTATE=PROCRUSTES** option
- the Normalized Oblique Transformation Matrix, if you request an oblique rotation, which, for the option **ROTATE=PROMAX**, is the product of the prerotation and the Procrustes rotation
- Inter-factor Correlations, if you specify an oblique rotation. Standard error estimates are included if the **SE** option is specified with **METHOD=ML**. Confidence limits and coverage displays are included if **COVER=** option is specified with **METHOD=ML**.

- Rotated Factor Pattern (Std Reg Coefs), if you specify an oblique rotation, giving standardized regression coefficients for predicting the variables from the factors. Standard error estimates are included if the **SE** option is specified with **METHOD=ML**. Confidence limits and coverage displays are included if **COVER=** option is specified with **METHOD=ML**.
- Reference Axis Correlations if you specify an oblique rotation. These are the partial correlations between the primary factors when all factors other than the two being correlated are partialled out.
- Reference Structure (Semipartial Correlations), if you request an oblique rotation. The reference structure is the matrix of semipartial correlations (Kerlinger and Pedhazur 1973) between variables and common factors, removing from each common factor the effects of other common factors. If the common factors are uncorrelated, the reference structure is equal to the factor pattern.
- Variance explained by each factor eliminating the effects of all other factors, if you specify an oblique rotation. Both Weighted and Unweighted values are produced if variable weights are used. These variances are equal to the (weighted) sum of the squared elements of the reference structure corresponding to each factor.
- Factor Structure (Correlations), if you request an oblique rotation. The (primary) factor structure is the matrix of correlations between variables and common factors. If the common factors are uncorrelated, the factor structure is equal to the factor pattern. Standard error estimates are included if the **SE** option is specified with **METHOD=ML**. Confidence limits and coverage displays are included if **COVER=** option is specified with **METHOD=ML**.
- Variance explained by each factor ignoring the effects of all other factors, if you request an oblique rotation. Both Weighted and Unweighted values are produced if variable weights are used. These variances are equal to the (weighted) sum of the squared elements of the factor structure corresponding to each factor.
- Final Communality Estimates for the rotated factors if you specify the **ROTATE=** option. The estimates should equal the unrotated communalities.
- Squared Multiple Correlations of the Variables with Each Factor, if you specify the **SCORE** or **ALL** option, except for unrotated principal components
- Standardized Scoring Coefficients, if you specify the **SCORE** or **ALL** option
- Plots of the Factor Pattern for rotated factors, if you specify the **PLOT** option and you request an orthogonal rotation. The number of plots is determined by the **NPLOT=** option. You can request the corresponding high-quality graphical plots by using the **PLOTS=** option.
- Plots of the Reference Structure for rotated factors, if you specify the **PLOT** option and you request an oblique rotation. The number of plots is determined by the **NPLOT=** option. Included are the Reference Axis Correlation and the Angle between the Reference Axes for each pair of factors plotted. You can request the corresponding high-quality graphical plots by using the **PLOTS=** option.
- A path diagram for the final factor solution if you specify the **PLOTS=PATHDIAGRAM** option or the **PATHDIAGRAM** statements.

If you specify the **ROTATE=PROMAX** option, the output includes results for both the prerotation and the Procrustes rotation.

## ODS Table Names

PROC FACTOR assigns a name to each table it creates. You can use these names to reference the table when using the Output Delivery System (ODS) to select tables and create output data sets. These names are listed in the Table 39.6. For more information about ODS, see Chapter 20, “Using the Output Delivery System.”

**Table 39.6** ODS Tables Produced by PROC FACTOR

ODS Table Name	Description	Option
AlphaCoef	Coefficient alpha for each factor	METHOD=ALPHA
AveParCorrControlPC	Average partial correlations after controlling for principal components	MAP or NFACTORS=MAP, MAP2, or MAP4
CanCorr	Squared canonical correlations	METHOD=ML
CondStdDev	Conditional standard deviations	SIMPLE with PARTIAL
ConvergenceStatus	Convergence status	METHOD=PRINIT, ALPHA, ML, or ULS
Corr	Correlations	CORR
Eigenvalues	Eigenvalues	default
Eigenvectors	Eigenvectors	EIGENVECTORS
FactorWeightRotate	Factor weights for rotation	HKPOWER=
FactorPattern	Factor pattern	default
FactorStructure	Factor structure	ROTATE= any oblique rotation
FinalCommun	Final communalities	default
FinalCommunWgt	Final communalities with weights	METHOD=ML or ALPHA
FitMeasures	Measures of fit	METHOD=ML
ImageCoef	Image coefficients	METHOD=IMAGE
ImageCov	Image covariance matrix	METHOD=IMAGE
ImageFactors	Image factor matrix	METHOD=IMAGE
InputFactorPattern	Input factor pattern	METHOD=PATTERN with PRINT or ALL
InputScoreCoef	Standardized input scoring coefficients	METHOD=SCORE with PRINT or ALL
InterFactorCorr	Interfactor correlations	ROTATE= any oblique rotation
InvCorr	Inverse correlation matrix	ALL
IterHistory	Iteration history	METHOD=PRINIT, ALPHA, ML, or ULS
MultipleCorr	Squared multiple correlations	METHOD=IMAGE or METHOD=HARRIS
NObs	Number of records and observations, input data type	default
NormObliqueTrans	Normalized oblique transformation matrix	ROTATE=PROCRUSTES, ROTATE=PROMAX
ObliqueRotFactPat	Rotated factor pattern	ROTATE= any oblique rotation
ObliqueTrans	Oblique transformation matrix	HKPOWER= or ROTATE= any oblique rotation except PROCRUSTES or PROMAX

Table 39.6 *continued*

ODS Table Name	Description	Option
OrthRotFactPat	Rotated factor pattern	ROTATE= any orthogonal rotation
OrthTrans	Orthogonal transformation matrix	ROTATE= any orthogonal rotation
ParallelAnalysis	Parallel analysis results	PARALLEL or NFACTORS=PARALLEL
ParCorrControlFactor	Partial correlations after controlling for factors	RESIDUAL
ParCorrControlVar	Partial correlations after controlling for other variables	MSA
PartialCorr	Partial correlations	MSA, CORR with PARTIAL
PriorCommunalEst	Prior communality estimates	PRIORS=, METHOD=ML or ALPHA
ProcrustesTarget	Target matrix for Procrustean transformation	ROTATE=PROCRUSTES, ROTATE=PROMAX
ProcrustesTrans	Procrustean transformation matrix	ROTATE=PROCRUSTES, ROTATE=PROMAX
RMSOffDiagPartials	Root mean square off-diagonal partials	RESIDUAL
RMSOffDiagResids	Root mean square off-diagonal residuals	RESIDUAL
ReferenceAxisCorr	Reference axis correlations	ROTATE= any oblique rotation
ReferenceStructure	Reference structure	ROTATE= any oblique rotation
ResCorrUniqueDiag	Residual correlations with uniqueness on the diagonal	RESIDUAL
SamplingAdequacy	Kaiser's measure of sampling adequacy	MSA
SignifTests	Significance tests	METHOD=ML
SimpleStatistics	Simple statistics	SIMPLE
StdScoreCoef	Standardized scoring coefficients	SCORE
VarExplain	Variance explained	default
VarExplainWgt	Variance explained with weights	METHOD=ML, or ALPHA
VarFactorCorr	Squared multiple correlations of the variables with each factor	SCORE
VarWeightRotate	Variable weights for rotation	NORM=WEIGHT, ROTATE=

## ODS Graphics

Statistical procedures use ODS Graphics to create graphs as part of their output. ODS Graphics is described in detail in Chapter 21, “[Statistical Graphics Using ODS.](#)”

Before you create graphs, ODS Graphics must be enabled (for example, by specifying the ODS GRAPHICS ON statement). For more information about enabling and disabling ODS Graphics, see the section “Enabling and Disabling ODS Graphics” on page 615 in Chapter 21, “Statistical Graphics Using ODS.”

The overall appearance of graphs is controlled by ODS styles. Styles and other aspects of using ODS Graphics are discussed in the section “A Primer on ODS Statistical Graphics” on page 614 in Chapter 21, “Statistical Graphics Using ODS.”

The names of the graphs that PROC FACTOR generates are listed in Table 39.7, along with the required statements and options.

**Table 39.7** Graphs Produced by PROC FACTOR

ODS Graph Name	Plot Description	Option
InitPatternPlot	Initial factor pattern	PLOTS=INITLOADINGS
InitRefStructurePlot	Initial reference structures	PLOTS=INITLOADINGS and PLOTREF
MAPPlot	Minimum average partial correlation analysis	PLOTS=MAP, MAP2, or MAP4
ParallelPlot	Parallel analysis	PLOTS=PARALLEL
PathDiagram	Path diagram	PLOTS=PATHDIAGRAM or PATHDIAGRAM statement
PatternPlot	Rotated factor pattern	PLOTS=LOADINGS
PrePatternPlot	Prerotated factor pattern	PLOTS=PRELOADINGS
PreRefStructurePlot	Prerotated reference structures	PLOTS=PRELOADINGS and PLOTREF
RefStructurePlot	Rotated reference structures	PLOTS=LOADINGS and PLOTREF
ScreePlot	Scree and variance explained plots	PLOTS=SCREE
VariancePlot	Plot of explained variance	PLOTS=SCREE(UNPACK)

---

## Examples: FACTOR Procedure

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### Example 39.1: Principal Component Analysis

This example analyzes socioeconomic data provided by Harman (1976). The five variables represent total population (Population), median school years (School), total employment (Employment), miscellaneous professional services (Services), and median house value (HouseValue). Each observation represents one of twelve census tracts in the Los Angeles Standard Metropolitan Statistical Area.

You conduct a principal component analysis by using the following statements:

```

data SocioEconomics;
  input Population School Employment Services HouseValue;
  datalines;
5700      12.8      2500      270      25000
1000      10.9      600       10      10000
3400      8.8       1000      10      9000
3800      13.6      1700      140     25000
4000      12.8      1600      140     25000
8200      8.3       2600      60      12000
1200      11.4      400       10      16000
9100      11.5      3300      60      14000
9900      12.5      3400      180     18000
9600      13.7      3600      390     25000
9600      9.6       3300      80      12000
9400      11.4      4000      100     13000
;

proc factor data=SocioEconomics simple corr;
run;

```

You begin with the specification of the raw data set with 12 observations. Then you use the `DATA=` option in the PROC FACTOR statement to specify the data set in the analysis. You also set the `SIMPLE` and `CORR` options for additional output results, which are shown in [Output 39.1.2](#) and [Output 39.1.3](#), respectively.

By default, PROC FACTOR assumes that all initial communalities are 1, which is the case for the current principal component analysis. If you intend to find common factors instead, use the `PRIORS=` option or the `PRIORS` statement to set initial communalities to values less than 1, which results in extracting the principal factors rather than the principal components. See [Example 39.2](#) for the specification of a principal factor analysis.

For the current principal component analysis, the first output table is displayed in the [Output 39.1.1](#).

#### **Output 39.1.1** Principal Component Analysis: Number of Observations

##### **Five Socioeconomic Variables** See Page 14 of Harman: Modern Factor Analysis, 3rd Ed **Principal Component Analysis**

##### **The FACTOR Procedure**

Input Data Type	Raw Data
<b>Number of Records Read</b>	12
<b>Number of Records Used</b>	12
<b>N for Significance Tests</b>	12

In [Output 39.1.1](#), the input data type is shown to be raw data. PROC FACTOR also accepts other data type such as correlations and covariances. See [Example 39.5](#) for the use of correlations as input data. For the current raw data set, PROC FACTOR reads in 12 records and all these 12 records are used. When there are missing values in the data set, these two numbers might not match due to the dropping of the records with missing values. The last row of the table shows that  $N = 12$  is used in the significance tests conducted in the analysis.

The `SIMPLE` option specified in the PROC FACTOR statement generates the means and standard deviations

of all observed variables in the analysis, as shown in [Output 39.1.2](#).

### Output 39.1.2 Principal Component Analysis: Simple Statistics

Means and Standard Deviations from 12 Observations		
Variable	Mean	Std Dev
Population	6241.667	3439.9943
School	11.442	1.7865
Employment	2333.333	1241.2115
Services	120.833	114.9275
HouseValue	17000.000	6367.5313

The ranges of means and standard deviations for the analysis are quite large. Variables are measured on quite different scales. However, this is not an issue because PROC FACTOR basically analyzes the standardized scales (that is, the correlations) of the variables.

The **CORR** option specified in the PROC FACTOR statement generates the output of the observed correlations in [Output 39.1.3](#).

### Output 39.1.3 Principal Component Analysis: Correlations

Correlations					
	Population	School	Employment	Services	HouseValue
Population	1.00000	0.00975	0.97245	0.43887	0.02241
School	0.00975	1.00000	0.15428	0.69141	0.86307
Employment	0.97245	0.15428	1.00000	0.51472	0.12193
Services	0.43887	0.69141	0.51472	1.00000	0.77765
HouseValue	0.02241	0.86307	0.12193	0.77765	1.00000

The correlation matrix shown in [Output 39.1.3](#) is analyzed by PROC FACTOR.

The first step of principal component analysis is to look at the eigenvalues of the correlation matrix. The larger eigenvalues are extracted first. Because there are five observed variables, five eigenvalues can be extracted, as shown in [Output 39.1.4](#).

### Output 39.1.4 Principal Component Analysis: Eigenvalues

Eigenvalues of the Correlation Matrix: Total = 5 Average = 1				
	Eigenvalue	Difference	Proportion	Cumulative
1	2.87331359	1.07665350	0.5747	0.5747
2	1.79666009	1.58182321	0.3593	0.9340
3	0.21483689	0.11490283	0.0430	0.9770
4	0.09993405	0.08467868	0.0200	0.9969
5	0.01525537		0.0031	1.0000

In [Output 39.1.4](#), the two largest eigenvalues are 2.8733 and 1.7967, which together account for 93.4% of the standardized variance. Thus, the first two principal components provide an adequate summary of the data for most purposes. Three components, which explain 97.7% of the variation, should be sufficient for almost any

application. PROC FACTOR retains the first two components on the basis of the eigenvalues-greater-than-one rule since the third eigenvalue is only 0.2148.

To express the observed variables as functions of the components (or factors, in general), you consult the factor loading matrix as shown in [Output 39.1.5](#).

**Output 39.1.5** Principal Component Analysis: Factor Pattern

Factor Pattern		
	Factor1	Factor2
Population	0.58096	0.80642
School	0.76704	-0.54476
Employment	0.67243	0.72605
Services	0.93239	-0.10431
HouseValue	0.79116	-0.55818

The factor pattern is often referred to as the factor loading matrix in factor analysis. The elements in the loading matrix are called factor loadings. There are at least two ways you can interpret these factor loadings. First, you can use this table to express the observed variables as functions of the extracted factors (or components, as in the current analysis). Each row of the factor loadings tells you the linear combination of the factor or component scores that would yield the expected value of the associated variable. Second, you can interpret each loading as a correlation between an observed variable and a factor or component, provided that the factor solution is an orthogonal one (that is, factors are uncorrelated), such as the current initial factor solution. Hence, the factor loadings indicate how strongly the variables and the factors or components are related.

In [Output 39.1.5](#), the first component (labeled “Factor1”) has large positive loadings for all five variables. Its correlation with Services (0.9324) is especially high. The second component is basically a contrast of Population (0.8064) and Employment (0.7261) against School (–0.5448) and HouseValue (–0.5582), with a very small loading on Services (–0.1043).

The total variance explained by the two components are shown in [Output 39.1.6](#).

**Output 39.1.6** Principal Component Analysis: Total Variance Explained by Factors

Variance Explained by Each Factor	
Factor1	Factor2
2.8733136	1.7966601

The first and second component account for 2.8733 and 1.7967, respectively, of the total variance of 5. In the initial factor solution, the total variance explained by the factors or components are the same as the eigenvalues extracted. (Compare the total variance with the eigenvalues shown in [Output 39.1.4](#).) Due to the dropping of the less important components, the sum of these two numbers is 4.6700, which is only a little bit less than total variance 5 of the original correlation matrix.

You can also look at the variance explained by the two components for each observed variables in [Output 39.1.7](#).

**Output 39.1.7** Principal Component Analysis: Final Community Estimates

Final Community Estimates: Total = 4.669974				
Population	School	Employment	Services	HouseValue
0.98782629	0.88510555	0.97930583	0.88023562	0.93750041

In [Output 39.1.7](#), the final communality estimates show that all the variables are well accounted for by the two components, with final communality estimates ranging from 0.8802 for *Services* to 0.9878 for *Population*. The sum of the communalities is 4.6700, which is the same as the sum of the variance explained by the two components, as shown in [Output 39.1.6](#).

**Principal Component Analysis by PROC FACTOR and PROC PRINCOMP**

The principal component analysis by PROC FACTOR emphasizes how the principal components explain the observed variables. The factor loadings in the factor pattern as shown in [Output 39.1.5](#) are the coefficients for combining the factor/component scores to yield the observed variable scores when the expected error residuals are zero. For example, the predicted standardized value of *Population* given the factor/component scores for *Factor1* and *Factor2* is given by:

$$\text{Population} = 0.58096 \times \text{Factor1} + 0.80642 \times \text{Factor2}$$

If you are primarily interested in getting the component scores as linear combinations of the observed variables, the factor loading matrix table is not the right one for you. However, you might request the standardized scoring coefficients by adding the `SCORE` option in the `FACTOR` statement:

```
proc factor data=SocioEconomics n=5 score;
run;
```

In the preceding PROC FACTOR statement, `N=5` is specified for retaining all five components. This is done for comparing the PROC FACTOR results with those of PROC PRINCOMP, which is described later. The `SCORE` option requests the display of the standardized scoring coefficients, which are shown in [Output 39.1.8](#).

**Output 39.1.8** Principal Component Analysis: Scoring Coefficients for Computing Component Scores

Standardized Scoring Coefficients					
	Factor1	Factor2	Factor3	Factor4	Factor5
Population	0.20219	0.44884	0.12841	0.64542	5.58240
School	0.26695	-0.30320	1.48612	-1.11846	1.41574
Employment	0.23403	0.40411	0.53496	0.07256	-5.65135
Services	0.32450	-0.05806	-1.43273	-1.58288	-0.00100
HouseValue	0.27535	-0.31068	-0.30129	2.41419	-0.66734

In [Output 39.1.8](#), each factor/component is expressed as a linear combination of the standardized observed variables. For example, the first principal component or *Factor1* is computed as:

$$0.2022 \times \text{Population} + 0.2670 \times \text{School} + 0.2340 \times \text{Employment} + 0.3245 \times \text{Services} + 0.2753 \times \text{HouseValue}$$

Again, when applying this formula you must use the standardized observed variables (with means 0 and standard deviations 1), but not the raw data.

Apart from some scaling differences, the set of scoring coefficients obtained from PROC FACTOR are equivalent to those obtained from PROC PRINCOMP, as specified by the following statement:

```
proc princomp data=SocioEconomics;
run;
```

PROC PRINCOMP displays the scoring coefficients as eigenvectors, which are shown in [Output 39.1.9](#).

**Output 39.1.9** Principal Component Analysis by PROC PRINCOMP: Eigenvectors

	Eigenvectors				
	Prin1	Prin2	Prin3	Prin4	Prin5
<b>Population</b>	0.342730	0.601629	0.059517	0.204033	0.689497
<b>School</b>	0.452507	-.406414	0.688822	-.353571	0.174861
<b>Employment</b>	0.396695	0.541665	0.247958	0.022937	-.698014
<b>Services</b>	0.550057	-.077817	-.664076	-.500386	-.000124
<b>HouseValue</b>	0.466738	-.416429	-.139649	0.763182	-.082425

For example, to get the first principal component score, you use the following formula:

$$0.3427 \times \text{Population} + 0.4525 \times \text{School} + 0.3967 \times \text{Employment} + 0.5500 \times \text{Services} + 0.4667 \times \text{HouseValue}$$

This formula is not exactly the same as the one shown by using PROC FACTOR. All scoring coefficients in PROC FACTOR are smaller, approximately a factor of 0.59 to those coefficients obtained from PROC PRINCOMP. The reason for the scalar difference is that PROC FACTOR assumes all factors/components to have variance of 1, while PROC PRINCOMP creates components that have variances equal to the eigenvalues. You can do a simple rescaling of the standardized scoring coefficients obtained from PROC FACTOR so that they match the associated eigenvectors from the PROC PRINCOMP. Basically, you need to rescale each column of the standardized scoring coefficients obtained from PROC FACTOR to have the sum of squares equaling one, which is a defining characteristic of eigenvectors. This could be accomplished by dividing each coefficient by the square root of the corresponding column sum of squares.

For the present example, you can use PROC STDIZE to do the rescaling, as shown in the following statements:

```
proc factor data=SocioEconomics n=5 score;
  ods output StdScoreCoef=Coef;
run;

proc stdize method=ustd mult=.44721 data=Coef out=eigenvectors;
  var Factor1-Factor5;
run;

proc print data=eigenvectors;
run;
```

First, you create an output set Coef for the standardized scoring coefficients by the ODS OUTPUT statement. Note that “StdScoreCoef” is the ODS table that contains the standardized scoring coefficients as shown in [Output 39.1.8](#). (See [Table 39.6](#) for all ODS table names for PROC FACTOR.) Next, you use METHOD=USTD in the PROC STDIZE statement to divide the output coefficients by the corresponding uncorrected (for mean) standard deviations. The following formula shows the relationship between the uncorrected standard deviation and the sum of squares:

$$\text{uncorrected standard deviation} = \sqrt{\text{sum of squares}/N}$$

Recall that what you intend to divide from each coefficient is its square root of the corresponding column sum of squares. Therefore, to adjust for what PROC STDIZE does using METHOD=USTD, you have to multiply each variable by a constant term of  $1/\sqrt{N}$  in the standardization. For the current example, this constant term is 0.44721 ( $= 1/\sqrt{5}$ ) and is specified through the MULT= option in the PROC STDIZE statement. With the OUT= option, the rescaled scoring coefficients are saved in the SAS data set eigenvectors. The printout of the data set in [Output 39.1.10](#) shows the rescaled standardized scoring coefficients obtained from PROC FACTOR.

**Output 39.1.10** Rescaled Standardized Scoring Coefficients

Obs	Variable	Factor1	Factor2	Factor3	Factor4	Factor5
1	Population	0.34273	0.60162	0.05952	0.20403	0.68949
2	School	0.45250	-0.40641	0.68882	-0.35357	0.17486
3	Employment	0.39669	0.54166	0.24796	0.02294	-0.69801
4	Services	0.55005	-0.07782	-0.66407	-0.50038	-0.00012
5	HouseValue	0.46673	-0.41643	-0.13965	0.76318	-0.08242

As you can see, these standardized scoring coefficients are essentially the same as those obtained from PROC PRINCOMP, as shown in [Output 39.1.9](#). This example shows that principal component analyses by PROC FACTOR and PROC PRINCOMP are indeed equivalent. PROC PRINCOMP emphasizes more the linear combinations of the variables to form the components, while PROC FACTOR expresses variables as linear combinations of the components in the output. If a principal component analysis of the data is all you need in a particular application, there is no reason to use PROC FACTOR instead of PROC PRINCOMP. Therefore, the following examples focus on common factor analysis for which that you can apply only PROC FACTOR, but not PROC PRINCOMP.

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## Example 39.2: Principal Factor Analysis

This example uses the data presented in [Example 39.1](#) and performs a principal factor analysis with squared multiple correlations for the prior communality estimates. Unlike [Example 39.1](#), which analyzes the principal components (with default PRIORS=ONE), the current analysis is based on a common factor model. To use a common factor model, you specify PRIORS=SMC in the PROC FACTOR statement, as shown in the following:

```
ods graphics on;

proc factor data=SocioEconomics
  priors=smc msa residual
  rotate=promax reorder
  outstat=fact_all
  plots=(scree initloadings preloadings loadings);
run;

ods graphics off;
```

In the PROC FACTOR statement, you include several other options to help you analyze the results. To help determine whether the common factor model is appropriate, you request the Kaiser's measure of sampling

adequacy with the **MSA** option. You specify the **RESIDUALS** option to compute the residual correlations and partial correlations.

The **ROTATE=** and **REORDER** options are specified to enhance factor interpretability. The **ROTATE=PROMAX** option produces an orthogonal varimax prerotation (default) followed by an oblique Procrustes rotation, and the **REORDER** option reorders the variables according to their largest factor loadings. An **OUTSTAT=** data set is created by PROC FACTOR and displayed in [Output 39.2.15](#).

PROC FACTOR can produce high-quality graphs that are very useful for interpreting the factor solutions. To request these graphs, ODS Graphics must be enabled. All ODS graphs in PROC FACTOR are requested with the **PLOTS=** option. In this example, you request a scree plot (**SCREE**) and loading plots for the factor matrix during the following three stages: initial unrotated solution (**INITLOADINGS**), prerotated (varimax) solution (**PRELOADINGS**), and promax-rotated solution (**LOADINGS**). The scree plot helps you determine the number of factors, and the loading plots help you visualize the patterns of factor loadings during various stages of analyses.

## Principal Factor Analysis: Kaiser's MSA and Factor Extraction Results

[Output 39.2.1](#) displays the results of the partial correlations and Kaiser's measure of sampling adequacy.

### Output 39.2.1 Principal Factor Analysis: Partial Correlations and Kaiser's MSA

Partial Correlations Controlling all other Variables					
	Population	School	Employment	Services	HouseValue
Population	1.00000	-0.54465	0.97083	0.09612	0.15871
School	-0.54465	1.00000	0.54373	0.04996	0.64717
Employment	0.97083	0.54373	1.00000	0.06689	-0.25572
Services	0.09612	0.04996	0.06689	1.00000	0.59415
HouseValue	0.15871	0.64717	-0.25572	0.59415	1.00000

Kaiser's Measure of Sampling Adequacy:					
Overall MSA = 0.57536759					
	Population	School	Employment	Services	HouseValue
	0.47207897	0.55158839	0.48851137	0.80664365	0.61281377

If the data are appropriate for the common factor model, the partial correlations (controlling all other variables) should be small compared to the original correlations. For example, the partial correlation between the variables School and HouseValue is 0.65, slightly less than the original correlation of 0.86 (see [Output 39.1.3](#)). The partial correlation between Population and School is  $-0.54$ , which is much larger in absolute value than the original correlation; this is an indication of trouble. Kaiser's **MSA** is a summary, for each variable and for all variables together, of how much smaller the partial correlations are than the original correlations. Values of 0.8 or 0.9 are considered good, while MSAs below 0.5 are unacceptable. The variables Population, School, and Employment have very poor MSAs. Only the Services variable has a good MSA. The overall MSA of 0.58 is sufficiently poor that additional variables should be included in the analysis to better define the common factors. A commonly used rule is that there should be at least three variables per factor. In the following analysis, you determine that there are two common factors in these data. Therefore, more variables are needed for a reliable analysis.

Output 39.2.2 displays the results of the principal factor extraction.

**Output 39.2.2** Principal Factor Analysis: Factor Extraction

Prior Community Estimates: SMC				
Population	School	Employment	Services	HouseValue
0.96859160	0.82228514	0.96918082	0.78572440	0.84701921

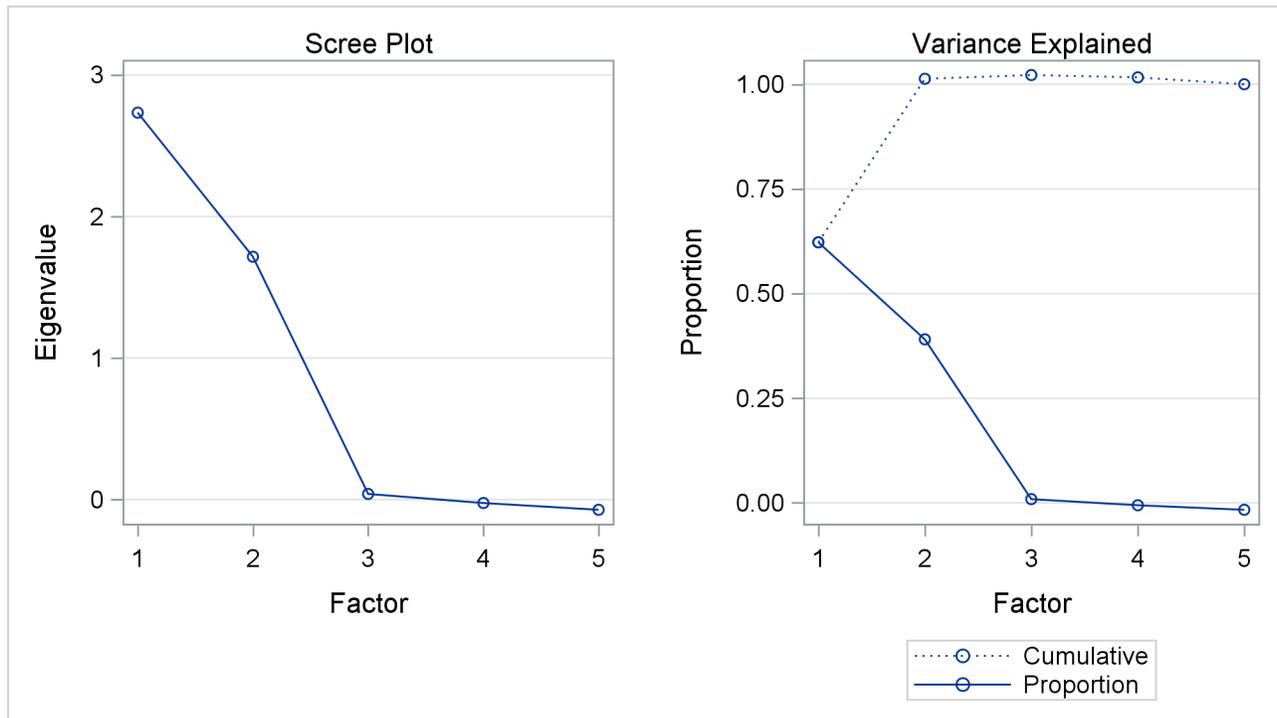
  

Eigenvalues of the Reduced Correlation Matrix: Total = 4.39280116 Average = 0.87856023				
	Eigenvalue	Difference	Proportion	Cumulative
1	2.73430084	1.01823217	0.6225	0.6225
2	1.71606867	1.67650586	0.3907	1.0131
3	0.03956281	0.06408626	0.0090	1.0221
4	-.02452345	0.04808427	-0.0056	1.0165
5	-.07260772		-0.0165	1.0000

The square multiple correlations are shown as prior communality estimates in [Output 39.2.2](#). The `PRIORS=SMC` option basically replaces the diagonal of the original observed correlation matrix by these square multiple correlations. Because the square multiple correlations are usually less than one, the resulting correlation matrix for factoring is called the reduced correlation matrix. In the current example, the SMCs are all fairly large; hence, you expect the results of the principal factor analysis to be similar to those in the principal component analysis.

The first two largest positive eigenvalues of the reduced correlation matrix account for 101.31% of the common variance. This is possible because the reduced correlation matrix, in general, is not necessarily positive definite, and negative eigenvalues for the matrix are possible. A pattern like this suggests that you might not need more than two common factors. The scree and variance explained plots of [Output 39.2.3](#) clearly support the conclusion that two common factors are present. Showing in the left panel of [Output 39.2.3](#) is the scree plot of the eigenvalues of the reduced correlation matrix. A sharp bend occurs at the third eigenvalue, reinforcing the conclusion that two common factors are present. These cumulative proportions of common variance explained by factors are plotted in the right panel of [Output 39.2.3](#), which shows that the curve essentially flattens out after the second factor.

**Output 39.2.3** Scree and Variance Explained Plots



**Principal Factor Analysis: Initial Factor Solution**

For the current analysis, PROC FACTOR retains two factors by certain default criteria. This decision agrees with the conclusion drawn by inspecting the scree plot. The principal factor pattern with the two factors is displayed in Output 39.2.4. This factor pattern is similar to the principal component pattern seen in Output 39.1.5 of Example 39.1. For example, the variable Services has the largest loading on the first factor, and the Population variable has the smallest. The variables Population and Employment have large positive loadings on the second factor, and the HouseValue and School variables have large negative loadings.

**Output 39.2.4** Initial Factor Pattern Matrix and Communalities

Factor Pattern		
	Factor1	Factor2
Services	0.87899	-0.15847
HouseValue	0.74215	-0.57806
Employment	0.71447	0.67936
School	0.71370	-0.55515
Population	0.62533	0.76621

Variance Explained by Each Factor		
	Factor1	Factor2
	2.7343008	1.7160687

**Output 39.2.4** *continued*

Final Community Estimates: Total = 4.450370				
Population	School	Employment	Services	HouseValue
0.97811334	0.81756387	0.97199928	0.79774304	0.88494998

Comparing the current factor loading matrix in [Output 39.2.4](#) with that in [Output 39.1.5](#) in [Example 39.1](#), you notice that the variables are arranged differently in the two output tables. This is due to the use of the **REORDER** option in the current analysis. The advantage of using this option might not be very obvious in [Output 39.2.4](#), but you can see its value when looking at the rotated solutions, as shown in [Output 39.2.7](#) and [Output 39.2.11](#).

The final communality estimates are all fairly close to the priors (shown in [Output 39.2.2](#)). Only the communality for the variable **HouseValue** increased appreciably, from 0.847 to 0.885. Therefore, you are sure that all the common variance is accounted for.

[Output 39.2.5](#) shows that the residual correlations (off-diagonal elements) are low, the largest being 0.03. The partial correlations are not quite as impressive, since the uniqueness values are also rather small. These results indicate that the squared multiple correlations are good but not quite optimal communality estimates.

**Output 39.2.5** Residual and Partial Correlations

Residual Correlations With Uniqueness on the Diagonal					
	Population	School	Employment	Services	HouseValue
Population	0.02189	-0.01118	0.00514	0.01063	0.00124
School	-0.01118	0.18244	0.02151	-0.02390	0.01248
Employment	0.00514	0.02151	0.02800	-0.00565	-0.01561
Services	0.01063	-0.02390	-0.00565	0.20226	0.03370
HouseValue	0.00124	0.01248	-0.01561	0.03370	0.11505

Root Mean Square Off-Diagonal Residuals: Overall = 0.01693282				
Population	School	Employment	Services	HouseValue
0.00815307	0.01813027	0.01382764	0.02151737	0.01960158

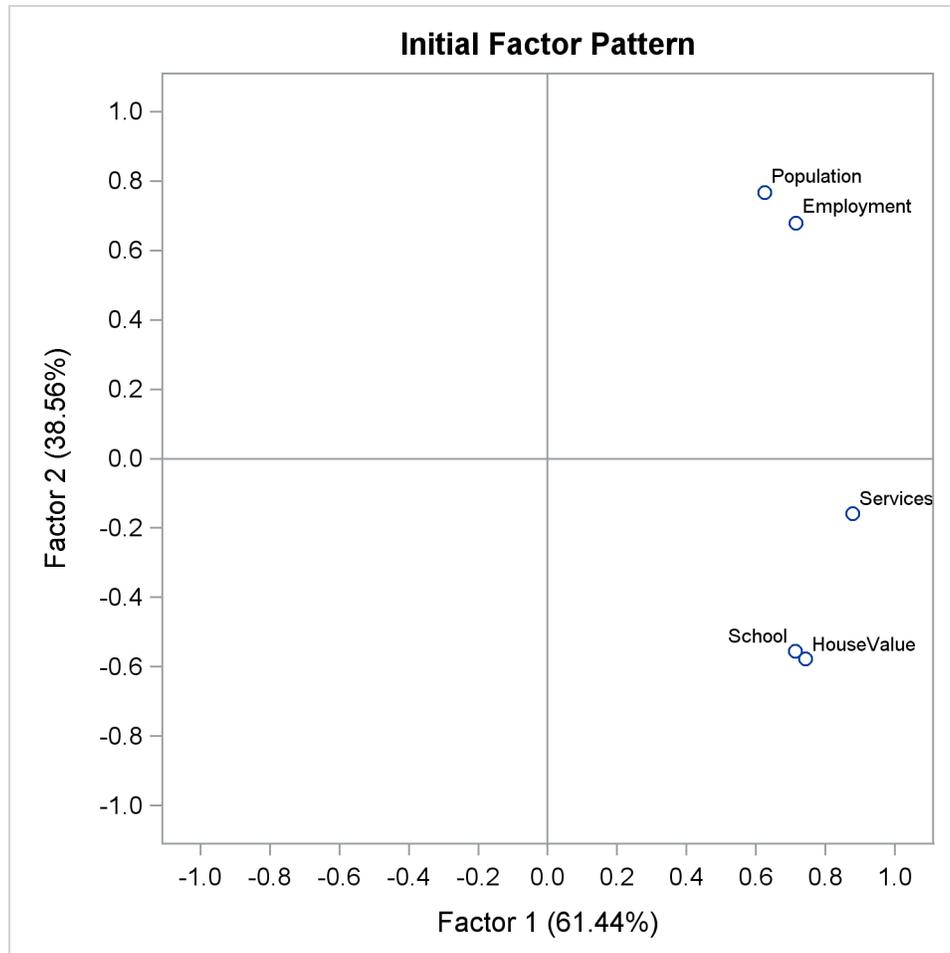
Partial Correlations Controlling Factors					
	Population	School	Employment	Services	HouseValue
Population	1.00000	-0.17693	0.20752	0.15975	0.02471
School	-0.17693	1.00000	0.30097	-0.12443	0.08614
Employment	0.20752	0.30097	1.00000	-0.07504	-0.27509
Services	0.15975	-0.12443	-0.07504	1.00000	0.22093
HouseValue	0.02471	0.08614	-0.27509	0.22093	1.00000

Root Mean Square Off-Diagonal Partial: Overall = 0.18550132				
Population	School	Employment	Services	HouseValue
0.15850824	0.19025867	0.23181838	0.15447043	0.18201538

As displayed in [Output 39.2.6](#), the unrotated factor pattern reveals two tight clusters of variables, with the variables **HouseValue** and **School** at the negative end of **Factor2** axis and the variables **Employment** and **Population** at the positive end. The **Services** variable is in between but closer to the **HouseValue** and **School**

variables. A good rotation would place the axes so that most variables would have zero loadings on most factors. As a result, the axes would appear as though they are put through the variable clusters.

**Output 39.2.6** Unrotated Factor Loading Plot



### Principal Factor Analysis: Varimax Prerotation

In [Output 39.2.7](#), the results of the varimax prerotation are shown. To yield the varimax-rotated factor loading (pattern), the initial factor loading matrix is postmultiplied by an orthogonal transformation matrix. This orthogonal transformation matrix is shown in [Output 39.2.7](#), followed by the varimax-rotated factor pattern. This rotation or transformation leads to small loadings of Population and Employment on the first factor and small loadings of HouseValue and School on the second factor. Services appears to have a larger loading on the first factor than it has on the second factor, although both loadings are substantial. Hence, Services appears to be factorially complex.

With the [REORDER](#) option in effect, you can see the variable clusters clearly in the factor pattern. The first factor is associated more with the first three variables (first three rows of variables): HouseValue, School, and Services. The second factor is associated more with the last two variables (last two rows of variables): Population and Employment.

For orthogonal factor solutions such as the current varimax-rotated solution, you can also interpret the values in the factor loading (pattern) matrix as correlations. For example, HouseValue and Factor 1 have a high correlation at 0.94, while Population and Factor 1 have a low correlation at 0.02.

**Output 39.2.7** Varimax Rotation: Transform Matrix and Rotated Pattern

Orthogonal Transformation Matrix		
	1	2
1	0.78895	0.61446
2	-0.61446	0.78895

Rotated Factor Pattern		
	Factor1	Factor2
HouseValue	0.94072	-0.00004
School	0.90419	0.00055
Services	0.79085	0.41509
Population	0.02255	0.98874
Employment	0.14625	0.97499

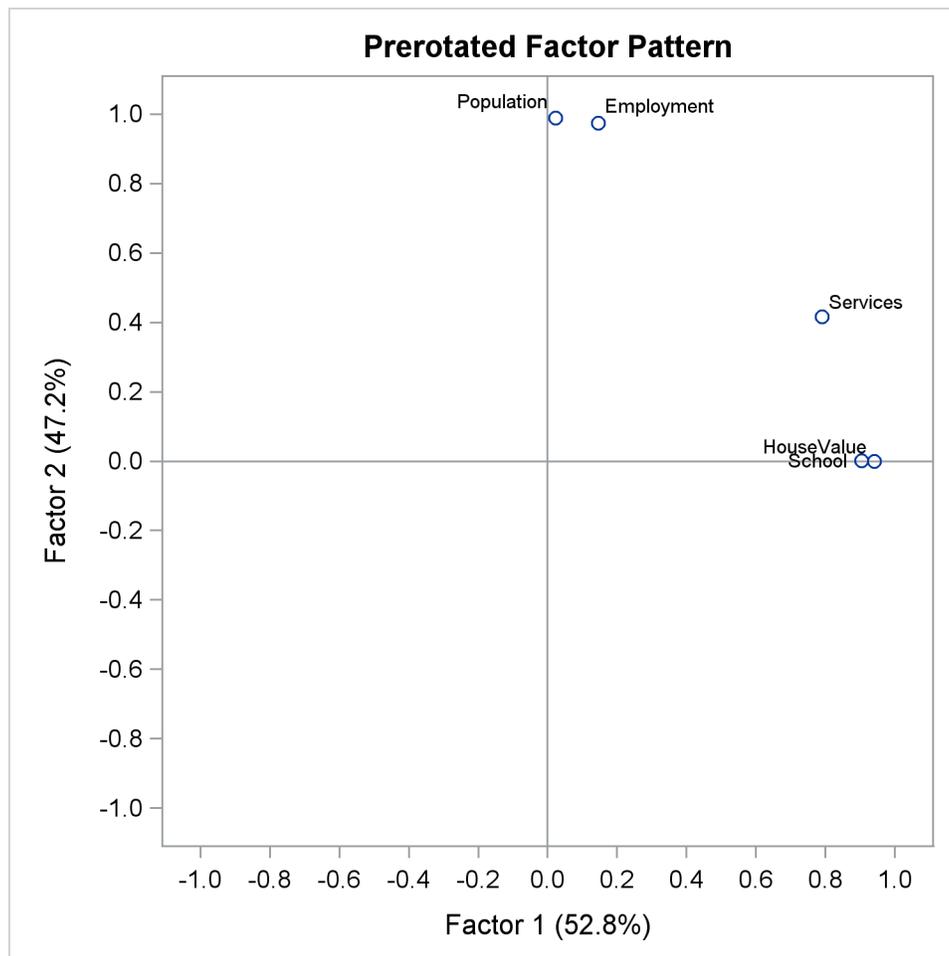
Variance Explained by Each Factor		
	Factor1	Factor2
	2.3498567	2.1005128

Final Community Estimates: Total = 4.450370				
Population	School	Employment	Services	HouseValue
0.97811334	0.81756387	0.97199928	0.79774304	0.88494998

The variance explained by the factors are more evenly distributed in the varimax-rotated solution, as compared with that of the unrotated solution. Indeed, this is a typical fact for any kinds of factor rotation. In the current example, before the varimax rotation the two factors explain 2.73 and 1.72, respectively, of the common variance (see [Output 39.2.4](#)). After the varimax rotation the two rotated factors explain 2.35 and 2.10, respectively, of the common variance. However, the total variance accounted for by the factors remains unchanged after the varimax rotation. This invariance property is also observed for the communalities of the variables after the rotation, as evidenced by comparing the current communality estimates in [Output 39.2.7](#) with those in [Output 39.2.4](#).

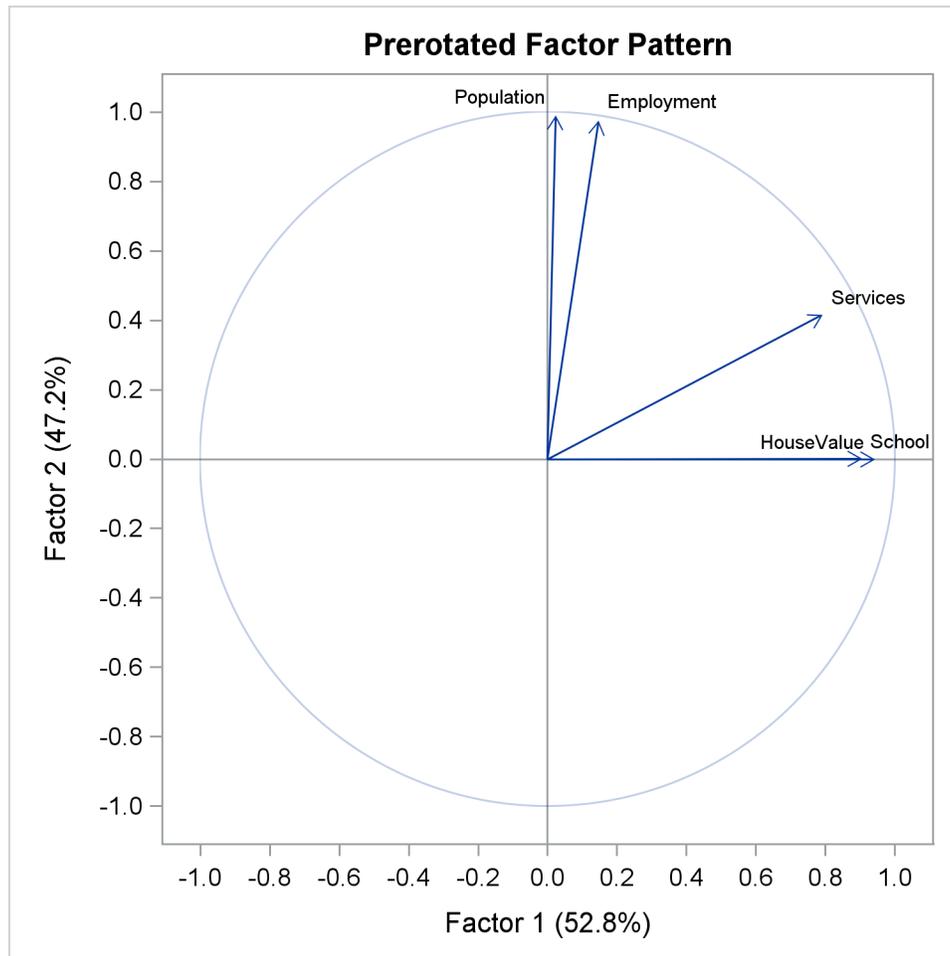
[Output 39.2.8](#) shows the graphical plot of the varimax-rotated factor loadings. Clearly, HouseValue and School cluster together on the Factor 1 axis, while Population and Employment cluster together on the Factor 2 axis. Service is closer to the cluster of HouseValue and School.

**Output 39.2.8** Varimax-Rotated Factor Loadings

An alternative to the scatter plot of factor loadings is the so-called vector plot of loadings, which is shown in [Output 39.2.9](#). The vector plot is requested with the suboption VECTOR in the **PLOTS=** option. That is:

```
plots=preloadings(vector)
```

This generates the vector plot of loadings in [Output 39.2.9](#).

**Output 39.2.9** Varimax-Rotated Factor Loadings: Vector Plot

### Principal Factor Analysis: Oblique Promax Rotation

For some researchers, the varimax-rotated factor solution in the preceding section might be good enough to provide them useful and interpretable results. For others who believe that common factors are seldom orthogonal, an obliquely rotated factor solution might be more desirable, or at least should be attempted.

PROC FACTOR provides a very large class of oblique factor rotations. The current example shows a particular one—namely, the promax rotation as requested by the `ROTATE=PROMAX` option.

The results of the promax rotation are shown in [Output 39.2.10](#) and [Output 39.2.11](#). The corresponding plot of factor loadings is shown in [Output 39.2.12](#).

**Output 39.2.10** Promax Rotation: Procrustean Target and Transformation

Target Matrix for Procrustean Transformation		
	Factor1	Factor2
HouseValue	1.00000	-0.00000
School	1.00000	0.00000
Services	0.69421	0.10045
Population	0.00001	1.00000
Employment	0.00326	0.96793

Procrustean Transformation Matrix		
	1	2
1	1.04117	-0.09865
2	-0.10572	0.96303

Normalized Oblique Transformation Matrix		
	1	2
1	0.73803	0.54202
2	-0.70555	0.86528

Output 39.2.10 shows the Procrustean target, to which the varimax factor pattern is rotated, followed by the display of the Procrustean transformation matrix. This is the matrix that transforms the varimax factor pattern so that the rotated pattern is as close as possible to the Procrustean target. However, because the variances of factors have to be fixed at 1 during the oblique transformation, a normalized version of the Procrustean transformation matrix is the one that is actually used in the transformation. This normalized transformation matrix is shown at the bottom of Output 39.2.10. Using this transformation matrix leads to the promax-rotated factor solution, as shown in Output 39.2.11.

**Output 39.2.11** Promax Rotation: Factor Correlations and Factor Pattern

Inter-Factor Correlations		
	Factor1	Factor2
Factor1	1.00000	0.20188
Factor2	0.20188	1.00000

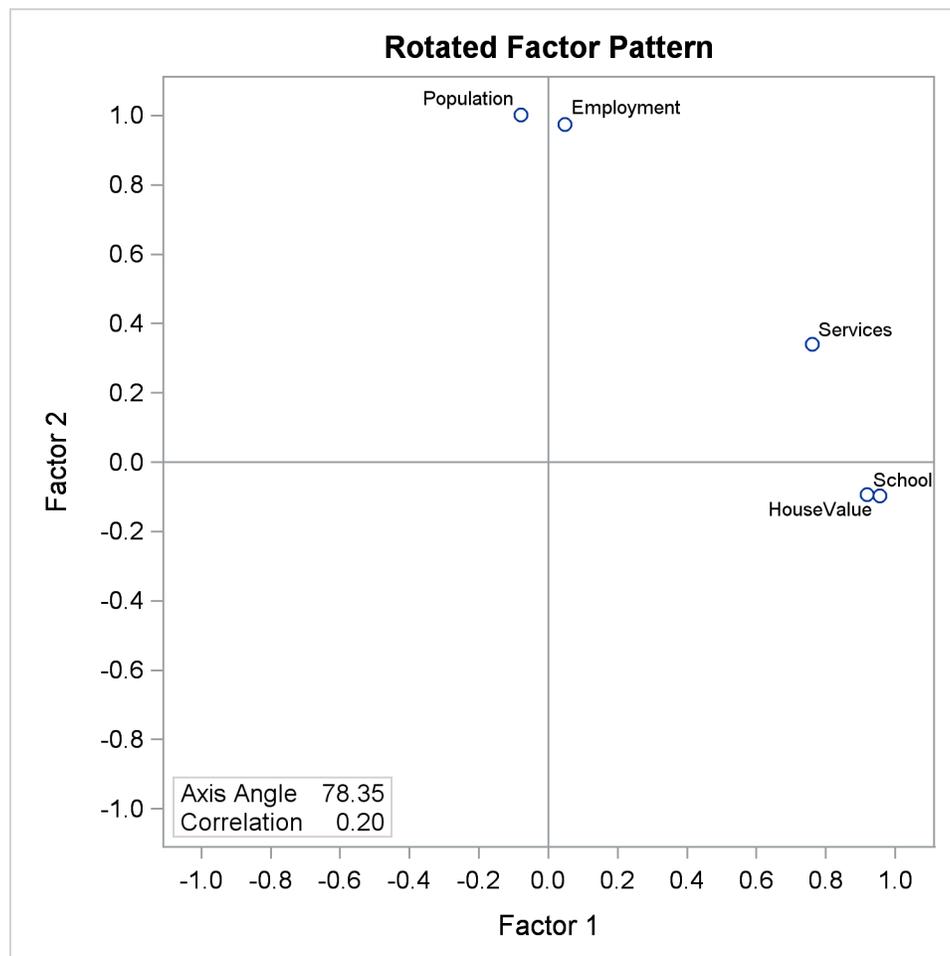
Rotated Factor Pattern (Standardized Regression Coefficients)		
	Factor1	Factor2
HouseValue	0.95558	-0.09792
School	0.91842	-0.09352
Services	0.76053	0.33932
Population	-0.07908	1.00192
Employment	0.04799	0.97509

After the promax rotation, the factors are no longer uncorrelated. As shown in Output 39.2.11, the correlation of the two factors is now 0.20. In the (initial) unrotated and the varimax solutions, the two factors are not correlated.

In addition to allowing the factors to be correlated, in an oblique factor solution you seek a pattern of factor loadings that is more “differentiated” (referred to as the “simple structures” in the literature). The more differentiated the loadings, the easier the interpretation of the factors.

For example, factor loadings of Services and Population on Factor 2 are 0.415 and 0.989, respectively, in the (orthogonal) varimax-rotated factor pattern (see [Output 39.2.7](#)). With the (oblique) promax rotation (see [Output 39.2.11](#)), these two loadings become even more differentiated with values 0.339 and 1.002, respectively. Overall, however, the factor patterns before and after the promax rotation do not seem to differ too much. This fact is confirmed by comparing the graphical plots of factor loadings. The plots in [Output 39.2.12](#) (promax-rotated factor loadings) and [Output 39.2.8](#) (varimax-rotated factor loadings) show very similar patterns.

**Output 39.2.12** Promax Rotation: Factor Loading Plot



Unlike the orthogonal factor solutions where you can interpret the factor loadings as correlations between variables and factors, in oblique factor solutions such as the promax solution, you have to turn to the factor structure matrix for examining the correlations between variables and factors. [Output 39.2.13](#) shows the factor structures of the promax-rotated solution.

**Output 39.2.13** Promax Rotation: Factor Structures and Final Communalities

Factor Structure (Correlations)				
	Factor1	Factor2		
HouseValue	0.93582	0.09500		
School	0.89954	0.09189		
Services	0.82903	0.49286		
Population	0.12319	0.98596		
Employment	0.24484	0.98478		
Variance Explained by Each Factor Ignoring Other Factors				
	Factor1	Factor2		
	2.4473495	2.2022803		
Final Communality Estimates: Total = 4.450370				
Population	School	Employment	Services	HouseValue
0.97811334	0.81756387	0.97199928	0.79774304	0.88494998

Basically, the factor structure matrix shown in [Output 39.2.13](#) reflects a similar pattern to the factor pattern matrix shown in [Output 39.2.11](#). The critical difference is that you can have the correlation interpretation only by using the factor structure matrix. For example, in the factor structure matrix shown in [Output 39.2.13](#), the correlation between Population and Factor 2 is 0.986. The corresponding value shown in the factor pattern matrix in [Output 39.2.11](#) is 1.002, which certainly cannot be interpreted as a correlation coefficient.

Common variance explained by the promax-rotated factors are 2.447 and 2.202, respectively, for the two factors. Unlike the orthogonal factor solutions (for example, the prerotated varimax solution), variance explained by these promax-rotated factors do not sum up to the total communality estimate 4.45. In oblique factor solutions, variance explained by oblique factors cannot be partitioned for the factors. Variance explained by a common factor is computed while ignoring the contributions from the other factors.

However, the communalities for the variables, as shown in the bottom of [Output 39.2.13](#), do not change from rotation to rotation. They are still the same set of communalities in the initial, varimax-rotated, and promax-rotated solutions. This is a basic fact about factor rotations: they only redistribute the variance explained by the factors; the total variance explained by the factors for any variable (that is, the communality of the variable) remains unchanged.

In the literature of exploratory factor analysis, reference axes had been an important tool in factor rotation. Nowadays, rotations are seldom done through the uses of the reference axes. Despite that, results about reference axes do provide additional information for interpreting factor analysis results. For the current example of the promax rotation, PROC FACTOR shows the relevant results about the reference axes in [Output 39.2.14](#).

**Output 39.2.14** Promax Rotation: Reference Axis Correlations and Reference Structures

Reference Axis Correlations		
	Factor1	Factor2
Factor1	1.00000	-0.20188
Factor2	-0.20188	1.00000

Reference Structure (Semipartial Correlations)		
	Factor1	Factor2
HouseValue	0.93591	-0.09590
School	0.89951	-0.09160
Services	0.74487	0.33233
Population	-0.07745	0.98129
Employment	0.04700	0.95501

Variance Explained by Each Factor Eliminating Other Factors		
	Factor1	Factor2
	2.2480892	2.0030200

To explain the results in the reference-axis system, some geometric interpretations of the factor axes are needed. Consider a single factor in a system of  $n$  common factors in an oblique factor solution. Taking away the factor under consideration, the remaining  $n - 1$  factors span a hyperplane in the factor space of  $n - 1$  dimensions. The vector that is orthogonal to this hyperplane is the reference axis (reference vector) of the factor under consideration. Using the same definition for the remaining factors, you have  $n$  reference vectors for  $n$  factors.

A factor in an oblique factor solution can be considered as the sum of two independent components: its associated reference vector and a component that is overlapped with all other factors. In other words, the reference vector of a factor is a unique part of the factor that is not predictable from all other factors. Thus, the loadings on a reference vector are the unique effects of the corresponding factor, partialling out the effects from all other factors. The variances explained by a reference vector are the unique variances explained by the corresponding factor, partialling out the variances explained by all other factors.

Output 39.2.14 shows the reference axis correlations. The correlation between the reference vectors is  $-0.20$ . Next, Output 39.2.14 shows the loadings on the reference vectors in the table entitled “Reference Structure (Semipartial Correlations).” As explained previously, loadings on a reference vector are also the unique effects of the corresponding factor, partialling out the effects from the all other factors. For example, the unique effect of Factor 1 on HouseValue is 0.936. Another important property of the reference vector system is that loadings on a reference vector are also correlations between the variables and the corresponding factor, partialling out the correlations between the variables and other factors. This means that the loading 0.936 in the reference structure table is the unique correlation between HouseValue and Factor 1, partialling out the correlation between HouseValue with Factor 2. Hence, as suggested by the title of table, all loadings reported in the “Reference Structure (Semipartial Correlations)” can be interpreted as semipartial correlations between variables and factors.

The last table shown in [Output 39.2.14](#) are the variances explained by the reference vectors. As explained previously, these are also unique variances explained by the factors, partialling out the variances explained by all other factors (or eliminating all other factors, as suggested by the title of the table). In the current example, Factor 1 explains 2.248 of the variable variances, partialling out all variable variances explained by Factor 2.

Notice that factor pattern (shown in [Output 39.2.11](#)), factor structures (correlations, shown in [Output 39.2.13](#)), and reference structures (semipartial correlations, shown in [Output 39.2.14](#)) give you different information about the oblique factor solutions such as the promax-rotated solution. However, for orthogonal factor solutions such as the varimax-rotated solution, factor structures and reference structures are all the same as the factor pattern.

### Principal Factor Analysis: Factor Rotations with Factor Pattern Input

The promax rotation is one of the many rotations that PROC FACTOR provides. You can specify many different rotation algorithms by using the `ROTATE=` options. In this section, you explore different rotated factor solutions from the initial principal factor solution. Specifically, you want to examine the factor patterns yielded by the quartimax transformation (an orthogonal transformation) and the Harris-Kaiser (an oblique transformation), respectively.

Rather than analyzing the entire problem again with new rotations, you can simply use the `OUTSTAT=` data set from the preceding factor analysis results.

First, the `OUTSTAT=` data set is printed using the following statements:

```
proc print data=fact_all;  
run;
```

The output data set is displayed in [Output 39.2.15](#).

**Output 39.2.15** Output Data Set  
**Factor Output Data Set**

Obs	_TYPE_	_NAME_	Population	School	Employment	Services	HouseValue
1	MEAN		6241.67	11.4417	2333.33	120.833	17000.00
2	STD		3439.99	1.7865	1241.21	114.928	6367.53
3	N		12.00	12.0000	12.00	12.000	12.00
4	CORR	Population	1.00	0.0098	0.97	0.439	0.02
5	CORR	School	0.01	1.0000	0.15	0.691	0.86
6	CORR	Employment	0.97	0.1543	1.00	0.515	0.12
7	CORR	Services	0.44	0.6914	0.51	1.000	0.78
8	CORR	HouseValue	0.02	0.8631	0.12	0.778	1.00
9	COMMUNAL		0.98	0.8176	0.97	0.798	0.88
10	PRIORS		0.97	0.8223	0.97	0.786	0.85
11	EIGENVAL		2.73	1.7161	0.04	-0.025	-0.07
12	UNROTATE	Factor1	0.63	0.7137	0.71	0.879	0.74
13	UNROTATE	Factor2	0.77	-0.5552	0.68	-0.158	-0.58
14	RESIDUAL	Population	0.02	-0.0112	0.01	0.011	0.00
15	RESIDUAL	School	-0.01	0.1824	0.02	-0.024	0.01
16	RESIDUAL	Employment	0.01	0.0215	0.03	-0.006	-0.02
17	RESIDUAL	Services	0.01	-0.0239	-0.01	0.202	0.03
18	RESIDUAL	HouseValue	0.00	0.0125	-0.02	0.034	0.12
19	PRETRANS	Factor1	0.79	-0.6145	.	.	.
20	PRETRANS	Factor2	0.61	0.7889	.	.	.
21	PREROTAT	Factor1	0.02	0.9042	0.15	0.791	0.94
22	PREROTAT	Factor2	0.99	0.0006	0.97	0.415	-0.00
23	TRANSFOR	Factor1	0.74	-0.7055	.	.	.
24	TRANSFOR	Factor2	0.54	0.8653	.	.	.
25	FCORR	Factor1	1.00	0.2019	.	.	.
26	FCORR	Factor2	0.20	1.0000	.	.	.
27	PATTERN	Factor1	-0.08	0.9184	0.05	0.761	0.96
28	PATTERN	Factor2	1.00	-0.0935	0.98	0.339	-0.10
29	RCORR	Factor1	1.00	-0.2019	.	.	.
30	RCORR	Factor2	-0.20	1.0000	.	.	.
31	REFERENC	Factor1	-0.08	0.8995	0.05	0.745	0.94
32	REFERENC	Factor2	0.98	-0.0916	0.96	0.332	-0.10
33	STRUCTUR	Factor1	0.12	0.8995	0.24	0.829	0.94
34	STRUCTUR	Factor2	0.99	0.0919	0.98	0.493	0.09

Various results from the previous factor analysis are saved in this data set, including the initial unrotated solution (its factor pattern is saved in observations with `_TYPE_=UNROTATE`), the prerotated varimax solution (its factor pattern is saved in observations with `_TYPE_=PREROTAT`), and the oblique promax solution (its factor pattern is saved in observations with `_TYPE_=PATTERN`).

When PROC FACTOR reads in an input data set with `TYPE=FACTOR`, the observations with `_TYPE_=PATTERN` are treated as the initial factor pattern to be rotated by PROC FACTOR. Hence, it is important that you provide the correct initial factor pattern for PROC FACTOR to read in.

In the current example, you need to provide the unrotated solution from the preceding analysis as the input factor pattern. The following statements create a TYPE=FACTOR data set fact2 from the preceding OUTSTAT= data set fact\_all:

```
data fact2(type=factor);
  set fact_all;
  if _TYPE_ in('PATTERN' 'FCORR') then delete;
  if _TYPE_='UNROTATE' then _TYPE_='PATTERN';
run;
```

In these statements, you delete observations with \_TYPE\_=PATTERN or \_TYPE\_=FCORR, which are for the promax-rotated factor solution, and change observations with \_TYPE\_=UNROTATE to \_TYPE\_=PATTERN in the new data set fact2. In this way, the initial orthogonal factor pattern matrix is saved in the observations with \_TYPE\_=PATTERN.

You use this new data set and rotate the initial solution to another oblique solution with the ROTATE=QUARTIMAX option, as shown in the following statements:

```
proc factor data=fact2 rotate=quartimax reorder;
run;
```

As shown in Output 39.2.16, the new rotation uses a TYPE=FACTOR input data set.

**Output 39.2.16** Quartimax Rotation With Input Factor Pattern  
**Quartimax Rotation From a TYPE=FACTOR Data Set**

**The FACTOR Procedure**

Input Data Type	FACTOR
N Set/Assumed in Data Set	12
N for Significance Tests	12

The quartimax-rotated factor pattern is displayed in Output 39.2.17.

**Output 39.2.17** Quartimax-Rotated Factor Pattern

Orthogonal Transformation Matrix		
	1	2
1	0.80138	0.59815
2	-0.59815	0.80138

Rotated Factor Pattern		
	Factor1	Factor2
HouseValue	0.94052	-0.01933
School	0.90401	-0.01799
Services	0.79920	0.39878
Population	0.04282	0.98807
Employment	0.16621	0.97179

**Output 39.2.17** *continued*

Variance Explained by Each Factor	
Factor1	Factor2
2.3699941	2.0803754

The quartimax rotation produces an orthogonal transformation matrix shown at the top of [Output 39.2.17](#). After the transformation, the factor pattern is shown next. Compared with the varimax-rotated factor pattern (see [Output 39.2.7](#)), the quartimax-rotated factor pattern shows some differences. The loadings of HouseValue and School on Factor 1 drop only slightly in the quartimax factor pattern, while the loadings of Services, Population, and Employment on Factor 1 gain relatively larger amounts. The total variance explained by Factor 1 in the varimax-rotated solution (see [Output 39.2.7](#)) is 2.350, while it is 2.370 after the quartimax-rotation. In other words, more variable variances are explained by the first factor in the quartimax factor pattern than in the varimax factor pattern. Although not very strongly demonstrated in the current example, this illustrates a well-known property about the quartimax rotation: it tends to produce a general factor for all variables.

Another oblique rotation is now explored. The Harris-Kaiser transformation weighted by the Cureton-Mulaik technique is applied to the initial factor pattern. To achieve this, you use the `ROTATE=HK` and `NORM=WEIGHT` options in the following PROC FACTOR statement:

```
ods graphics on;

proc factor data=fact2 rotate=hk norm=weight reorder plots=loadings;
run;

ods graphics off;
```

[Output 39.2.18](#) shows the variable weights in the rotation.

**Output 39.2.18** Harris-Kaiser Rotation: Weights

Variable Weights for Rotation				
Population	School	Employment	Services	HouseValue
0.95982747	0.93945424	0.99746396	0.12194766	0.94007263

While all other variables have weights at least as large as 0.93, the weight for Services is only 0.12. This means that due to its small weight, Services is not as important as the other variables for determining the rotation (transformation). This makes sense when you look at the initial unrotated factor pattern plot in [Output 39.2.6](#). In the plot, there are two main clusters of variables, and Services does not seem to fall into either of the clusters. In order to yield a Harris-Kaiser rotation (transformation) that would gear towards two clusters, the Cureton-Mulaik weighting essentially downweights the contribution from Services in the factor rotation.

The results of the Harris-Kaiser factor solution are displayed in [Output 39.2.19](#), with a graphical plot of rotated loadings displayed in [Output 39.2.20](#).

**Output 39.2.19** Harris-Kaiser Rotation: Factor Correlations and Factor Pattern

Inter-Factor Correlations		
	Factor1	Factor2
Factor1	1.00000	0.08358
Factor2	0.08358	1.00000

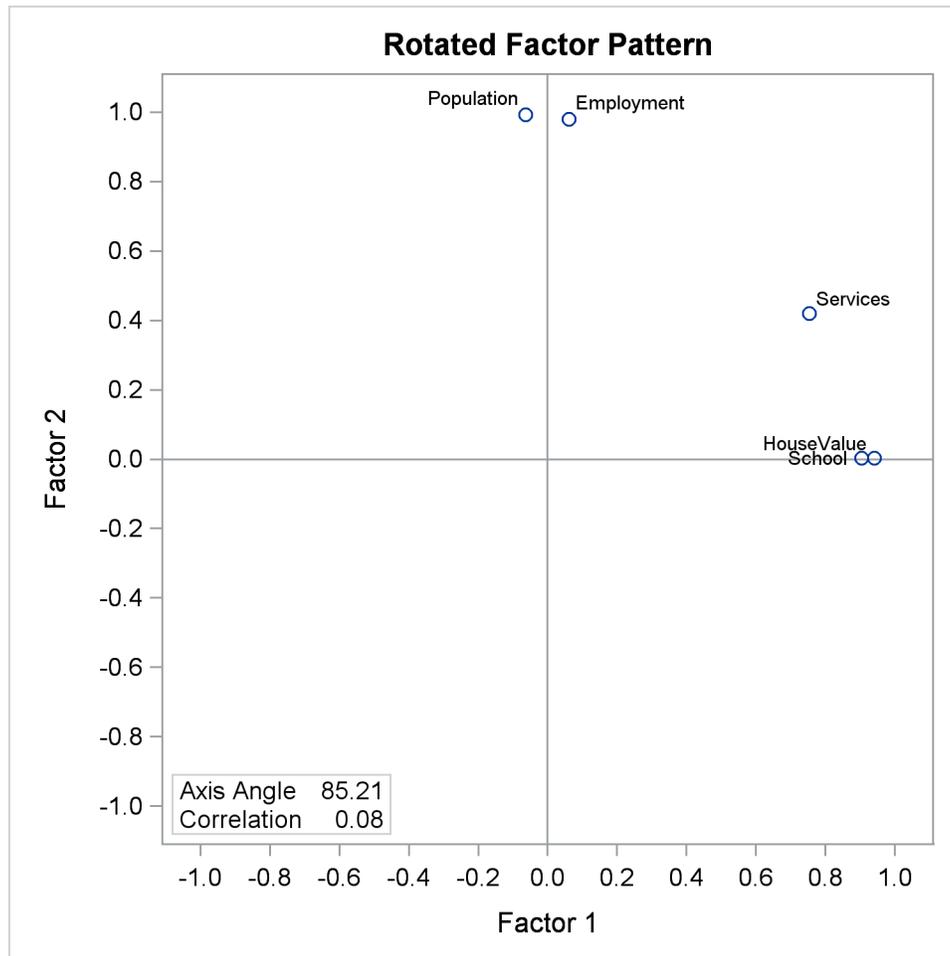
  

Rotated Factor Pattern (Standardized Regression Coefficients)		
	Factor1	Factor2
HouseValue	0.94048	0.00279
School	0.90391	0.00327
Services	0.75459	0.41892
Population	-0.06335	0.99227
Employment	0.06152	0.97885

Because the Harris-Kaiser produces an oblique factor solution, you compare the current results with that of the promax (see [Output 39.2.11](#)), which also produces an oblique factor solution. The correlation between the factors in the Harris-Kaiser solution is 0.084; this value is much smaller than the same correlation in the promax solution, which is 0.201. However, the Harris-Kaiser rotated factor pattern shown in [Output 39.2.19](#) is more or less the same as that of the promax-rotated factor pattern shown in [Output 39.2.11](#). Which solution would you consider to be more reasonable or interpretable?

From the statistical point of view, the Harris-Kaiser and promax factor solutions are equivalent. They explain the observed variable relationships equally well. From the simplicity point of view, however, you might prefer to interpret the Harris-Kaiser solution because the factor correlation is smaller. In other words, the factors in the Harris-Kaiser solution do not overlap that much conceptually; hence they should be more distinctive to interpret. However, in practice simplicity in factor correlations might not be the only principle to consider. Researchers might actually expect to have some factors to be highly correlated based on theoretical or substantive grounds.

Although the Harris-Kaiser and the promax factor patterns are very similar, the graphical plots of the loadings from the two solutions paint slightly different pictures. The plot of the promax-rotated loadings is shown in [Output 39.2.12](#), while the plot of the loadings for the current Harris-Kaiser solution is shown in [Output 39.2.20](#).

**Output 39.2.20** Harris-Kaiser Rotation: Factor Loading Plot

The two factor axes in the Harris-Kaiser rotated pattern ([Output 39.2.20](#)) clearly cut through the centers of the two variable clusters, while the Factor 1 axis in the promax solution lies above a variable cluster ([Output 39.2.12](#)). The reason for this subtle difference is that in the Harris-Kaiser rotation, the Services is a “loner” that has been downweighted by the Cureton-Mulaik technique (see its relatively small weight in [Output 39.2.18](#)). As a result, the rotated axes are basically determined by the two variable clusters in the Harris-Kaiser rotation.

As far as the current discussion goes, it is not recommending one rotation method over another. Rather, it simply illustrates how you could control certain types of characteristics of factor rotation through the many options supported by PROC FACTOR. Should you prefer an orthogonal rotation to an oblique rotation? Should you choose the oblique factor solution with the smallest factor correlations? Should you use a weighting scheme that would enable you to find independent variable clusters? While PROC FACTOR enables you to explore all these alternatives, you must consult advanced textbooks and published articles to get satisfactory and complete answers to these questions.

### Example 39.3: Determining the Number of Factors to Retain

This example uses the data presented in [Example 39.1](#) to demonstrate the following advanced methods that help you determine the number of factors to retain:

- minimum average partial correlation (MAP) analysis
- parallel analysis

To use these methods, you can specify the MAP option or the PARALLEL option in the PROC FACTOR statement. These options display the results of the requested analysis but do not use the results to determine the number of factors to retain. To use either analysis to determine the number of factors to retain, specify the `NFACTORS=name` option with the desired argument (MAP, MAP2, MAP4, or PARALLEL). If you do not specify these advanced methods in the `NFACTORS=` option, the procedure determines the number of factors by using some basic criteria, which are based on the specified or default values of the `MINEIGEN=`, `NFACTORS=n`, and `PROPORTION=` options. For more information, see the section “Number of Factors to Retain” on page 2525.

In [Example 39.1](#), the following specification causes PROC FACTOR to retain two factors by the basic criteria:

```
proc factor data=Socioeconomics
  simple corr;
run;
```

The output shows that:

**2 factors will be retained by the MINEIGEN criterion.**

This example repeats the analysis by specifying the MAP and parallel analysis options:

```
ods graphics on;

proc factor data=SocioEconomics
  parallel(alpha=0.01 nsims=10000 seed=20170229) map
  plots=(parallel map);
run;

ods graphics off;
```

It would be interesting to see whether these two advanced methods would suggest the same number of factors as that suggested by the default use of the MINEIGEN criterion in [Example 39.1](#).

## Parallel Analysis

Parallel analysis compares each of eigenvalues of the input data correlation matrix to an empirical distribution of eigenvalues. Each eigenvalue from the input correlation matrix that exceeds a critical value (based on a one-sided  $\alpha$ -level) in the corresponding empirical distribution suggests a factor to be retained. For more information, see the **PARALLEL** option and the section “Number of Factors to Retain” on page 2525.

The parallel analysis results are displayed in **Output 39.3.1**. The output table summarizes the eigenvalues of the input correlation matrix and compares those eigenvalues to the critical values of the parallel analysis. Because the first two eigenvalues of the input correlation matrix exceed their corresponding critical values, the parallel analysis suggests that two factors be retained, in agreement with the number retained by the **MINEIGEN=** criterion in **Example 39.1**.

**Output 39.3.1** Table of Results for the Parallel Analysis

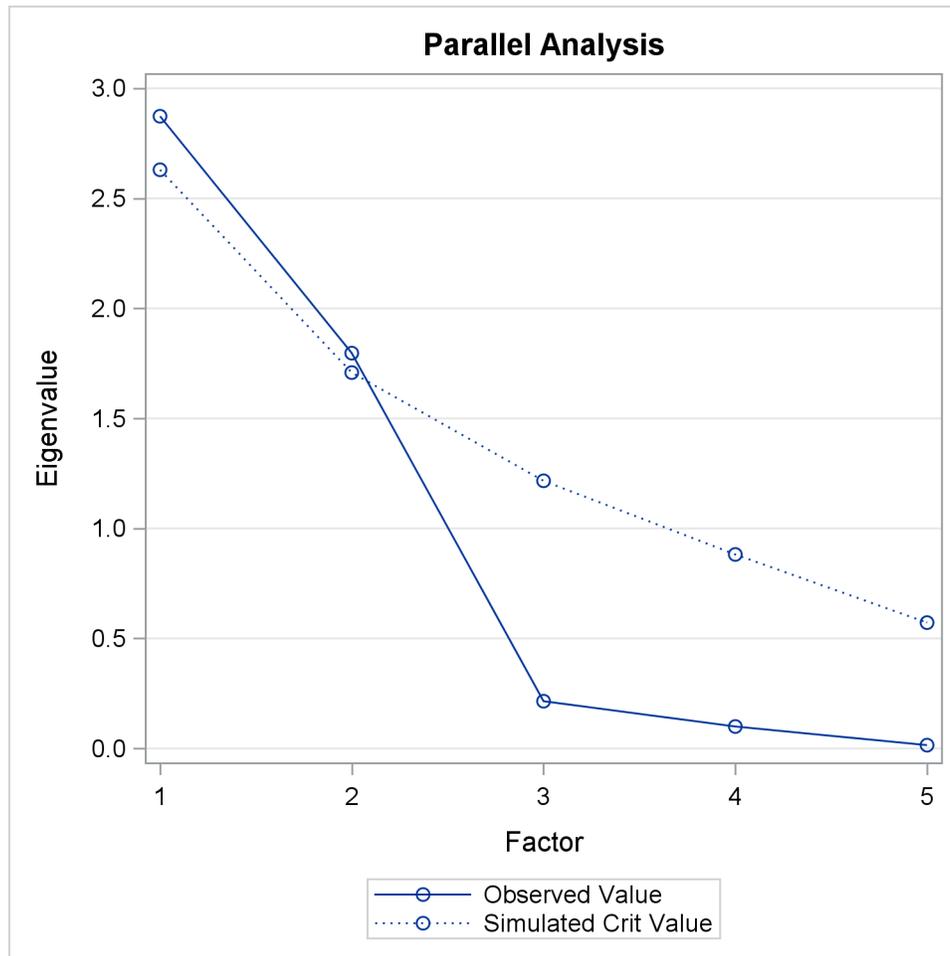
Parallel Analysis: NSims=10000 Seed=20170229		
	Observed Eigenvalue	Simulated Crit Val
1	2.8733	2.6298*
2	1.7967	1.7083*
3	0.2148	1.2164
4	0.0999	0.8818
5	0.0153	0.5720

\* Retained Dimension (Obs > Crit, alpha=0.01)

You can use parallel analysis to directly determine the number of factors to retain by specifying **NFACTORS=PARALLEL** as follows:

```
proc factor data=SocioEconomics
  nfactors=parallel(alpha=0.01 nsims=10000 seed=20170229);
run;
```

When you request a parallel analysis (using either the **PARALLEL** option or the **NFACTORS=PARALLEL** option in the **PROC FACTOR** statement), you can obtain a graphical summary of the results by also specifying the **PLOTS=PARALLEL** option. As shown in **Output 39.3.2**, the scree plot for a parallel analysis contains two lines. The first line is a traditional scree plot and shows the eigenvalues of the sample correlation matrix, sorted in descending order. The second line is constructed from the critical values that are obtained from the parallel analysis. The suggested number of factors to retain is indicated by the intersection of these two lines.

**Output 39.3.2** Graphical Summary of the Parallel Analysis

You can manipulate some parallel analysis options to assess the numerical stability of the parallel analysis results. That is, you can specify different values in the `ALPHA= $p$` , `NSIMS= $n$` , and `SEED= $n$`  suboptions to determine whether the suggested number of factors would change. For a complete definition of these suboptions, see the [PARALLEL](#) option description. You can use the `ALPHA= $p$`  suboption to adjust how conservative the parallel analysis will be. As  $p$  decreases, the critical values in the parallel analysis increase, resulting in a more conservative number of factors suggested by the parallel analysis. You can use the `NSIMS= $n$`  suboption to balance the trade-off between the accuracy of the simulated critical values and the computational time required for the parallel analysis. For data sets that contain few observations relative to the number of variables, you need to use a larger `NSIMS=` value to ensure the numerical accuracy of the simulated critical values. Finally, you can specify the `SEED=` value so that the simulation result of the parallel analysis is reproducible.

## Minimum Average Partial Correlation Analysis (MAP)

The MAP computes averages of squared and fourth-powered partial correlations of variables after recursively controlling for the first, second, and so on, principal components. The number of partialled-out components that corresponds to the minimum average of the squared or fourth-powered partial correlations suggests the number of factors to be retained. For more information, see the [MAP](#) option and the section “[Number of Factors to Retain](#)” on page 2525.

The minimum average partial correlation analysis results are displayed in [Output 39.3.3](#). The output table contains the average squared and fourth-powered partial correlations after controlling for the indicated number of principal components. Because the minimum value (for both squared and fourth-powered partial correlations) occurs when two components are partialled out, the MAP analysis suggests that two factors be retained. This is in agreement with the number retained by the [MINEIGEN=](#) criterion in [Example 39.1](#).

**Output 39.3.3** Table of Results for the MAP

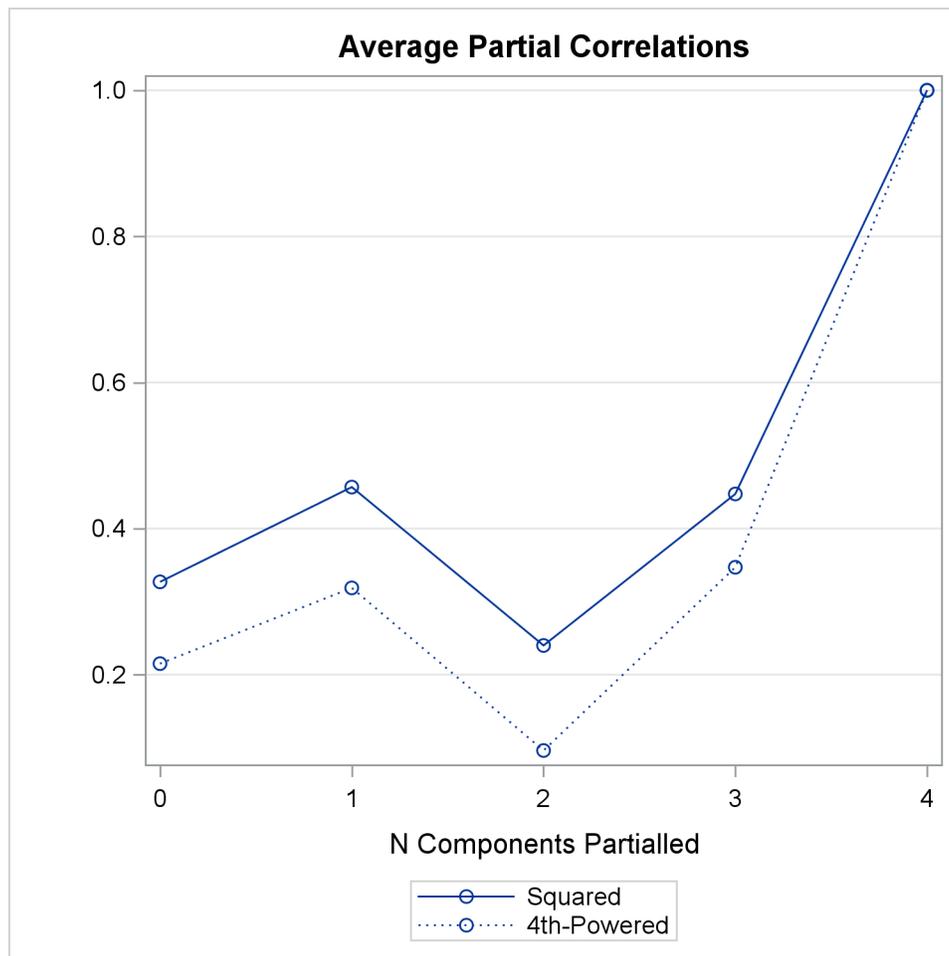
Average Partial Correlations Controlling Principal Components		
N Prin Comp Partialled	Squared	Fourth- Powered
0	0.3270	0.2151
1	0.4568	0.3188
2	0.2400*	0.0962*
3	0.4474	0.3470
4	1.0000	1.0000

\* MAP = Minimum Values in Columns

You can use a MAP analysis to directly determine the number of factors to retain by specifying [NFACTORS=MAP2](#) or [NFACTORS=MAP4](#). For example, the following statements request that the number of factors be determined by identifying the number of controlled principal components that results in the minimum average of the squared partial correlations:

```
proc factor data=SocioEconomics
  nfactors=map2;
run;
```

When you request a minimum average partial correlation analysis (using either the [MAP](#) option or the [NFACTORS=MAP2](#) or [NFACTORS=MAP4](#) option), you can obtain a graphical summary of the results with the [PLOTS=MAP](#) option. As shown in [Output 39.3.4](#), the MAP plot provides a visualization of the MAP results that are shown in [Output 39.3.3](#).

**Output 39.3.4** Graphical Summary of the MAP

### Example 39.4: Maximum Likelihood Factor Analysis

This example uses maximum likelihood factor analyses for one, two, and three factors. It is already apparent from the principal factor analysis that the best number of common factors is almost certainly two. The one- and three-factor ML solutions reinforce this conclusion and illustrate some of the numerical problems that can occur. The following statements produce [Output 39.4.1](#) through [Output 39.4.3](#):

```

title3 'Maximum Likelihood Factor Analysis with One Factor';
proc factor data=SocioEconomics method=ml heywood n=1;
run;

title3 'Maximum Likelihood Factor Analysis with Two Factors';
proc factor data=SocioEconomics method=ml heywood n=2;
run;

title3 'Maximum Likelihood Factor Analysis with Three Factors';
proc factor data=SocioEconomics method=ml heywood n=3;
run;

```

[Output 39.4.1](#) displays the results of the analysis with one factor.

**Output 39.4.1** Maximum Likelihood Factor Analysis

**Maximum Likelihood Factor Analysis with One Factor**

**The FACTOR Procedure**

Input Data Type	Raw Data
Number of Records Read	12
Number of Records Used	12
N for Significance Tests	12

**Maximum Likelihood Factor Analysis with One Factor**

**The FACTOR Procedure**  
**Initial Factor Method: Maximum Likelihood**

**Prior Commuality Estimates: SMC**

Population	School	Employment	Services	HouseValue
0.96859160	0.82228514	0.96918082	0.78572440	0.84701921

**Preliminary Eigenvalues:**  
**Total = 76.1165859 Average = 15.2233172**

	Eigenvalue	Difference	Proportion	Cumulative
1	63.7010086	50.6462895	0.8369	0.8369
2	13.0547191	12.7270798	0.1715	1.0084
3	0.3276393	0.6749199	0.0043	1.0127
4	-0.3472805	0.2722202	-0.0046	1.0081
5	-0.6195007		-0.0081	1.0000

**1 factor will be retained by the NFACTOR criterion.**

Iteration	Criterion	Ridge	Change	Communalities				
1	6.5429218	0.0000	0.1033	0.93828	0.72227	1.00000	0.71940	0.74371
2	3.1232699	0.0000	0.7288	0.94566	0.02380	1.00000	0.26493	0.01487

Convergence criterion satisfied.

**Significance Tests Based on 12 Observations**

Test	DF	Chi-Square	Pr > ChiSq
H0: No common factors	10	54.2517	<.0001
HA: At least one common factor			
H0: 1 Factor is sufficient	5	24.4656	0.0002
HA: More factors are needed			

Chi-Square without Bartlett's Correction	34.355969
Akaike's Information Criterion	24.355969
Schwarz's Bayesian Criterion	21.931436
Tucker and Lewis's Reliability Coefficient	0.120231

**Output 39.4.1** *continued*

Squared Canonical Correlations		
Factor1		
		1.0000000

Eigenvalues of the Weighted Reduced Correlation Matrix: Total = 0 Average = 0		
Eigenvalue	Difference	
1	Infty	Infty
2	1.92716032	2.15547340
3	-.22831308	0.56464322
4	-.79295630	0.11293464
5	-.90589094	

Factor Pattern	
	Factor1
Population	0.97245
School	0.15428
Employment	1.00000
Services	0.51472
HouseValue	0.12193

Variance Explained by Each Factor		
Factor	Weighted	Unweighted
Factor1	17.8010629	2.24926004

Final Community Estimates and Variable Weights		
Total Community: Weighted = 17.801063 Unweighted = 2.249260		
Variable	Community	Weight
Population	0.94565561	18.4011648
School	0.02380349	1.0243839
Employment	1.00000000	Infty
Services	0.26493499	1.3604239
HouseValue	0.01486595	1.0150903

The solution on the second iteration is so close to the optimum that PROC FACTOR cannot find a better solution; hence you receive this message:

**Convergence criterion satisfied.**

When this message appears, you should try rerunning PROC FACTOR with different prior communality estimates to make sure that the solution is correct. In this case, other prior estimates lead to the same solution or possibly to worse local optima, as indicated by the information criteria or the chi-square values.

The variable Employment has a communality of 1.0 and, therefore, an infinite weight that is displayed next to the final communality estimate as a missing/infinite value. The first eigenvalue is also infinite. Infinite values are ignored in computing the total of the eigenvalues and the total final communality.

Output 39.4.2 displays the results of the analysis with two factors. The analysis converges without incident. This time, however, the Population variable is a Heywood case.

**Output 39.4.2** Maximum Likelihood Factor Analysis: Two Factors

Input Data Type	Raw Data
Number of Records Read	12
Number of Records Used	12
N for Significance Tests	12

Prior Communality Estimates: SMC				
Population	School	Employment	Services	HouseValue
0.96859160	0.82228514	0.96918082	0.78572440	0.84701921

Preliminary Eigenvalues:				
Total = 76.1165859 Average = 15.2233172				
Eigenvalue	Difference	Proportion	Cumulative	
1 63.7010086	50.6462895	0.8369	0.8369	
2 13.0547191	12.7270798	0.1715	1.0084	
3 0.3276393	0.6749199	0.0043	1.0127	
4 -0.3472805	0.2722202	-0.0046	1.0081	
5 -0.6195007		-0.0081	1.0000	

**2 factors will be retained by the NFACTOR criterion.**

Iteration	Criterion	Ridge	Change	Communalities				
1	0.3431221	0.0000	0.0471	1.00000	0.80672	0.95058	0.79348	0.89412
2	0.3072178	0.0000	0.0307	1.00000	0.80821	0.96023	0.81048	0.92480
3	0.3067860	0.0000	0.0063	1.00000	0.81149	0.95948	0.81677	0.92023
4	0.3067373	0.0000	0.0022	1.00000	0.80985	0.95963	0.81498	0.92241
5	0.3067321	0.0000	0.0007	1.00000	0.81019	0.95955	0.81569	0.92187

Convergence criterion satisfied.

**Significance Tests Based on 12 Observations**

Test	DF	Chi-Square	Pr > ChiSq
H0: No common factors	10	54.2517	<.0001
HA: At least one common factor			
H0: 2 Factors are sufficient	1	2.1982	0.1382
HA: More factors are needed			

Chi-Square without Bartlett's Correction	3.3740530
Akaike's Information Criterion	1.3740530
Schwarz's Bayesian Criterion	0.8891463
Tucker and Lewis's Reliability Coefficient	0.7292200

**Output 39.4.2** *continued***Squared Canonical  
Correlations**

Factor1	Factor2
1.0000000	0.9518891

**Eigenvalues of the Weighted Reduced Correlation  
Matrix: Total = 19.7853157 Average = 4.94632893**

	Eigenvalue	Difference	Proportion	Cumulative
1	Infy	Infy		
2	19.7853143	19.2421292	1.0000	1.0000
3	0.5431851	0.5829564	0.0275	1.0275
4	-0.0397713	0.4636411	-0.0020	1.0254
5	-0.5034124		-0.0254	1.0000

**Factor Pattern**

	Factor1	Factor2
<b>Population</b>	1.00000	0.00000
<b>School</b>	0.00975	0.90003
<b>Employment</b>	0.97245	0.11797
<b>Services</b>	0.43887	0.78930
<b>HouseValue</b>	0.02241	0.95989

**Variance Explained by Each  
Factor**

Factor	Weighted	Unweighted
<b>Factor1</b>	24.4329707	2.13886057
<b>Factor2</b>	19.7853143	2.36835294

**Final Community Estimates and  
Variable Weights**

**Total Community:**  
**Weighted = 44.218285**  
**Unweighted = 4.507214**

Variable	Communality	Weight
<b>Population</b>	1.00000000	Infy
<b>School</b>	0.81014489	5.2682940
<b>Employment</b>	0.95957142	24.7246669
<b>Services</b>	0.81560348	5.4256462
<b>HouseValue</b>	0.92189372	12.7996793

The results of the three-factor analysis are shown in [Output 39.4.3](#).

**Output 39.4.3** Maximum Likelihood Factor Analysis: Three Factors

Input Data Type	Raw Data
<b>Number of Records Read</b>	12
<b>Number of Records Used</b>	12
<b>N for Significance Tests</b>	12

**Output 39.4.3** *continued*

---

**Prior Commuality Estimates: SMC**

Population	School	Employment	Services	HouseValue
0.96859160	0.82228514	0.96918082	0.78572440	0.84701921

---

**Preliminary Eigenvalues:**  
**Total = 76.1165859 Average = 15.2233172**

	Eigenvalue	Difference	Proportion	Cumulative
1	63.7010086	50.6462895	0.8369	0.8369
2	13.0547191	12.7270798	0.1715	1.0084
3	0.3276393	0.6749199	0.0043	1.0127
4	-0.3472805	0.2722202	-0.0046	1.0081
5	-0.6195007		-0.0081	1.0000

---

**3 factors will be retained by the NFACTOR criterion.**

**Warning:** Too many factors for a unique solution.

Iteration	Criterion	Ridge	Change	Communalities				
1	0.1798029	0.0313	0.0501	0.96081	0.84184	1.00000	0.80175	0.89716
2	0.0016405	0.0313	0.0678	0.98081	0.88713	1.00000	0.79559	0.96500
3	0.0000041	0.0313	0.0094	0.98195	0.88603	1.00000	0.80498	0.96751
4	0.0000000	0.0313	0.0006	0.98202	0.88585	1.00000	0.80561	0.96735

---

ERROR: Converged, but not to a proper optimum.

**Try a different 'PRIORS' statement.**

**Significance Tests Based on 12 Observations**

Test	DF	Chi-Square	Pr > ChiSq
H0: No common factors	10	54.2517	<.0001
HA: At least one common factor			
H0: 3 Factors are sufficient	-2	0.0000	.
HA: More factors are needed			

---

Chi-Square without Bartlett's Correction	0.0000003
Akaike's Information Criterion	4.0000003
Schwarz's Bayesian Criterion	4.9698136
Tucker and Lewis's Reliability Coefficient	0.0000000

---

**Squared Canonical Correlations**

Factor1	Factor2	Factor3
1.0000000	0.9751895	0.6894465

---

**Output 39.4.3** *continued*

**Eigenvalues of the Weighted Reduced Correlation Matrix: Total = 41.5254193 Average = 10.3813548**

	<b>Eigenvalue</b>	<b>Difference</b>	<b>Proportion</b>	<b>Cumulative</b>
<b>1</b>	Infy	Infy		
<b>2</b>	39.3054826	37.0854258	0.9465	0.9465
<b>3</b>	2.2200568	2.2199693	0.0535	1.0000
<b>4</b>	0.0000875	0.0002949	0.0000	1.0000
<b>5</b>	-0.0002075		-0.0000	1.0000

**Factor Pattern**

	<b>Factor1</b>	<b>Factor2</b>	<b>Factor3</b>
<b>Population</b>	0.97245	-0.11233	-0.15409
<b>School</b>	0.15428	0.89108	0.26083
<b>Employment</b>	1.00000	-0.00000	0.00000
<b>Services</b>	0.51472	0.72416	-0.12766
<b>HouseValue</b>	0.12193	0.97227	-0.08473

**Variance Explained by Each Factor**

<b>Factor</b>	<b>Weighted</b>	<b>Unweighted</b>
<b>Factor1</b>	54.6115241	2.24926004
<b>Factor2</b>	39.3054826	2.27634375
<b>Factor3</b>	2.2200568	0.11525433

**Final Community Estimates and Variable Weights**

**Total Community:**  
**Weighted = 96.137063**  
**Unweighted = 4.640858**

<b>Variable</b>	<b>Community</b>	<b>Weight</b>
<b>Population</b>	0.98201660	55.6066901
<b>School</b>	0.88585165	8.7607194
<b>Employment</b>	1.00000000	Infy
<b>Services</b>	0.80564301	5.1444261
<b>HouseValue</b>	0.96734687	30.6251078

In the results, a warning message is displayed:

**WARNING: Too many factors for a unique solution.**

The number of parameters in the model exceeds the number of elements in the correlation matrix from which they can be estimated, so an infinite number of different perfect solutions can be obtained. The criterion approaches zero at an improper optimum, as indicated by this message:

**Converged, but not to a proper optimum.**

The degrees of freedom for the chi-square test are  $-2$ , so a probability level cannot be computed for three factors. Note also that the variable Employment is a Heywood case again.

The probability levels for the chi-square test are 0.0001 for the hypothesis of no common factors, 0.0002 for one common factor, and 0.1382 for two common factors. Therefore, the two-factor model seems to be an adequate representation. Akaike's information criterion and Schwarz's Bayesian criterion attain their minimum values at two common factors, so there is little doubt that two factors are appropriate for these data.

---

## Example 39.5: Using Confidence Intervals to Locate Salient Factor Loadings

This example illustrates how you can use the standard errors and confidence intervals to understand the pattern of factor loadings under the maximum likelihood estimation. There are nine tests and you want a three-factor solution ( $N=3$ ) for a correlation matrix based on 200 observations. The following statements define the input data set and specify the desirable analysis by the FACTOR procedure:

```
data test(type=corr);
  title 'Quartimin-Rotated Factor Solution with Standard Errors';
  input _name_ $ test1-test9;
  _type_ = 'corr';
  datalines;
Test1      1  .561  .602  .290  .404  .328  .367  .179  -.268
Test2    .561  1  .743  .414  .526  .442  .523  .289  -.399
Test3    .602  .743  1  .286  .343  .361  .679  .456  -.532
Test4    .290  .414  .286  1  .677  .446  .412  .400  -.491
Test5    .404  .526  .343  .677  1  .584  .408  .299  -.466
Test6    .328  .442  .361  .446  .584  1  .333  .178  -.306
Test7    .367  .523  .679  .412  .408  .333  1  .711  -.760
Test8    .179  .289  .456  .400  .299  .178  .711  1  -.725
Test9   -.268 -.399 -.532 -.491 -.466 -.306 -.760 -.725  1
;

title2 'A nine-variable-three-factor example';
proc factor data=test method=ml reorder rotate=quartimin
  nobs=200 n=3 se cover=.45 alpha=.1;
run;
```

In the PROC FACTOR statement, you apply quartimin rotation with (default) Kaiser normalization. You define loadings with magnitudes greater than 0.45 to be salient (**COVER=0.45**) and use 90% confidence intervals (**ALPHA=0.1**) to judge the salience. The **REORDER** option is specified so that variables that have similar loadings with factors are clustered together.

After the quartimin rotation, the correlation matrix for factors is shown in [Output 39.5.1](#).

**Output 39.5.1** Quartimin-Rotated Factor Correlations with Standard Errors

Inter-Factor Correlations With 90% confidence limits Estimate/StdErr/LowerCL/UpperCL			
	Factor1	Factor2	Factor3
<b>Factor1</b>	1.00000	0.41283	0.38304
	0.00000	0.06267	0.06060
	.	0.30475	0.27919
	.	0.51041	0.47804
<b>Factor2</b>	0.41283	1.00000	0.47006
	0.06267	0.00000	0.05116
	0.30475	.	0.38177
	0.51041	.	0.54986
<b>Factor3</b>	0.38304	0.47006	1.00000
	0.06060	0.05116	0.00000
	0.27919	0.38177	.
	0.47804	0.54986	.

The factors are medium to highly correlated. The confidence intervals seem to be very wide, suggesting that the estimation of factor correlations might not be very accurate for this sample size. For example, the 90% confidence interval for the correlation between Factor1 and Factor2 is (0.30, 0.51), a range of 0.21. You might need a larger sample to get a narrower interval, or you might need a better estimation.

Next, coverage displays for factor loadings are shown in [Output 39.5.2](#).

**Output 39.5.2** Using the Rotated Factor Pattern to Interpret the Factors

Rotated Factor Pattern (Standardized Regression Coefficients)			
With 90% confidence limits; Cover  *  = 0.45?			
	Estimate	StdErr	LowerCL/UpperCL/Coverage Display
	Factor1	Factor2	Factor3
<b>test8</b>	0.86810	-0.05045	0.00114
	0.03282	0.03185	0.03087
	0.80271	-0.10265	-0.04959
	0.91286	0.00204	0.05187
	0*[]	*[0]	[0]*
<b>test7</b>	0.73204	0.27296	0.01098
	0.04434	0.05292	0.03838
	0.65040	0.18390	-0.05211
	0.79697	0.35758	0.07399
	0*[]	0[]*	[0]*
<b>test9</b>	-0.79654	-0.01230	-0.17307
	0.03948	0.04225	0.04420
	-0.85291	-0.08163	-0.24472
	-0.72180	0.05715	-0.09955
	[]*0	*[0]	*[]0
<b>test3</b>	0.27715	0.91156	-0.19727
	0.05489	0.04877	0.02981
	0.18464	0.78650	-0.24577
	0.36478	0.96481	-0.14778
	0[]*	0*[]	*[]0
<b>test2</b>	0.01063	0.71540	0.20500
	0.05060	0.05148	0.05496
	-0.07248	0.61982	0.11310
	0.09359	0.79007	0.29342
	[0]*	0*[]	0[]*
<b>test1</b>	-0.07356	0.63815	0.13983
	0.04245	0.05380	0.05597
	-0.14292	0.54114	0.04682
	-0.00348	0.71839	0.23044
	*[]0	0*[]	0[]*
<b>test5</b>	0.00863	0.03234	0.91282
	0.04394	0.04387	0.04509
	-0.06356	-0.03986	0.80030
	0.08073	0.10421	0.96323
	[0]*	[0]*	0*[]
<b>test4</b>	0.22357	-0.07576	0.67925
	0.05956	0.03640	0.05434
	0.12366	-0.13528	0.57955
	0.31900	-0.01569	0.75891
	0[]*	*[]0	0*[]
<b>test6</b>	-0.04295	0.21911	0.53183
	0.05114	0.07481	0.06905
	-0.12656	0.09319	0.40893
	0.04127	0.33813	0.63578
	*[0]	0[]*	0[*]

The coverage displays in [Output 39.5.2](#) show that Test8, Test7, and Test9 have salient relationships with Factor1. The coverage displays are either '0\*[ ]' or '[ ]\*0', indicating that the entire 90% confidence intervals for the corresponding loadings are beyond the salience value at 0.45. On the other hand, the coverage display for Test3 on Factor1 is '0[ ]\*'. This indicates that even though the loading estimate is significantly larger than zero, it is not large enough to be salient. Similarly, Test3, Test2, and Test1 have salient relationships with Factor2, while Test5 and Test4 have salient relationships with Factor3. For Test6, its relationship with Factor3 is a little bit ambiguous; the 90% confidence interval approximately covers values between 0.40 and 0.64. This means that the population value might have been smaller or larger than 0.45. It is marginal evidence for a salient relationship.

For oblique factor solutions, some researchers prefer to examine the factor structure loadings, which represent correlations, for determining salient relationships. In [Output 39.5.3](#), the factor structure loadings and the associated standard error estimates and coverage displays are shown.

**Output 39.5.3** Using the Factor Structure to Interpret the Factors

Factor Structure (Correlations)			
With 90% confidence limits; Cover [*] = 0.45?			
Estimate/StdErr/LowerCL/UpperCL/Coverage	Display		
	Factor1	Factor2	Factor3
<b>test8</b>	0.84771	0.30847	0.30994
	0.02871	0.06593	0.06263
	0.79324	0.19641	0.20363
	0.88872	0.41257	0.40904
	0[*]	0[*]	0[*]
<b>test7</b>	0.84894	0.58033	0.41970
	0.02688	0.05265	0.06060
	0.79834	0.48721	0.31523
	0.88764	0.66041	0.51412
	0[*]	0[*]	0[*]
<b>test9</b>	-0.86791	-0.42248	-0.48396
	0.02522	0.06187	0.05504
	-0.90381	-0.51873	-0.56921
	-0.81987	-0.31567	-0.38841
	[*]0	[*]0	[*]0
<b>test3</b>	0.57790	0.93325	0.33738
	0.05069	0.02953	0.06779
	0.48853	0.86340	0.22157
	0.65528	0.96799	0.44380
	0[*]	0[*]	0[*]
<b>test2</b>	0.38449	0.81615	0.54535
	0.06143	0.03106	0.05456
	0.27914	0.75829	0.44946
	0.48070	0.86126	0.62883
	0[*]	0[*]	0[*]
<b>test1</b>	0.24345	0.67351	0.41162
	0.06864	0.04284	0.05995
	0.12771	0.59680	0.30846
	0.35264	0.73802	0.50522
	0[*]	0[*]	0[*]
<b>test5</b>	0.37163	0.46498	0.93132
	0.06092	0.04979	0.03277
	0.26739	0.37923	0.85159
	0.46727	0.54282	0.96894
	0[*]	0[*]	0[*]
<b>test4</b>	0.45248	0.33583	0.72927
	0.05876	0.06289	0.04061
	0.35072	0.22867	0.65527
	0.54367	0.43494	0.78941
	0[*]	0[*]	0[*]
<b>test6</b>	0.25122	0.45137	0.61837
	0.07140	0.05858	0.05051
	0.13061	0.34997	0.52833
	0.36450	0.54232	0.69465
	0[*]	0[*]	0[*]

The interpretations based on the factor structure matrix do not change much from that based on the factor loadings except for Test3 and Test9. Test9 now has a salient correlation with Factor3. For Test3, it has salient correlations with both Factor1 and Factor2. Fortunately, there are still tests that have salient correlations only with either Factor1 or Factor2 (but not both). This would make interpretations of factors less problematic.

## Example 39.6: Creating Path Diagrams for Factor Solutions

The section “Getting Started: FACTOR Procedure” on page 2490 analyzes a data set that contains 14 ratings of 103 police officers to demonstrate some basic techniques in factor analysis. To illustrate the creation and uses of path diagrams, this example analyzes this data set again by using the following statements:

```
ods graphics on;

proc factor data=jobratings(drop='Overall Rating'n)
  priors=smc rotate=quartimin plots=pathdiagram;
label
  'Judgment under Pressure'n = 'Judgment'
  'Communication Skills'n = 'Comm Skills'
  'Interpersonal Sensitivity'n = 'Sensitivity'
  'Willingness to Confront Problems'n = 'Confront Problems'
  'Desire for Self-Improvement'n = 'Self-Improve'
  'Observational Skills'n = 'Obs Skills'
  'Dependability'n = 'Dependable';
run;
```

The PRIORS=SMC option specifies that the squared multiple correlations are to be used as the prior communality estimates. As a result, the factors are extracted by the principal factor method. The ROTATE=QUARTIMIN option requests the use of the quartimin rotation to obtain the final factor solution. The PLOTS=PATHDIAGRAM option requests a path diagram for the final solution. The LABEL statement specifies labels for variables.

When variables do not have labels, PROC FACTOR displays the variable names in path diagrams. But when variables have labels, PROC FACTOR displays labels, instead of variable names, in path diagrams. Because some variables in this example have very long variable names, PROC FACTOR might truncate these long names in the output path diagram. Therefore, to avoid truncations in the output diagram, you can either create a data set with shorter variable names or use the LABEL statement to specify shorter labels. This example illustrates the use of the LABEL statement.

Except for the PLOTS=PATHDIAGRAM option, previous examples have already described the FACTOR options that are used in this example. Therefore, this example focuses only on the creation of path diagrams.

Output 39.6.1 and Output 39.6.2 show the quartimin-rotated factor correlations and factor pattern, respectively.

### Output 39.6.1 Quartimin-Rotated Factor Correlations

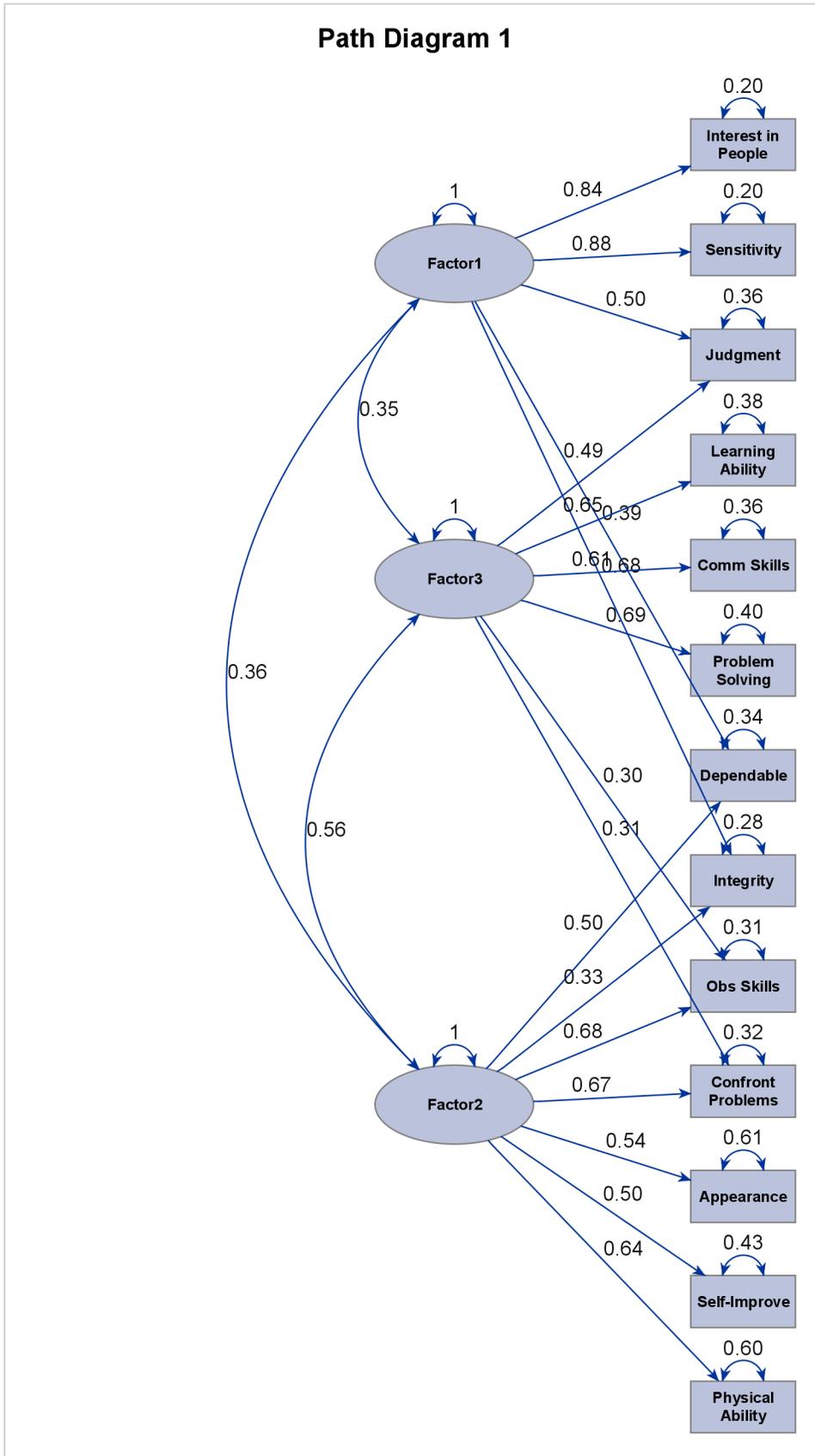
Inter-Factor Correlations			
	Factor1	Factor2	Factor3
Factor1	1.00000	0.36103	0.34823
Factor2	0.36103	1.00000	0.55721
Factor3	0.34823	0.55721	1.00000

**Output 39.6.2** Quartimin-Rotated Factor Pattern

Rotated Factor Pattern (Standardized Regression Coefficients)		Factor1	Factor2	Factor3
<b>Communication Skills</b>	Comm Skills	0.21280	0.13541	0.61091
<b>Problem Solving</b>		0.17222	0.01424	0.68767
<b>Learning Ability</b>		-0.09904	0.24961	0.65430
<b>Judgment under Pressure</b>	Judgment	0.49876	-0.02005	0.48879
<b>Observational Skills</b>	Obs Skills	-0.15748	0.67661	0.30273
<b>Willingness to Confront Problems</b>	Confront Problems	-0.19106	0.66639	0.31135
<b>Interest in People</b>		0.84249	0.12734	-0.00710
<b>Interpersonal Sensitivity</b>	Sensitivity	0.87832	-0.12964	0.15116
<b>Desire for Self-Improvement</b>	Self-Improve	0.19078	0.49891	0.23297
<b>Appearance</b>		0.05254	0.53846	0.10857
<b>Dependability</b>	Dependable	0.39241	0.50035	0.12032
<b>Physical Ability</b>		0.14404	0.63901	-0.15220
<b>Integrity</b>		0.68277	0.32719	-0.01887

Output 39.6.3 shows the path diagram for the quartimin-rotated factor solution. The path diagram represents correlations among factors by double-headed links or paths. For example, Output 39.6.3 represents the correlation between Factor1 and Factor2 by a curved double-headed link. The numerical value, 0.36, is the correlation between the two factors, as can be verified from the table in Output 39.6.1. Similarly, Output 39.6.3 shows other factor correlations by curved double-headed links.

**Output 39.6.3** Default Path Diagram for the Quartimin-Rotated Solution



The path diagram in [Output 39.6.3](#) also represents factor variances and error variances by double-headed links. However, each of these links points to an individual variable, rather than to a pair of variables as the double-headed links for correlations do. The path diagram also displays the numerical values of factor variances or error variances next to the associated links.

The directed links from factors to variables in the path diagram represent the effects of factors on the variables. The path diagram displays the numerical values of these effects, which are the loading estimates that are shown in [Output 39.6.2](#). However, to aid the interpretation of the factors, the path diagram does not show all factor loadings or their corresponding links. By default, the path diagram displays only the links that have loadings greater than 0.3 in magnitude. For example, instead of associating Factor1 with all variables, the path diagram in [Output 39.6.3](#) displays only five directed links from Factor1 to the variables. The weaker links that have loadings less than 0.3 are not shown.

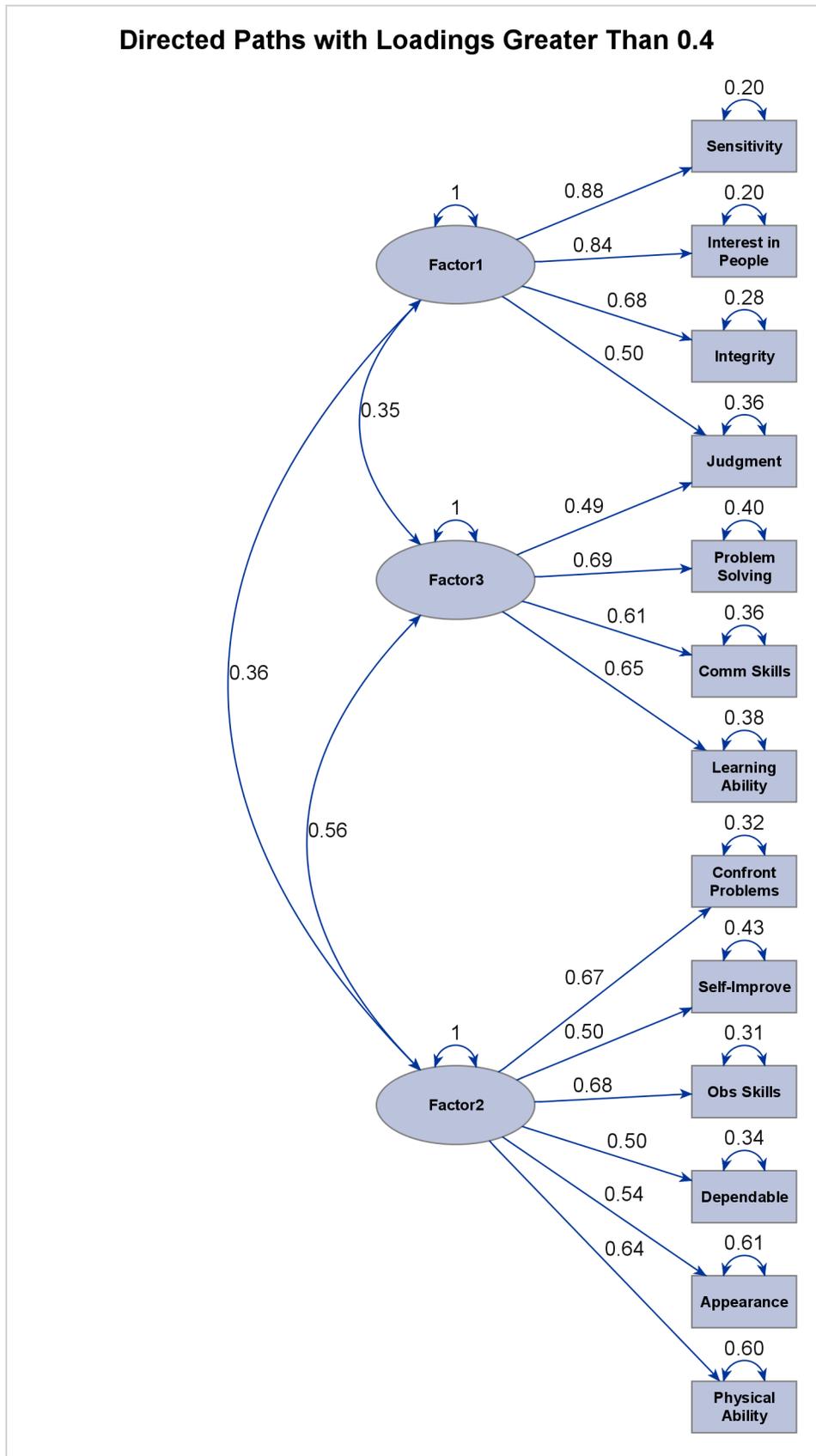
The use of the 0.3 loading value (or greater in magnitude) for relating factors to variables is referred to as the “0.3-rule” in the field of factor analysis. However, this is only a convention, and sometimes you might want to use a different criterion to interpret the factors. For example, the path diagram in [Output 39.6.3](#) shows that variables Dependability, Integrity, and Observational Skills are all associated with more than one factor. Hence, factors might not be interpreted unambiguously.

One way to tackle this interpretation problem is to set a stricter criterion for interpreting factors. You can use the `FUZZ=` option to set such a criterion. For example, you specify the following `PATHDIAGRAM` statement to display only the strong directed links that are associated with a 0.4 or greater magnitude in the loading estimates:

```
pathdiagram fuzz=0.4 title='Directed Paths with Loadings Greater Than 0.4';
```

The preceding statement also uses the `TITLE=` option to specify a customized title for the path diagram. [Output 39.6.4](#) shows the resulting path diagram. In this path diagram, only one observed variable is linked to two factors. All other observed variables link to unique factors. Therefore, compared to the path diagram in [Output 39.6.3](#), the path diagram in [Output 39.6.4](#) provides a much “cleaner” picture for interpreting the factors.

**Output 39.6.4** Path Diagram Showing Strong Links



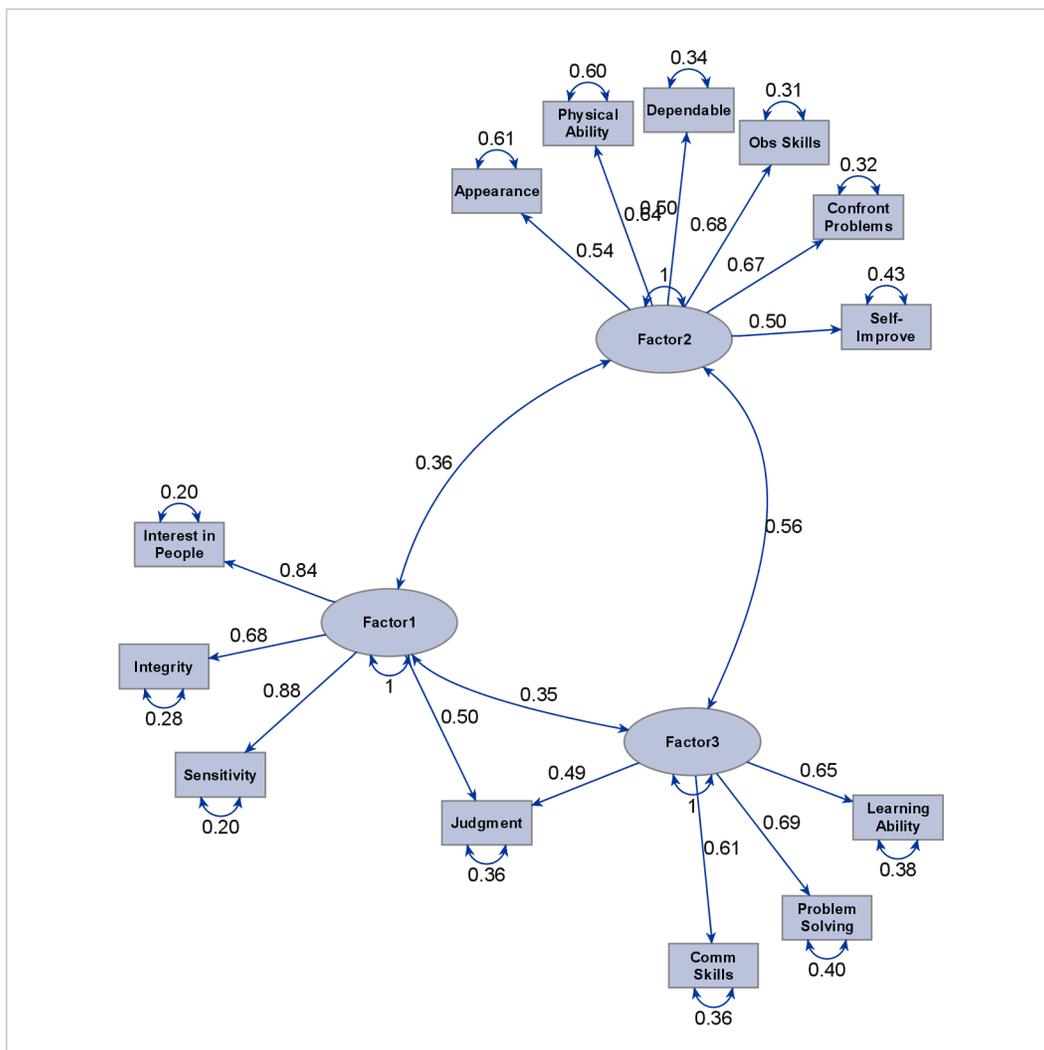
The current example has 13 observed variables in the path diagram. By default, PROC FACTOR uses the process-flow algorithm to lay out the variables. However, when the number of observed variables becomes large, the process-flow algorithm needs a lot of vertical space to align all observed variables in a vertical line. Displaying such a “long” path diagram in limited space (for example, in a page) might compromise the clarity of the path diagram.

To handle this issue, PROC FACTOR switches to the GRIP algorithm when the number of variables is greater than 14. However, you can override the layout algorithm whenever you find it useful to do so. For example, the ARRANGE=GRIP option in the following PATHDIAGRAM statement requests that the GRIP algorithm be used:

```
pathdiagram fuzz=0.4 arrange=grip scale=0.85 notitle;
```

The SCALE= option shrinks the nodes so that the nodes are well-separated in the path diagram. If you do not use this option, some nodes would have been overlapped. The NOTITLE option suppresses the display of the title. Output 39.6.5 shows the resulting path diagram, which spreads out the variables instead of aligning them vertically, as it does when it uses the process-flow algorithm in Output 39.6.4.

**Output 39.6.5** Path Diagram Showing Strong Links by Using the ARRANGE=GRIP Algorithm



For more information about the options for customizing path diagrams, see the PATHDIAGRAM statement.

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