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SAS/STAT® 9.2 User's Guide

The CANCORR Procedure

(Book Excerpt)

SAS® Documentation

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Chapter 26

The CANCORR Procedure

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Overview: CANCORR Procedure

The CANCORR procedure performs canonical correlation, partial canonical correlation, and canonical redundancy analysis.

Canonical correlation is a generalization of multiple correlation for analyzing the relationship between two sets of variables. In multiple correlation, you examine the relationship between a linear combination of a set of explanatory variables, **X**, and a *single* response variable, **Y**. In canonical correlation, you examine the relationship between linear combinations of the set of **X** variables and linear combinations of a *set* of **Y** variables. These linear combinations are called *canonical*

variables or *canonical variates*. Either set of variables can be considered explanatory or response variables, since the statistical model is symmetric in the two sets of variables. Simple and multiple correlation are special cases of canonical correlation in which one or both sets contain a single variable.

The CANCORR procedure tests a series of hypotheses that each canonical correlation and all smaller canonical correlations are zero in the population. PROC CANCORR uses an F approximation (Rao 1973; Kshirsagar 1972) that gives better small sample results than the usual χ^2 approximation. At least one of the two sets of variables should have an approximate multivariate normal distribution in order for the probability levels to be valid.

Both standardized and unstandardized canonical coefficients are computed, as well as the four *canonical structure* matrices showing correlations between the two sets of canonical variables and the two sets of original variables. A canonical redundancy analysis (Stewart and Love 1968; Cooley and Lohnes 1971) can also be done. PROC CANCORR provides multiple regression analysis options to aid in interpreting the canonical correlation analysis. You can examine the linear regression of each variable on the opposite set of variables.

PROC CANCORR can produce a data set containing the scores of each observation on each canonical variable, and you can use the PRINT procedure to list these values. A plot of each canonical variable against its counterpart in the other group is often useful, and you can use PROC SGPLOT with the output data set to produce these plots. A second output data set contains the canonical correlations, coefficients, and most other statistics computed by the procedure.

Background

Canonical correlation was developed by Hotelling (1935, 1936). The application of canonical correlation is discussed by Cooley and Lohnes (1971), Tatsuoka (1971), and Mardia, Kent, and Bibby (1979). One of the best theoretical treatments is given by Kshirsagar (1972).

Given a set of p **X** variables and q **Y** variables, the CANCORR procedure finds the linear combinations

$$w_1 = a_{11}x_1 + a_{21}x_2 + \cdots + a_{p1}x_p$$
$$v_1 = b_{11}y_1 + b_{21}y_2 + \cdots + b_{q1}y_q$$

such that the two canonical variables, w_1 and v_1, have the largest possible correlation. This maximized correlation between the two canonical variables is the first canonical correlation. The coefficients of the linear combinations are canonical coefficients or canonical weights. It is customary to normalize the canonical coefficients so that each canonical variable has a variance of 1.

PROC CANCORR continues by finding a second set of canonical variables, uncorrelated with the first pair, that produces the second-highest correlation coefficient. That is, the second pair of canonical variables is

$$w_2 = a_{12}x_1 + a_{22}x_2 + \cdots + a_{p2}x_p$$
$$v_2 = b_{12}y_1 + b_{22}y_2 + \cdots + b_{q2}y_q$$

such that w_2 is uncorrelated with w_1 and v_1, v_2 is uncorrelated with w_1 and v_1, and w_2 and v_2 have the largest possible correlation subject to these constraints. The process of constructing canonical variables continues until the number of pairs of canonical variables is $\min(p, q)$, the number of variables in the smaller group.

Each canonical variable is uncorrelated with all the other canonical variables of either set except for the one corresponding canonical variable in the opposite set. The canonical coefficients are not generally orthogonal, however, so the canonical variables do not represent jointly perpendicular directions through the space of the original variables.

The first canonical correlation is at least as large as the multiple correlation between any variable and the opposite set of variables. It is possible for the first canonical correlation to be very large while all the multiple correlations for predicting one of the original variables from the opposite set of canonical variables are small. Canonical redundancy analysis (Stewart and Love 1968; Cooley and Lohnes 1971; van den Wollenberg 1977) examines how well the original variables can be predicted from the canonical variables.

PROC CANCORR can also perform partial canonical correlation, which is a multivariate generalization of ordinary partial correlation (Cooley and Lohnes 1971; Timm 1975). Most commonly used parametric statistical methods, ranging from *t* tests to multivariate analysis of covariance, are special cases of partial canonical correlation.

Getting Started: CANCORR Procedure

The following example demonstrates how you can use the CANCORR procedure to calculate and test canonical correlations between two sets of variables.

Suppose you want to determine the degree of correspondence between a set of job characteristics and measures of employee satisfaction. Using a survey instrument for employees, you calculate three measures of job satisfaction. With another instrument designed for supervisors, you calculate the corresponding job characteristics profile.

Your three variables associated with job satisfaction are as follows:

- career track satisfaction: employee satisfaction with career direction and the possibility of future advancement, expressed as a percent
- management and supervisor satisfaction: employee satisfaction with supervisor's communication and management style, expressed as a percent
- financial satisfaction: employee satisfaction with salary and other benefits, using a scale measurement from 1 to 10 (1=unsatisfied, 10=satisfied)

The three variables associated with job characteristics are as follows:

- task variety: degree of variety involved in tasks, expressed as a percent
- feedback: degree of feedback required in job tasks, expressed as a percent
- autonomy: degree of autonomy required in job tasks, expressed as a percent

The following statements create the SAS data set Jobs and request a canonical correlation analysis:

```
data Jobs;
   input Career Supervisor Finance Variety Feedback Autonomy;
   label Career    ='Career Satisfaction' Variety ='Task Variety'
         Supervisor='Supervisor Satisfaction' Feedback='Amount of Feedback'
         Finance   ='Financial Satisfaction' Autonomy='Degree of Autonomy';
   datalines;
72  26  9          10  11  70
63  76  7          85  22  93
96  31  7          83  63  73
96  98  6          82  75  97
84  94  6          36  77  97
66  10  5          28  24  75
31  40  9          64  23  75
45  14  2          19  15  50
42  18  6          33  13  70
79  74  4          23  14  90
39  12  2          37  13  70
54  35  3          23  74  53
60  75  5          45  58  83
63  45  5          22  67  53
;

 proc cancorr data=Jobs
                  vprefix=Satisfaction wprefix=Characteristics
                  vname='Satisfaction Areas' wname='Job Characteristics';
    var  Career Supervisor Finance;
    with Variety Feedback Autonomy;
 run;
```

The DATA= option in the PROC CANCORR statement specifies Jobs as the SAS data set to be analyzed. The VPREFIX and WPREFIX options specify the prefixes for naming the canonical variables from the VAR statement and the WITH statement, respectively. The VNAME option specifies 'Satisfaction Areas' to refer to the set of variables from the VAR statement. Similarly, the WNAME option specifies 'Job Characteristics' to refer to the set of variables from the WITH statement.

The VAR statement defines the first of the two sets of variables to be analyzed as Career, Supervisor, and Finance. The WITH statement defines the second set of variables to be Variety, Feedback, and Autonomy. The results of this analysis are displayed in Figure 26.1 to Figure 26.4.

Figure 26.1 displays the canonical correlation, adjusted canonical correlation, approximate standard error, and squared canonical correlation for each pair of canonical variables. The first canonical

correlation (the correlation between the first pair of canonical variables) is 0.9194. This value represents the highest possible correlation between any linear combination of the job satisfaction variables and any linear combination of the job characteristics variables.

Figure 26.1 also lists the likelihood ratio and associated statistics for testing the hypothesis that the canonical correlations in the current row and all that follow are zero.

Figure 26.1 Canonical Correlations, Eigenvalues, and Likelihood Tests

The CANCORR Procedure

Canonical Correlation Analysis

	Canonical Correlation	Adjusted Canonical Correlation	Approximate Standard Error	Squared Canonical Correlation
1	0.919412	0.898444	0.042901	0.845318
2	0.418649	0.276633	0.228740	0.175267
3	0.113366	.	0.273786	0.012852

Eigenvalues of Inv(E)*H
= CanRsq/(1-CanRsq)

	Eigenvalue	Difference	Proportion	Cumulative
1	5.4649	5.2524	0.9604	0.9604
2	0.2125	0.1995	0.0373	0.9977
3	0.0130		0.0023	1.0000

Test of H0: The canonical correlations in the current row and all that follow are zero

	Likelihood Ratio	Approximate F Value	Num DF	Den DF	Pr > F
1	0.12593148	2.93	9	19.621	0.0223
2	0.81413359	0.49	4	18	0.7450
3	0.98714819	0.13	1	10	0.7257

The first approximate F value of 2.93 corresponds to the test that all three canonical correlations are zero. Since the p-value is small (0.0223), you would reject the null hypothesis at the 0.05 level. The second approximate F value of 0.49 corresponds to the test that both the second and the third canonical correlations are zero. Since the p-value is large (0.7450), you would fail to reject the hypothesis and conclude that only the first canonical correlation is significant.

Figure 26.2 lists several multivariate statistics and tests that use approximations based on the F distribution for the null hypothesis that all canonical correlations are zero. Alternatively, you can specify MSTAT=EXACT to compute exact p-values for three of the four tests (Wilks' Lambda, the Hotelling-Lawley Trace, and Roy's greatest root) and an improved F approximation for the fourth (Pillai's Trace). These statistics are described in the section "Multivariate Tests" on page 102 in Chapter 4, "Introduction to Regression Procedures."

Figure 26.2 Multivariate Statistics and F Approximations

Multivariate Statistics and F Approximations

S=3 M=-0.5 N=3

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.12593148	2.93	9	19.621	0.0223
Pillai's Trace	1.03343732	1.75	9	30	0.1204
Hotelling-Lawley Trace	5.69042615	4.76	9	9.8113	0.0119
Roy's Greatest Root	5.46489324	18.22	3	10	0.0002

NOTE: F Statistic for Roy's Greatest Root is an upper bound.

The small p-values for these tests (< 0.05), except for Pillai's trace, suggest rejecting the null hypothesis that all canonical correlations are zero in the population, confirming the results of the preceding likelihood ratio test (Figure 26.1). With only one of the tests resulting in a p-value larger than 0.05, you can assume that the first canonical correlation is significant. The next step is to interpret or identify the two canonical variables corresponding to this significant correlation.

Even though canonical variables are artificial, they can often be "identified" in terms of the original variables. This is done primarily by inspecting the standardized coefficients of the canonical variables and the correlations between the canonical variables and their original variables. Since only the first canonical correlation is significant, only the first pair of canonical variables (Satisfaction1 and Characteristics1) need to be identified.

PROC CANCORR calculates and displays the raw canonical coefficients for the job satisfaction variables and the job characteristic variables. However, since the original variables do not necessarily have equal variance and are not measured in the same units, the raw coefficients must be standardized to allow interpretation. The coefficients are standardized by multiplying the raw coefficients with the standard deviation of the associated variable.

The standardized canonical coefficients in Figure 26.3 show that the first canonical variable for the Satisfaction group is a weighted sum of the variables Supervisor (0.7854) and Career (0.3028), with the emphasis on Supervisor. The coefficient for the variable Finance is near 0. Thus, a person satisfied with his or her supervisor and with a large degree of career satisfaction would score high on the canonical variable Satisfaction1.

Figure 26.3 Standardized Canonical Coefficients from the CANCORR Procedure

Standardized Canonical Coefficients for the Satisfaction Areas

		Satisfaction1	Satisfaction2	Satisfaction3
Career	Career Satisfaction	0.3028	-0.5416	1.0408
Supervisor	Supervisor Satisfaction	0.7854	0.1305	-0.9085
Finance	Financial Satisfaction	0.0538	0.9754	0.3329

Figure 26.3 *continued*

Standardized Canonical Coefficients for the Job Characteristics

		Characteristics1	Characteristics2
Variety	Task Variety	-0.1108	0.8095
Feedback	Amount of Feedback	0.5520	-0.7722
Autonomy	Degree of Autonomy	0.8403	0.1020

Standardized Canonical Coefficients for the Job Characteristics

		Characteristics3
Variety	Task Variety	0.9071
Feedback	Amount of Feedback	0.4194
Autonomy	Degree of Autonomy	-0.8297

The coefficients for the job characteristics variables show that degree of autonomy (Autonomy) and amount of feedback (Feedback) contribute heavily to the Characteristics1 canonical variable (0.8403 and 0.5520, respectively).

Figure 26.4 shows the table of correlations between the canonical variables and the original variables.

Figure 26.4 Canonical Structure Correlations from the CANCORR Procedure

The CANCORR Procedure

Canonical Structure

Correlations Between the Satisfaction Areas and Their Canonical Variables

		Satisfaction1	Satisfaction2	Satisfaction3
Career	Career Satisfaction	0.7499	-0.2503	0.6123
Supervisor	Supervisor Satisfaction	0.9644	0.0362	-0.2618
Finance	Financial Satisfaction	0.2873	0.8814	0.3750

Correlations Between the Job Characteristics and Their Canonical Variables

		Characteristics1	Characteristics2
Variety	Task Variety	0.4863	0.6592
Feedback	Amount of Feedback	0.6216	-0.5452
Autonomy	Degree of Autonomy	0.8459	0.4451

Correlations Between the Job Characteristics and Their Canonical Variables

		Characteristics3
Variety	Task Variety	0.5736
Feedback	Amount of Feedback	0.5625
Autonomy	Degree of Autonomy	-0.2938

Figure 26.4 *continued*

Correlations Between the Satisfaction Areas and the Canonical Variables of the Job Characteristics

		Characteristics1	Characteristics2
Career	Career Satisfaction	0.6895	−0.1048
Supervisor	Supervisor Satisfaction	0.8867	0.0152
Finance	Financial Satisfaction	0.2642	0.3690

Correlations Between the Satisfaction Areas and the Canonical Variables of the Job Characteristics

		Characteristics3
Career	Career Satisfaction	0.0694
Supervisor	Supervisor Satisfaction	−0.0297
Finance	Financial Satisfaction	0.0425

Correlations Between the Job Characteristics and the Canonical Variables of the Satisfaction Areas

		Satisfaction1	Satisfaction2	Satisfaction3
Variety	Task Variety	0.4471	0.2760	0.0650
Feedback	Amount of Feedback	0.5715	−0.2283	0.0638
Autonomy	Degree of Autonomy	0.7777	0.1863	−0.0333

Although these univariate correlations must be interpreted with caution since they do not indicate how the original variables contribute *jointly* to the canonical analysis, they are often useful in the identification of the canonical variables.

Figure 26.4 shows that the supervisor satisfaction variable Supervisor is strongly associated with the Satisfaction1 canonical variable, with a correlation of 0.9644. Slightly less influential is the variable Career, which has a correlation with the canonical variable of 0.7499. Thus, the canonical variable Satisfaction1 seems to represent satisfaction with supervisor and career track.

The correlations for the job characteristics variables show that the canonical variable Characteristics1 seems to represent all three measured variables, with degree of autonomy variable (Autonomy) being the most influential (0.8459).

Hence, you can interpret these results to mean that job characteristics and job satisfaction are related—jobs that possess a high degree of autonomy and level of feedback are associated with workers who are more satisfied with their supervisor and their career. While financial satisfaction is a factor in job satisfaction, it is not as important as the other measured satisfaction-related variables.

Syntax: CANCORR Procedure

The following statements are available in PROC CANCORR:

PROC CANCORR < *options* > ;
  WITH *variables* ;
  BY *variables* ;
  FREQ *variable* ;
  PARTIAL *variables* ;
  VAR *variables* ;
  WEIGHT *variable* ;

The PROC CANCORR statement and the WITH statement are required. The rest of this section provides detailed syntax information for each of the preceding statements, beginning with the PROC CANCORR statement. The remaining statements are covered in alphabetical order.

PROC CANCORR Statement

PROC CANCORR < *options* > ;

The PROC CANCORR statement starts the CANCORR procedure and optionally identifies input and output data sets, specifies the analyses performed, and controls displayed output. Table 26.1 summarizes the options.

Table 26.1 Summary of PROC CANCORR Statement Options

Option	Description
Specify computational details	
EDF=	specifies error degrees of freedom if input observations are regression residuals
MSTAT=	specifies the method of evaluating the multivariate test statistics
NOINT	omits intercept from canonical correlation and regression models
RDF=	specifies regression degrees of freedom if input observations are regression residuals
SINGULAR=	specifies the singularity criterion
Specify input and output data sets	
DATA=	specifies input data set name
OUT=	specifies output data set name
OUTSTAT=	specifies output data set name containing various statistics
Specify labeling options	
PARPREFIX=	specifies a prefix for naming residual variables
VNAME=	specifies a name to refer to VAR statement variables
VPREFIX=	specifies a prefix for naming VAR statement canonical variables

Table 26.1 *continued*

Option	Description
WNAME=	specifies a name to refer to WITH statement variables
WPREFIX=	specifies a prefix for naming WITH statement canonical variables
Control amount of output	
ALL	produces simple statistics, input variable correlations, and canonical redundancy analysis
CORR	produces input variable correlations
NCAN=	specifies number of canonical variables for which full output is desired
NOPRINT	suppresses all displayed output
REDUNDANCY	produces canonical redundancy analysis
SHORT	suppresses default output from canonical analysis
SIMPLE	produces means and standard deviations
Request regression analyses	
VDEP	requests multiple regression analyses with the VAR variables as dependents and the WITH variables as regressors
VREG	requests multiple regression analyses with the VAR variables as regressors and the WITH variables as dependents
WDEP	same as VREG
WREG	same as VDEP
Specify regression statistics	
ALL	produces all regression statistics and includes these statistics in the OUTSTAT= data set
B	produces raw regression coefficients
CLB	produces 95% confidence interval limits for the regression coefficients
CORRB	produces correlations among regression coefficients
INT	requests statistics for the intercept when you specify the B, CLB, SEB, T, or PROBT option
PCORR	displays partial correlations between regressors and dependents
PROBT	displays probability levels for t statistics
SEB	displays standard errors of regression coefficients
SMC	displays squared multiple correlations and F tests
SPCORR	displays semipartial correlations between regressors and dependents
SQPCORR	displays squared partial correlations between regressors and dependents
SQSPCORR	displays squared semipartial correlations between regressors and dependents
TB	displays standardized regression coefficients
T	displays t statistics for regression coefficients

Following are explanations of the options that can be used in the PROC CANCORR statement (in alphabetic order).

ALL

displays simple statistics, correlations among the input variables, the confidence limits for the regression coefficients, and the canonical redundancy analysis. If you specify the VDEP or WDEP option, the ALL option displays all related regression statistics (unless the NOPRINT option is specified) and includes these statistics in the OUTSTAT= data set.

B

produces raw regression coefficients from the regression analyses.

CLB

produces the 95% confidence limits for the regression coefficients from the regression analyses.

CORR

C

produces correlations among the original variables. If you include a PARTIAL statement, the CORR option produces a correlation matrix for all variables in the analysis, the regression statistics (R square, RMSE), the standardized regression coefficients for both the VAR and WITH variables as predicted from the PARTIAL statement variables, and partial correlation matrices.

CORRB

produces correlations among the regression coefficient estimates.

DATA=*SAS-data-set*

names the SAS data set to be analyzed by PROC CANCORR. It can be an ordinary SAS data set or a TYPE=CORR, COV, FACTOR, SSCP, UCORR, or UCOV data set. By default, the procedure uses the most recently created SAS data set.

EDF=*error-df*

specifies the error degrees of freedom if the input observations are residuals from a regression analysis. The effective number of observations is the EDF= value plus one. If you have 100 observations, then specifying EDF=99 has the same effect as omitting the EDF= option.

INT

requests that statistics for the intercept be included when B, CLB, SEB, T, or PROBT is specified for the regression analyses.

MSTAT=FAPPROX | EXACT

specifies the method of evaluating the multivariate test statistics. The default is MSTAT=FAPPROX, which specifies that the multivariate tests are evaluated using the usual approximations based on the F distribution, as discussed in the section "Multivariate Tests" on page 102 in Chapter 4, "Introduction to Regression Procedures." Alternatively, you can specify MSTAT=EXACT to compute exact p-values for three of the four tests (Wilks' lambda, the Hotelling-Lawley trace, and Roy's greatest root) and an improved F approximation for the fourth (Pillai's trace). While MSTAT=EXACT provides better control of the

significance probability for the tests, especially for Roy's greatest root, computations for the exact *p*-values can be appreciably more demanding, and are in fact infeasible for large problems (many dependent variables). Thus, although MSTAT=EXACT is more accurate for most data, it is not the default method.

NCAN=*number*

specifies the number of canonical variables for which full output is desired. The *number* must be less than or equal to the number of canonical variables in the analysis.

The value of the NCAN= option specifies the number of canonical variables for which canonical coefficients and canonical redundancy statistics are displayed, and the number of variables shown in the canonical structure matrices. The NCAN= option does not affect the number of displayed canonical correlations.

If an OUTSTAT= data set is requested, the NCAN= option controls the number of canonical variables for which statistics are output. If an OUT= data set is requested, the NCAN= option controls the number of canonical variables for which scores are output.

NOINT

omits the intercept from the canonical correlation and regression models. Standard deviations, variances, covariances, and correlations are not corrected for the mean. If you use a TYPE=SSCP data set as input to the CANCORR procedure and list the variable Intercept in the VAR or WITH statement, the procedure runs as if you also specified the NOINT option. If you use NOINT and also create an OUTSTAT= data set, the data set is TYPE=UCORR.

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."

OUT=*SAS-data-set*

creates an output SAS data set to contain all the original data plus scores on the canonical variables. If you want to create a permanent SAS data set, you must specify a two-level name. The OUT= option cannot be used when the DATA= data set is TYPE=CORR, COV, FACTOR, SSCP, UCORR, or UCOV. For details about OUT= data sets, see the section "Output Data Sets" on page 1046. See *SAS Language Reference: Concepts* for more information about permanent SAS data sets.

OUTSTAT=*SAS-data-set*

creates an output SAS data set containing various statistics, including the canonical correlations and coefficients and the multiple regression statistics you request. If you want to create a permanent SAS data set, you must specify a two-level name. For details about OUTSTAT= data sets, see the section "Output Data Sets" on page 1046. See *SAS Language Reference: Concepts* for more information about permanent SAS data sets.

PCORR

produces partial correlations between regressors and dependent variables, removing from each dependent variable and regressor the effects of all other regressors.

PROBT

produces probability levels for the t statistics in the regression analyses.

RDF=*regression-df*

specifies the regression degrees of freedom if the input observations are residuals from a regression analysis. The effective number of observations is the actual number minus the RDF= value. The degrees of freedom for the intercept should not be included in the RDF= option.

REDUNDANCY

RED

produces canonical redundancy statistics.

PARPREFIX=*name*

PPREFIX=*name*

specifies a prefix for naming the residual variables in the OUT= data set and the OUTSTAT= data set. By default, the prefix is R_. The number of characters in the prefix plus the maximum length of the variable names should not exceed the current name length defined by the VALIDVARNAME= system option.

SEB

produces standard errors of the regression coefficients.

SHORT

suppresses all default output from the canonical analysis except the tables of canonical correlations and multivariate statistics.

SIMPLE

S

produces means and standard deviations.

SINGULAR=*p*

SING=*p*

specifies the singularity criterion, where $0 < p < 1$. If a variable in the PARTIAL statement has an R square as large as $1 - p$ (where p is the value of the SINGULAR= option) when predicted from the variables listed before it in the statement, the variable is assigned a standardized regression coefficient of 0, and the SAS log generates a linear dependency warning message. By default, SINGULAR=1E−8.

SMC

produces squared multiple correlations and F tests for the regression analyses.

SPCORR

produces semipartial correlations between regressors and dependent variables, removing from each regressor the effects of all other regressors.

SQPCORR

produces squared partial correlations between regressors and dependent variables, removing from each dependent variable and regressor the effects of all other regressors.

SQSPCORR

produces squared semipartial correlations between regressors and dependent variables, removing from each regressor the effects of all other regressors.

STB

produces standardized regression coefficients.

T

produces *t* statistics for the regression coefficients.

VDEP

WREG

requests multiple regression analyses with the VAR variables as dependent variables and the WITH Variables as regressors.

VNAME=*label*

VN=*label*

specifies a character constant to refer to variables from the VAR statement in the output. Enclose the constant in single or double quotes. If you omit the VNAME= option, these variables are referred to as the VAR variables. The number of characters in the label should not exceed the label length defined by the VALIDVARNAME= system option. For more information about the VALIDVARNAME= system option, see *SAS Language Reference: Dictionary*.

VPREFIX=*name*

VP=*name*

specifies a prefix for naming canonical variables from the VAR statement. By default, these canonical variables are given the names V1, V2, and so on. If you specify VPREFIX=ABC, the names are ABC1, ABC2, and so on. The number of characters in the prefix plus the number of digits required to designate the variables should not exceed the name length defined by the VALIDVARNAME= system option. For more information about the VALIDVARNAME= system option, see *SAS Language Reference: Dictionary*.

WDEP

VREG

requests multiple regression analyses with the WITH variables as dependent variables and the VAR variables as regressors.

WNAME=*label*

WN=*label*

specifies a character constant to refer to variables in the WITH statement in the output. Enclose the constant in single or double quotes. If you omit the WNAME= option, these variables are referred to as the WITH variables. The number of characters in the label should not exceed the label length defined by the VALIDVARNAME= system option. For more information about the VALIDVARNAME= system option, see *SAS Language Reference: Dictionary*.

WPREFIX=*name*

WP=*name*

specifies a prefix for naming canonical variables from the WITH statement. By default, these canonical variables are given the names W1, W2, and so on. If you specify WPREFIX=XYZ, the names are XYZ1, XYZ2, and so on. The number of characters in the prefix plus the number of digits required to designate the variables should not exceed the label length defined by the VALIDVARNAME= system option. For more information about the VALIDVARNAME= system option, see *SAS Language Reference: Dictionary*.

BY Statement

BY *variables* **;**

You can specify a BY statement with PROC CANCORR to obtain separate analyses on observations in groups 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 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 BY statement option NOTSORTED or DESCENDING in the BY statement for PROC CANCORR. 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.

For more information about the BY statement, *SAS Language Reference: Concepts*. For more information about the DATASETS procedure, see the *Base SAS Procedures Guide*.

FREQ Statement

FREQ *variable* **;**

If one variable in your input data set represents the frequency of occurrence for other values in the observation, specify the variable's name in a FREQ statement. PROC CANCORR then treats the data set as if each observation appeared n times, where n is the value of the FREQ variable for the observation. If the value of the FREQ variable is less than one, the observation is not used in the analysis. Only the integer portion of the value is used. The total number of observations is considered to be equal to the sum of the FREQ variable when PROC CANCORR calculates significance probabilities.

PARTIAL Statement

PARTIAL *variables* **;**

You can use the PARTIAL statement to base the canonical analysis on partial correlations. The variables in the PARTIAL statement are partialed out of the VAR and WITH variables. If you request an OUT= or OUTSTAT= data set, the residual variables are named by prefixing the characters R_ by default or the string specified in the RPREFIX= option to the VAR variables.

VAR Statement

VAR *variables* **;**

The VAR statement lists the variables in the first of the two sets of variables to be analyzed. The variables must be numeric. If you omit the VAR statement, all numeric variables not mentioned in other statements make up the first set of variables. If, however, the DATA= data set is TYPE=SSCP, the default set of variables used as VAR variables does not include the variable Intercept.

WEIGHT Statement

WEIGHT *variable* **;**

If you want to compute weighted product-moment correlation coefficients, specify the name of the weighting variable in a WEIGHT statement. The WEIGHT and FREQ statements have a similar effect, except the WEIGHT statement does not alter the degrees of freedom or number of observations. An observation is used in the analysis only if the WEIGHT variable is greater than zero.

WITH Statement

WITH *variables* **;**

The WITH statement lists the variables in the second set of variables to be analyzed. The variables must be numeric. The WITH statement is required.

Details: CANCORR Procedure

Missing Values

If an observation has a missing value for any of the variables in the analysis, that observation is omitted from the analysis.

Formulas

Assume without loss of generality that the two sets of variables, $\mathbf{X}$ with p variables and $\mathbf{Y}$ with q variables, have means of zero. Let n be the number of observations, and let m be $n-1$.

Note that the scales of eigenvectors and canonical coefficients are arbitrary. PROC CANCORR follows the usual procedure of rescaling the canonical coefficients so that each canonical variable has a variance of one.

There are several different sets of formulas that can be used to compute the canonical correlations, $\rho_i, i = 1, \ldots, \min(p, q)$, and unscaled canonical coefficients:

1. Let $\mathbf{S}_{XX} = \mathbf{X}'\mathbf{X}/m$ be the covariance matrix of $\mathbf{X}$, $\mathbf{S}_{YY} = \mathbf{Y}'\mathbf{Y}/m$ be the covariance matrix of $\mathbf{Y}$, and $\mathbf{S}_{XY} = \mathbf{X}'\mathbf{Y}/m$ be the covariance matrix between $\mathbf{X}$ and $\mathbf{Y}$. Then the eigenvalues of $\mathbf{S}_{YY}^{-1}\mathbf{S}_{XY}'\mathbf{S}_{XX}^{-1}\mathbf{S}_{XY}$ are the squared canonical correlations, and the right eigenvectors are raw canonical coefficients for the $\mathbf{Y}$ variables. The eigenvalues of $\mathbf{S}_{XX}^{-1}\mathbf{S}_{XY}\mathbf{S}_{YY}^{-1}\mathbf{S}_{XY}'$ are the squared canonical correlations, and the right eigenvectors are raw canonical coefficients for the $\mathbf{X}$ variables.

2. Let $\mathbf{T} = \mathbf{Y}'\mathbf{Y}$ and $\mathbf{H} = \mathbf{Y}'\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{Y}$. The eigenvalues ξ_i of $\mathbf{T}^{-1}\mathbf{H}$ are the squared canonical correlations, ρ_i^2, and the right eigenvectors are raw canonical coefficients for the $\mathbf{Y}$ variables. Interchange $\mathbf{X}$ and $\mathbf{Y}$ in the preceding formulas, and the eigenvalues remain the same, but the right eigenvectors are raw canonical coefficients for the $\mathbf{X}$ variables.

3. Let $\mathbf{E} = \mathbf{T} - \mathbf{H}$. The eigenvalues of $\mathbf{E}^{-1}\mathbf{H}$ are $\lambda_i = \rho_i^2/(1-\rho_i^2)$. The right eigenvectors of $\mathbf{E}^{-1}\mathbf{H}$ are the same as the right eigenvectors of $\mathbf{T}^{-1}\mathbf{H}$.

4. Canonical correlation can be viewed as a principal component analysis of the predicted values of one set of variables from a regression on the other set of variables, in the metric of the error covariance matrix. For example, regress the $\mathbf{Y}$ variables on the $\mathbf{X}$ variables. Call the predicted values $\mathbf{P} = \mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{Y}$ and the residuals $\mathbf{R} = \mathbf{Y} - \mathbf{P} = (\mathbf{I} - \mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}')\mathbf{Y}$. The error covariance matrix is $\mathbf{R}'\mathbf{R}/m$. Choose a transformation $\mathbf{Q}$ that converts the error covariance matrix to an identity—that is, $(\mathbf{RQ})'(\mathbf{RQ}) = \mathbf{Q}'\mathbf{R}'\mathbf{RQ} = m\mathbf{I}$. Apply the same transformation to the predicted values to yield, say, $\mathbf{Z} = \mathbf{PQ}$. Now do a principal component analysis on the covariance matrix of $\mathbf{Z}$, and you get the eigenvalues of $\mathbf{E}^{-1}\mathbf{H}$. Repeat with $\mathbf{X}$ and $\mathbf{Y}$ variables interchanged, and you get the same eigenvalues.

   To show this relationship between canonical correlation and principal components, note that $\mathbf{P}'\mathbf{P} = \mathbf{H}$, $\mathbf{R}'\mathbf{R} = \mathbf{E}$, and $\mathbf{QQ}' = m\mathbf{E}^{-1}$. Let the covariance matrix of $\mathbf{Z}$ be $\mathbf{G}$. Then $\mathbf{G} = \mathbf{Z}'\mathbf{Z}/m = (\mathbf{PQ})'\mathbf{PQ}/m = \mathbf{Q}'\mathbf{P}'\mathbf{PQ}/m = \mathbf{Q}'\mathbf{HQ}/m$. Let $\mathbf{u}$ be an eigenvector of $\mathbf{G}$ and κ be the corresponding eigenvalue. Then by definition, $\mathbf{Gu} = \kappa\mathbf{u}$; hence $\mathbf{Q}'\mathbf{HQu}/m = \kappa\mathbf{u}$. Premultiplying both sides by $\mathbf{Q}$ yields $\mathbf{QQ}'\mathbf{HQu}/m = \kappa\mathbf{Qu}$ and thus $\mathbf{E}^{-1}\mathbf{HQu} = \kappa\mathbf{Qu}$. Hence $\mathbf{Qu}$ is an eigenvector of $\mathbf{E}^{-1}\mathbf{H}$ and κ is also an eigenvalue of $\mathbf{E}^{-1}\mathbf{H}$.

5. If the covariance matrices are replaced by correlation matrices, the preceding formulas yield standardized canonical coefficients instead of raw canonical coefficients.

The formulas for multivariate test statistics are shown in the section "Multivariate Tests" on page 102 in Chapter 4, "Introduction to Regression Procedures." Formulas for linear regression are provided in other sections of that chapter.

Output Data Sets

OUT= Data Set

The OUT= data set contains all the variables in the original data set plus new variables containing the canonical variable scores. The number of new variables is twice that specified by the NCAN= option. The names of the new variables are formed by concatenating the values given by the VPREFIX= and WPREFIX= options (the defaults are V and W) with the numbers 1, 2, 3, and so on. The new variables have mean 0 and variance equal to 1. An OUT= data set cannot be created if the DATA= data set is TYPE=CORR, COV, FACTOR, SSCP, UCORR, or UCOV.

If you use a PARTIAL statement, the OUT= data set also contains the residuals from predicting the VAR variables from the PARTIAL variables. The names of the residual variables are formed by concatenating the values given by the PARPREFIX= option (the default is R_) with the numbers 1, 2, 3, and so on.

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 contains several results in addition to those produced by PROC CORR.

The new data set contains the following variables:

- the BY variables, if any
- two new character variables, _TYPE_ and _NAME_
- Intercept, if the INT option is used
- the variables analyzed (those in the VAR statement and the WITH statement)

Each observation in the new data set contains some type of statistic as indicated by the _TYPE_ variable. The values of the _TYPE_ variable are as follows.

TYPE	
MEAN	means
STD	standard deviations
USTD	uncorrected standard deviations. When you specify the NOINT option in the PROC CANCORR statement, the OUTSTAT= data set contains standard deviations not corrected for the mean (_TYPE_='USTD').

N	number of observations on which the analysis is based. This value is the same for each variable.
SUMWGT	sum of the weights if a WEIGHT statement is used. This value is the same for each variable.
CORR	correlations. The _NAME_ variable contains the name of the variable corresponding to each row of the correlation matrix.
UCORR	uncorrected correlation matrix. When you specify the NOINT option in the PROC CANCORR statement, the OUTSTAT= data set contains a matrix of correlations not corrected for the means.
CORRB	correlations among the regression coefficient estimates
STB	standardized regression coefficients. The _NAME_ variable contains the name of the dependent variable.
B	raw regression coefficients
SEB	standard errors of the regression coefficients
LCLB	95% lower confidence limits for the regression coefficients
UCLB	95% upper confidence limits for the regression coefficients
T	t statistics for the regression coefficients
PROBT	probability levels for the t statistics
SPCORR	semipartial correlations between regressors and dependent variables
SQSPCORR	squared semipartial correlations between regressors and dependent variables
PCORR	partial correlations between regressors and dependent variables
SQPCORR	squared partial correlations between regressors and dependent variables
RSQUARED	R squares for the multiple regression analyses
ADJRSQ	adjusted R squares
LCLRSQ	approximate 95% lower confidence limits for the R squares
UCLRSQ	approximate 95% upper confidence limits for the R squares
F	F statistics for the multiple regression analyses
PROBF	probability levels for the F statistics
CANCORR	canonical correlations
SCORE	standardized canonical coefficients. The _NAME_ variable contains the name of the canonical variable. To obtain the canonical variable scores, these coefficients should be multiplied by the standardized data, using means obtained from the observation with _TYPE_='MEAN' and standard deviations obtained from the observation with _TYPE_='STD'.
RAWSCORE	raw canonical coefficients. To obtain the canonical variable scores, these coefficients should be multiplied by the raw data centered by means obtained from the observation with _TYPE_='MEAN'.

USCORE	scoring coefficients to be applied without subtracting the mean from the raw variables. These are standardized canonical coefficients computed under a NOINT model. To obtain the canonical variable scores, these coefficients should be multiplied by the data that are standardized by the uncorrected standard deviations obtained from the observation with _TYPE_='USTD'.
STRUCTUR	canonical structure.

Computational Resources

Notation

Let

$$
\begin{aligned}
n &= \text{number of observations} \\
v &= \text{number of variables} \\
w &= \text{number of WITH variables} \\
p &= \max(v, w) \\
q &= \min(v, w) \\
b &= v + w \\
t &= \text{total number of variables (VAR, WITH, and PARTIAL)}
\end{aligned}
$$

Time Requirements

The time required to compute the correlation matrix is roughly proportional to

$$n(p+q)^2$$

The time required for the canonical analysis is roughly proportional to

$$\frac{1}{6}p^3 + p^2q + \frac{3}{2}pq^2 + 5q^3$$

but the coefficient for q^3 varies depending on the number of QR iterations in the singular value decomposition.

Memory Requirements

The minimum memory required is approximately

$$4(v^2 + w^2 + t^2)$$

bytes. Additional memory is required if you request the VDEP or WDEP option.

Displayed Output

If the SIMPLE option is specified, PROC CANCORR produces means and standard deviations for each input variable. If the CORR option is specified, PROC CANCORR produces correlations among the input variables. Unless the NOPRINT option is specified, PROC CANCORR displays a table of canonical correlations containing the following:

- Canonical Correlations. These are always nonnegative.
- Adjusted Canonical Correlations (Lawley 1959), which are asymptotically less biased than the raw correlations and can be negative. The adjusted canonical correlations might not be computable, and they are displayed as missing values if two canonical correlations are nearly equal or if some are close to zero. A missing value is also displayed if an adjusted canonical correlation is larger than a previous adjusted canonical correlation.
- Approx Standard Errors, which are the approximate standard errors of the canonical correlations
- Squared Canonical Correlations
- Eigenvalues of INV(E)*H, which are equal to CanRsq/(1−CanRsq), where CanRsq is the corresponding squared canonical correlation. Also displayed for each eigenvalue is the Difference from the next eigenvalue, the Proportion of the sum of the eigenvalues, and the Cumulative proportion.
- Likelihood Ratio for the hypothesis that the current canonical correlation and all smaller ones are zero in the population. The likelihood ratio for all canonical correlations equals Wilks' lambda.
- Approx F statistic based on Rao's approximation to the distribution of the likelihood ratio (Rao 1973, p. 556; Kshirsagar 1972, p. 326)
- Num DF and Den DF (numerator and denominator degrees of freedom) and Pr $> F$ (probability level) associated with the F statistic

Unless you specify the NOPRINT option, PROC CANCORR produces a table of multivariate statistics for the null hypothesis that all canonical correlations are zero in the population. These statistics, as described in the section "Multivariate Tests" on page 102 in Chapter 4, "Introduction to Regression Procedures," are as follows:

- Wilks' lambda
- Pillai's trace
- Hotelling-Lawley trace
- Roy's greatest root

For each of the preceding statistics, PROC CANCORR displays the following, depending on the specification of the MSTAT= option.

If you specify MSTAT=FAPPROX (also the default value), the following statistics are displayed:

- an F approximation or upper bound
- Num DF, the numerator degrees of freedom
- Den DF, the denominator degrees of freedom
- Pr $> F$, the probability level

If you specify MSTAT=EXACT, the following statistic is displayed:

- a t value

Unless you specify the SHORT or NOPRINT option, PROC CANCORR displays the following:

- both Raw (unstandardized) and Standardized Canonical Coefficients normalized to give canonical variables with unit variance. Standardized coefficients can be used to compute canonical variable scores from the standardized (zero mean and unit variance) input variables. Raw coefficients can be used to compute canonical variable scores from the input variables without standardizing them.
- all four Canonical Structure matrices, giving Correlations Between the canonical variables and the original variables

If you specify the REDUNDANCY option, PROC CANCORR displays the following:

- the Canonical Redundancy Analysis (Stewart and Love 1968; Cooley and Lohnes 1971), including Raw (unstandardized) and Standardized Variance and Cumulative Proportion of the Variance of each set of variables Explained by Their Own Canonical Variables and Explained by The Opposite Canonical Variables
- the Squared Multiple Correlations of each variable with the first m canonical variables of the opposite set, where m varies from 1 to the number of canonical correlations

If you specify the VDEP option, PROC CANCORR performs multiple regression analyses with the VAR variables as dependent variables and the WITH variables as regressors. If you specify the WDEP option, PROC CANCORR performs multiple regression analyses with the WITH variables as dependent variables and the VAR variables as regressors. If you specify the VDEP or WDEP option and also specify the ALL option, PROC CANCORR displays the following items. You can also specify individual options to request a subset of the output generated by the ALL option; or you can suppress the output by specifying the NOPRINT option.

SMC	Squared Multiple Correlations and F Tests. For each regression model, identified by its dependent variable name, PROC CANCORR displays the R square, Adjusted R square (Wherry 1931), F Statistic, and Pr $> F$. Also for each regression model, PROC CANCORR displays an Approximate 95% Confidence Interval for the population R square (Helland 1987). These confidence limits are valid only when the regressors are random and when the regressors and dependent variables are approximately distributed according to a multivariate normal distribution. The average R squares for the models considered, unweighted and weighted by variance, are also given.
CORRB	Correlations Among the Regression Coefficient Estimates
STB	Standardized Regression Coefficients
B	Raw Regression Coefficients
SEB	Standard Errors of the Regression Coefficients
CLB	95% confidence limits for the regression coefficients
T	T Statistics for the Regression Coefficients
PROBT	Probability > |T| for the Regression Coefficients
SPCORR	Semipartial Correlations between regressors and dependent variables, Removing from Each Regressor the Effects of All Other Regressors
SQSPCORR	Squared Semipartial Correlations between regressors and dependent variables, Removing from Each Regressor the Effects of All Other Regressors
PCORR	Partial Correlations between regressors and dependent variables, Removing the Effects of All Other Regressors from Both Regressor and Criterion
SQPCORR	Squared Partial Correlations between regressors and dependent variables, Removing the Effects of All Other Regressors from Both Regressor and Criterion

ODS Table Names

PROC CANCORR 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 Table 26.2.

For more information about ODS, see Chapter 20, "Using the Output Delivery System."

All of the tables in Table 26.2 are created with the specification of the PROC CANCORR statement; a few tables need an additional PARTIAL statement.

Table 26.2 ODS Tables Produced by PROC CANCORR

ODS Table Name	Description	Statement and Option
AvgRSquare	Average R squares (weighted and unweighted)	VDEP, WDEP, SMC, or ALL
CanCorr	Canonical correlations	default
CanStructureVCan	Correlations between the VAR canonical variables and the VAR and WITH variables	default (if SHORT is not specified)
CanStructureWCan	Correlations between the WITH canonical variables and the WITH and VAR variables	default (if SHORT is not specified)
ConfidenceLimits	95% confidence limits for the regression coefficients	VDEP, WDEP, CLB, or ALL
Corr	Correlations among the original variables	CORR or ALL
CorrOnPartial	Partial correlations	PARTIAL statement with CORR or ALL
CorrRegCoefEst	Correlations among the regression coefficient estimates	VDEP, WDEP, CORRB, or ALL
MultStat	Multivariate statistics	default
NObsNVar	Number of observations and variables	SIMPLE or ALL
ParCorr	Partial correlations	VDEP, WDEP, PCORR, or ALL
ProbtRegCoef	Prob > |t| for the regression coefficients	VDEP, WDEP, PROBT, or ALL
RawCanCoefV	Raw canonical coefficients for the VAR variables	default (if SHORT is not specified)
RawCanCoefW	Raw canonical coefficients for the WITH variables	default (if SHORT is not specified)
RawRegCoef	Raw regression coefficients	VDEP, WDEP, B, or ALL
Redundancy	Canonical redundancy analysis	REDUNDANCY or ALL
Regression	Squared multiple correlations and F tests	VDEP, WDEP, SMC, or ALL
RSquareRMSEOnPartial	R squares and RMSEs on PARTIAL variables	PARTIAL statement with CORR or ALL
SemiParCorr	Semipartial correlations	VDEP, WDEP, SPCORR, or ALL
SimpleStatistics	Simple statistics	SIMPLE or ALL
SqMultCorr	Canonical redundancy analysis: squared multiple correlations	REDUNDANCY or ALL
SqParCorr	Squared partial correlations	VDEP, WDEP, SQPCORR, or ALL
SqSemiParCorr	Squared semipartial correlations	VDEP, WDEP, SQSPCORR, or ALL
StdCanCoefV	Standardized canonical coefficients for the VAR variables	default (if SHORT is not specified)

Table 26.2 *continued*

ODS Table Name	Description	Statement and Option
StdCanCoefW	Standardized canonical coefficients for the WITH variables	default (if SHORT is not specified)
StdErrRawRegCoef	Standard errors of the raw regression coefficients	VDEP, WDEP, SEB, or ALL
StdRegCoef	Standardized regression coefficients	VDEP, WDEP, STB, or ALL
StdRegCoefOnPartial	Standardized regression coefficients on PARTIAL variables	PARTIAL statement with CORR or ALL
tValueRegCoef	*t* values for the regression coefficients	VDEP, WDEP, T, or ALL

Example: CANCORR Procedure

Example 26.1: Canonical Correlation Analysis of Fitness Club Data

Three physiological and three exercise variables are measured on 20 middle-aged men in a fitness club. You can use the CANCORR procedure to determine whether the physiological variables are related in any way to the exercise variables. The following statements create the SAS data set Fit and produce Output 26.1.1 through Output 26.1.5:

```
data Fit;
   input Weight Waist Pulse Chins Situps Jumps;
   datalines;
191  36  50   5  162   60
189  37  52   2  110   60
193  38  58  12  101  101
162  35  62  12  105   37
189  35  46  13  155   58
182  36  56   4  101   42
211  38  56   8  101   38
167  34  60   6  125   40
176  31  74  15  200   40
154  33  56  17  251  250
169  34  50  17  120   38
166  33  52  13  210  115
154  34  64  14  215  105
247  46  50   1   50   50
193  36  46   6   70   31
202  37  62  12  210  120
176  37  54   4   60   25
157  32  52  11  230   80
156  33  54  15  225   73
138  33  68   2  110   43
;
```

```
proc cancorr data=Fit all
     vprefix=Physiological vname='Physiological Measurements'
     wprefix=Exercises wname='Exercises';
   var Weight Waist Pulse;
   with Chins Situps Jumps;
   title 'Middle-Aged Men in a Health Fitness Club';
   title2 'Data Courtesy of Dr. A. C. Linnerud, NC State Univ';
run;
```

Output 26.1.1 Correlations among the Original Variables

Middle-Aged Men in a Health Fitness Club
Data Courtesy of Dr. A. C. Linnerud, NC State Univ

The CANCORR Procedure

Correlations Among the Original Variables

Correlations Among the Physiological Measurements

	Weight	Waist	Pulse
Weight	1.0000	0.8702	-0.3658
Waist	0.8702	1.0000	-0.3529
Pulse	-0.3658	-0.3529	1.0000

Correlations Among the Exercises

	Chins	Situps	Jumps
Chins	1.0000	0.6957	0.4958
Situps	0.6957	1.0000	0.6692
Jumps	0.4958	0.6692	1.0000

Correlations Between the Physiological Measurements and the Exercises

	Chins	Situps	Jumps
Weight	-0.3897	-0.4931	-0.2263
Waist	-0.5522	-0.6456	-0.1915
Pulse	0.1506	0.2250	0.0349

Output 26.1.1 displays the correlations among the original variables. The correlations between the physiological and exercise variables are moderate, the largest being -0.6456 between Waist and Situps. There are larger within-set correlations: 0.8702 between Weight and Waist, 0.6957 between Chins and Situps, and 0.6692 between Situps and Jumps.

Output 26.1.2 Canonical Correlations and Multivariate Statistics

Middle-Aged Men in a Health Fitness Club
Data Courtesy of Dr. A. C. Linnerud, NC State Univ

The CANCORR Procedure

Canonical Correlation Analysis

	Canonical Correlation	Adjusted Canonical Correlation	Approximate Standard Error	Squared Canonical Correlation
1	0.795608	0.754056	0.084197	0.632992
2	0.200556	-.076399	0.220188	0.040223
3	0.072570	.	0.228208	0.005266

Eigenvalues of Inv(E)*H
= CanRsq/(1-CanRsq)

	Eigenvalue	Difference	Proportion	Cumulative
1	1.7247	1.6828	0.9734	0.9734
2	0.0419	0.0366	0.0237	0.9970
3	0.0053		0.0030	1.0000

Test of H0: The canonical correlations in the
current row and all that follow are zero

	Likelihood Ratio	Approximate F Value	Num DF	Den DF	Pr > F
1	0.35039053	2.05	9	34.223	0.0635
2	0.95472266	0.18	4	30	0.9491
3	0.99473355	0.08	1	16	0.7748

Multivariate Statistics and F Approximations

S=3 M=-0.5 N=6

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.35039053	2.05	9	34.223	0.0635
Pillai's Trace	0.67848151	1.56	9	48	0.1551
Hotelling-Lawley Trace	1.77194146	2.64	9	19.053	0.0357
Roy's Greatest Root	1.72473874	9.20	3	16	0.0009

NOTE: F Statistic for Roy's Greatest Root is an upper bound.

As Output 26.1.2 shows, the first canonical correlation is 0.7956, which would appear to be substantially larger than any of the between-set correlations. The probability level for the null hypothesis that all the canonical correlations are zero in the population is only 0.0635, so no firm conclusions can be drawn. The remaining canonical correlations are not worthy of consideration, as can be seen from the probability levels and especially from the negative adjusted canonical correlations.

Because the variables are not measured in the same units, the standardized coefficients rather than the raw coefficients should be interpreted. The correlations given in the canonical structure matrices should also be examined.

Output 26.1.3 Raw and Standardized Canonical Coefficients

Raw Canonical Coefficients for the Physiological Measurements

	Physiological1	Physiological2	Physiological3
Weight	-0.031404688	-0.076319506	-0.007735047
Waist	0.4932416756	0.3687229894	0.1580336471
Pulse	-0.008199315	-0.032051994	0.1457322421

Raw Canonical Coefficients for the Exercises

	Exercises1	Exercises2	Exercises3
Chins	-0.066113986	-0.071041211	-0.245275347
Situps	-0.016846231	0.0019737454	0.0197676373
Jumps	0.0139715689	0.0207141063	-0.008167472

Standardized Canonical Coefficients for the Physiological Measurements

	Physiological1	Physiological2	Physiological3
Weight	-0.7754	-1.8844	-0.1910
Waist	1.5793	1.1806	0.5060
Pulse	-0.0591	-0.2311	1.0508

Standardized Canonical Coefficients for the Exercises

	Exercises1	Exercises2	Exercises3
Chins	-0.3495	-0.3755	-1.2966
Situps	-1.0540	0.1235	1.2368
Jumps	0.7164	1.0622	-0.4188

The first canonical variable for the physiological variables, displayed in Output 26.1.3, is a weighted difference of Waist (1.5793) and Weight (−0.7754), with more emphasis on Waist. The coefficient for Pulse is near 0. The correlations between Waist and Weight and the first canonical variable are both positive, 0.9254 for Waist and 0.6206 for Weight. Weight is therefore a suppressor variable, meaning that its coefficient and its correlation have opposite signs.

The first canonical variable for the exercise variables also shows a mixture of signs, subtracting Situps (−1.0540) and Chins (−0.3495) from Jumps (0.7164), with the most weight on Situps. All the correlations are negative, indicating that Jumps is also a suppressor variable.

It might seem contradictory that a variable should have a coefficient of opposite sign from that of its correlation with the canonical variable. In order to understand how this can happen, consider a simplified situation: predicting Situps from Waist and Weight by multiple regression. In informal terms, it seems plausible that obese people should do fewer sit-ups than skinny people. Assume that the men in the sample do not vary much in height, so there is a strong correlation between Waist and Weight (0.8702). Examine the relationships between obesity and the independent variables:

- People with large waists tend to be more obese than people with small waists. Hence, the correlation between Waist and Situps should be negative.
- People with high weights tend to be more obese than people with low weights. Therefore, Weight should correlate negatively with Situps.
- For a fixed value of Weight, people with large waists tend to be shorter and more obese. Thus, the multiple regression coefficient for Waist should be negative.
- For a fixed value of Waist, people with higher weights tend to be taller and skinnier. The multiple regression coefficient for Weight should therefore be positive, of opposite sign from the correlation between Weight and Situps.

Therefore, the general interpretation of the first canonical correlation is that Weight and Jumps act as suppressor variables to enhance the correlation between Waist and Situps. This canonical correlation might be strong enough to be of practical interest, but the sample size is not large enough to draw definite conclusions.

The canonical redundancy analysis (Output 26.1.4) shows that neither of the first pair of canonical variables is a good overall predictor of the opposite set of variables, the proportions of variance explained being 0.2854 and 0.2584. The second and third canonical variables add virtually nothing, with cumulative proportions for all three canonical variables being 0.2969 and 0.2767.

Output 26.1.4 Canonical Redundancy Analysis

Middle-Aged Men in a Health Fitness Club
Data Courtesy of Dr. A. C. Linnerud, NC State Univ

The CANCORR Procedure

Canonical Redundancy Analysis

Standardized Variance of the Physiological Measurements Explained by

Canonical Variable Number	Their Own Canonical Variables: Proportion	Their Own Canonical Variables: Cumulative Proportion	Canonical R-Square	The Opposite Canonical Variables: Proportion	The Opposite Canonical Variables: Cumulative Proportion
1	0.4508	0.4508	0.6330	0.2854	0.2854
2	0.2470	0.6978	0.0402	0.0099	0.2953
3	0.3022	1.0000	0.0053	0.0016	0.2969

Standardized Variance of the Exercises Explained by

Canonical Variable Number	Their Own Canonical Variables: Proportion	Their Own Canonical Variables: Cumulative Proportion	Canonical R-Square	The Opposite Canonical Variables: Proportion	The Opposite Canonical Variables: Cumulative Proportion
1	0.4081	0.4081	0.6330	0.2584	0.2584
2	0.4345	0.8426	0.0402	0.0175	0.2758
3	0.1574	1.0000	0.0053	0.0008	0.2767

The squared multiple correlations (Output 26.1.5) indicate that the first canonical variable of the physiological measurements has some predictive power for Chins (0.3351) and Situps (0.4233) but almost none for Jumps (0.0167). The first canonical variable of the exercises is a fairly good predictor of Waist (0.5421), a poorer predictor of Weight (0.2438), and nearly useless for predicting Pulse (0.0701).

Output 26.1.5 Canonical Redundancy Analysis

Squared Multiple Correlations Between the Physiological Measurements and the First M Canonical Variables of the Exercises

M	1	2	3
Weight	0.2438	0.2678	0.2679
Waist	0.5421	0.5478	0.5478
Pulse	0.0701	0.0702	0.0749

Squared Multiple Correlations Between the Exercises and the First M Canonical Variables of the Physiological Measurements

M	1	2	3
Chins	0.3351	0.3374	0.3396
Situps	0.4233	0.4365	0.4365
Jumps	0.0167	0.0536	0.0539

References

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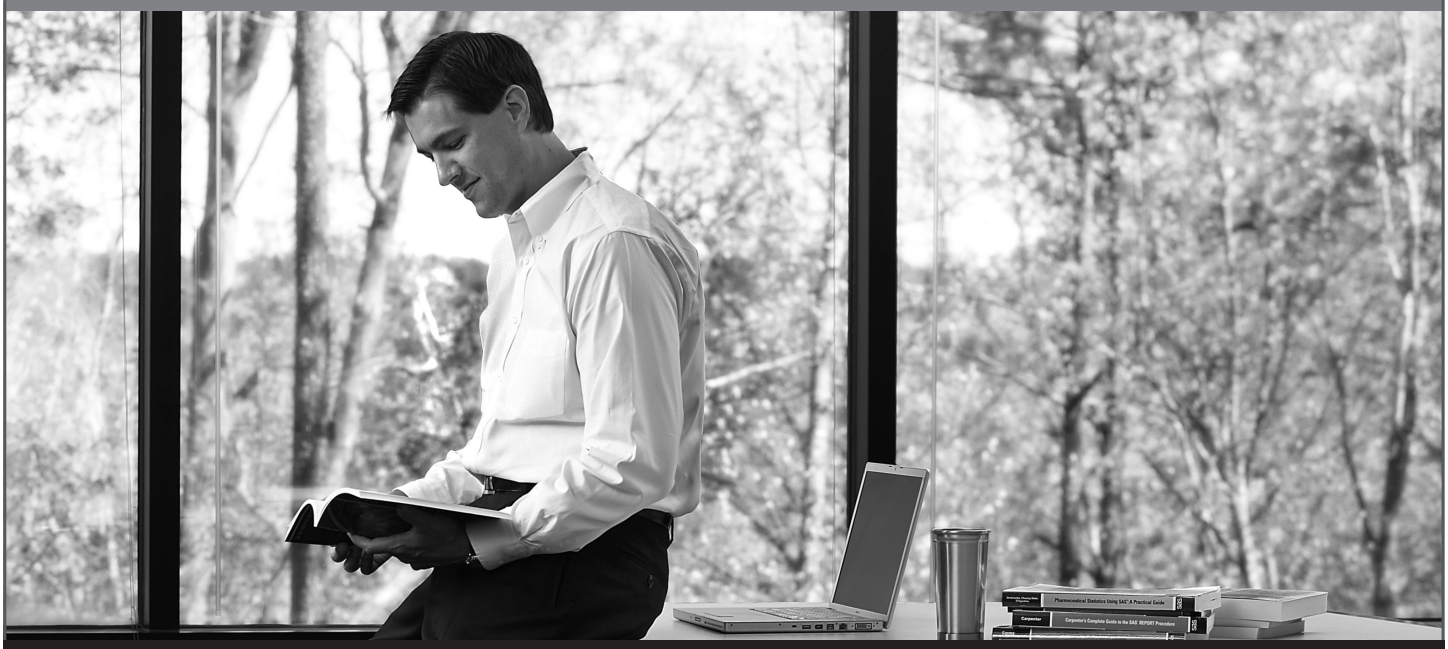

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