Two-way multivariate analysis of variance: A BASIC program for microcomputers

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Multivariate analysis of variance (MANOVA) is an expansion of the univariate ANOVA to cases involving more than one dependent variable. This technique allows one to perform a global analysis of the effects of a given number of independent variables on a set of dependent variables all correlated to varying degrees. When applicable, MANOVA should be preferred to subjecting the data to a series of univariate ANOVAs, since it provides safeguards against the increase in the margin of error inherent to multiple univariate tests. Furthermore, the procedure can reveal and take into account the relationships existing within the data set. Thus, it represents a more general and powerful method of data analysis than its univariate counterpart. The rational and computational procedures associated with this technique have been presented in Lindeman, Merenda, and Gold (1980) and Tatsuoka (1971). The purpose of the program presented here is to perform two-way MANOVA on independent samples comprising equal or unequal numbers of subjects. When the sample sizes are unequal, an unweighted-means analysis is performed. In all cases, the MANOVA is followed by multiple factorial discriminant analysis to identify the nature of the dimensions on which the groups might differ and to enable multiple comparisons between group centroids. In this case, the eigenstructure is obtained using the deflation-power method. The corresponding algorithm was derived from Douglass (1983).

Input. The program requests the number of levels of both factor A (row) and factor B (column), the number of variables (V), and the number of subjects within each combination of factors (S). The raw data can then be entered either sequentially from the keyboard or from a disk file. In the latter case, the data file editor (described earlier, in Coulombe, 1983) can be used to generate a data file suitable as input to this program. The file contains, first, the total number of scores and then the scores themselves, from $A_1B_1S_1V_1$ to $A_{na}B_{nb}S_{n(rc)}V_{nv}$, the last index moving fastest.

Output. All outputs are directed to the line printer. To obtain screen output, each LPRINT statement should be replaced by a PRINT statement. This can be achieved easily with the line editor (EDLIN) provided with MS-DOS. Table 1 is a sample printout obtained using data presented in Lindeman et al., (1980, p. 233). After the

scores observed in each cell are entered, the sums of squares and cross-products (SSCP) matrix for that cell is printed, followed by descriptive statistics for each variable. After data entry is completed, the SSCP matrices for error (Within), total, row, column, and interaction are printed, followed by the determinant values corresponding to each effect. Then, the MANOVA table, containing the computed values of Wilks' lambda, together with Bartlett's and Rao's tests of significance, is printed. Bartlett's statistic is approximately distributed as chi-square; Rao's statistic is approximately distributed as F. The appropriate number of degrees of freedom is printed in each case.

Table 1
Sample Output From MANOVA Programs

TWO-WAY MULTIVARIATE ANALYSIS OF VARIANCE			
SSCP MATRIX FOR A 1 B 1			
	111.600	-7.600	
	-7.600	402.100	
VARIABLE	MEAN	STD. DEV.	
1	17.8	3.521365	
2	24.7	6.684145	
SSCP MATRIX FOR A 1 B 2			
	109.600	130.199	
	130.199	890.400	
VARIABLE	MEAN	STD. DEV.	
1	30.2	3.489661	
2	56.4	9.946526	
SSCP MATRIX FOR A 1 B 3			
	94.400	27.801	
	27.801	624.102	
VARIABLE	MEAN	STD. DEV.	
1	46.4	3.238662	
2	66.3	8.327342	
SSCP MATRIX FOR A 2 B 1			
	108.400	-117.800	
	-117.800	590.100	
VARIABLE	MEAN	STD. DEV.	
1	21.4	3.470509	
2	41.7	8.097321	
SSCP MATRIX FOR A 2 B 2			
	109.600	-3.801	
	-3.801	686.400	
VARIABLE	MEAN	STD. DEV.	
1	37.8	3.489661	
2	55.6	8.733081	
SSCP MATRIX FOR A 2 B 3			
	109.600	-205.801	
	-205.801	1582.898	

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VARIABLE	MEAN	STD. DEV.
1	36.8	3.489661
2	60.1	13.26189

WITHIN SSCP MATRIX

643.199	-177.001
-177.001	4776.001

TOTAL SSCP MATRIX

6451.734	7349.797
7349.797	16227.594

Sr MATRIX

4.272	26.680
26.680	166.680

Sc MATRIX

4994.136	6953.604
6953.604	9811.221

Src MATRIX

810.132	546.523
546.523	1473.711

DETERMINANT TABLE

EFFECT	Sh + Se
ROW	3177649
COLUMN	3.631071E+07
ROW X COLUMN	8946353
ERROR	3040590

MANOVA TABLE

SOURCE	LAMBDA	D.F.	BARTLETT	D.F.	RAO	DF1, DF2
ROW FACTOR	0.95687	1	2.3368	2	1.19	2 53
COL FACTOR	0.08374	2	132.6833	4	65.08	4 106
ROW X COL	0.33987	2	57.7369	4	18.96	4 106
WITHIN		54				

DISCRIMINANT FUNCTION ANALYSIS : ROW FACTOR

Function	1
Eigenvalue	0.04507
Discr. Pwr	1.00000
Lambda	0.95687
R-Squared	0.04313
Chi-Square	2.3366
D. F.	2

Standardized Discriminant Function (weights):

	1
X 1	0.8141
X 2	0.5807

Discriminant Function evaluated at Group Centroid

A	1
1	54.148
2	56.518

DISCRIMINANT FUNCTION ANALYSIS : COLUMN FACTOR

Function	1	2
Eigenvalue	10.70971	0.01984
Discr. Pwr	0.99398	0.00184
Lambda	0.08374	0.98055
R-Squared	0.91626	0.01945

Chi-Square	132.6833	1.0509
D. F.	4	1

Standardized Discriminant Function (weights):

	1	2
X 1	0.9778	0.8131
X 2	0.2093	-0.5822

Discriminant Function evaluated at Group Centroid

B	1	2
1	26.115	-3.392
2	44.969	-4.957
3	53.908	-2.969

DISCRIMINANT FUNCTION ANALYSIS : INTERACTION FACTOR

Function	1	2
Eigenvalue	1.44399	0.20389
Discr. Pwr	0.11624	0.01641
Lambda	0.33987	0.83064
R-Squared	0.66013	0.16936
Chi-Square	57.7369	9.9275
D. F.	4	1

Standardized Discriminant Function (weights):

	1	2
X 1	0.9892	0.6512
X 2	0.1463	-0.7589

Discriminant Function evaluated at Group Centroid

A	B	1	2
1	1	21.223	-7.154
1	2	38.128	-23.137
1	3	55.602	-20.101
2	1	27.271	-17.711
2	2	45.529	-17.580
2	3	45.198	-21.647

Following the MANOVA table, a discriminant function analysis is performed for each effect (row, column, and row $\times$ column interaction). The corresponding output includes, for each possible function: (1) the eigenvalues, (2) the index of discriminatory power, (3) Wilks' lambda, (4) the coefficient of determination, and (5) test of significance. Finally, the standardized discriminant function weights and the group centroids are printed.

Program Language and Requirements. The program was written in GW-BASIC on a Tandy 2000 with two disk drives, under MS-DOS. This language is directly compatible with that of the IBM PC and work-alikes. The program can be transported easily to other computers using Microsoft BASIC. It occupies about 9K of memory, leaving approximately 53K for execution on the Tandy 2000. Under these conditions, problems involving 10 levels of factor A, 10 levels of factor B, 15 variables, and 200 subjects per cell can be analyzed. Critical calculations are performed in double precision. Time requirements to execute the program can be decreased significantly by compiling it with a BASIC compiler.

Availability. A listing of the program is available free from the author. A diskette for the IBM PC or the Tandy 2000 is also available for \$15.00. Please send postal money order only.

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