ANALYSIS OF UNBALANCED FACTORIAL DESIGNS WITH HETEROSCEDASTIC DATA (VALLEJO, FERNÁNDEZ & LIVACIC-ROJAS; JSCS)

1. Formulating contrast matrices for main and interaction effects

Type III analysis. Using the population mean parameter vector $\boldsymbol{\mu}$, the null hypotheses of no main effects and of no interaction can be written as $H_0(A):\mathbf{C}_A\boldsymbol{\mu}=\mathbf{0}$, $H_0(B):\mathbf{C}_B\boldsymbol{\mu}=\mathbf{0}$, and $H_0(AB):\mathbf{C}_{AB}\boldsymbol{\mu}=\mathbf{0}$, where $\mathbf{C}_A=\mathbf{P}_a\otimes(1/b)\mathbf{1}_b'$, $\mathbf{C}_B=(1/a)\mathbf{1}_a'\otimes\mathbf{P}_b$, $\mathbf{C}_{AB}=\mathbf{P}_a\otimes\mathbf{P}_b$, and circle times operator [$\otimes$] denotes the Kronecker product of two matrices. Here, $\mathbf{P}_a=(\mathbf{1}_{a-1}\,|\,-\mathbf{I}_{a-1})$ and $\mathbf{P}_b=(\mathbf{1}_{b-1}\,|\,-\mathbf{I}_{b-1})$ are matrices of between-subjects contrasts with full row rank, where $\mathbf{I}_b$ and $\mathbf{I}_a$ are identity matrices, of dimension *b* and *a*, respectively.

Type II analysis. In order to test the $H_0(A)$ under Type II sum of squares the matrix $\mathbf{C}_A$ is defined as $\mathbf{C}_A=\mathbf{C}_A\otimes\mathbf{R}_B$, where $\mathbf{R}_A=\{r_{jj'}\}$ for $j,j'=1,...,a-1$ with $r_{jj}=\sum_{k=1}n_{jk}-n_{jk}^2/n_{+k}$, $r_{j'k}=-\sum_{j=1}-n_{jk}n_{j'k}/n_{+k}$ for $j\neq j'$, n_{jk} is the number of observations in the *jk*th cell, and $n_{+k}=\sum_j n_{jk}$. A similar procedure must be followed to construct the matrix $\mathbf{C}_B$. The coefficient matrix for testing the *AB* interaction is the same as it was for the Type III SS.

Type I analysis. To test $H_0(A)$ under Type I sum of squares the matrix $\mathbf{C}_A$ is constructed as follows: $\mathbf{C}_A=\mathbf{C}_A\otimes\mathbf{D}_B$, where $\mathbf{D}_B=\mathrm{diag}(n_{jk}/n_{j+})$, and $n_{j+}=\sum_k n_{jk}$. The hypothesis tested by Type I SS for the main effect of *B* is the same as it was for the Type II SS. The coefficient matrix for testing the *AB* interaction is the same as it was for the Type III SS.

2. SAS code used in the article for implementing the mixed model for the Type I, Type II and Type III analysis

```
proc mixed data =vallejo;
ods output 'type 3 tests of fixed effects'=probf1;
ods select 'type 3 tests of fixed effects';
class y1 y2;
model y=y1|y2/ddfm=kr htype=1, 2, 3;
repeated/type=un(1) group=y1*y2;
ods listing exclude 'type 3 tests of fixed effects';
run;

proc glm data=vallejo;
ods output 'multivariate tests'=probf2;
ods select 'multivariate tests';
class y1 y2;
model y=y1|y2/ss1, ss2, ss3;
manova h=y1 y2 y1*y2/summary;
ods listing exclude 'multivariate tests';
run;
```

3. The population's means and variances employed in the power analysis (1-β = 0.60)

VS	R(N/V)	R(M/V)	S. CELLS	S. VARIANCES	POPULATION MEANS
ROW	Null	Null	$\begin{bmatrix} 4, & 7, & 3, & 6, & 5 \\ 3, & 5, & 7, & 9, & 11 \end{bmatrix}$	$\begin{bmatrix} 1, & 1, & 1, & 1, & 1 \\ 1, & 1, & 1, & 1, & 1 \end{bmatrix}$	$\begin{bmatrix} -0.8105, & 0, & 0, & 0, & -0.8105 \\ +0.8105, & 0, & 0, & 0, & +0.8105 \end{bmatrix}$
ROW	+	+	$\begin{bmatrix} 4, & 7, & 3, & 6, & 5 \\ 3, & 5, & 7, & 9, & 11 \end{bmatrix}$	$\begin{bmatrix} 1, & 1, & 1, & 1, & 1 \\ 1, & 2, & 4, & 6, & 9 \end{bmatrix}$	$\begin{bmatrix} -1.1166, & 0, & 0, & 0, & -1.1166 \\ +1.1166, & 0, & 0, & 0, & +1.1166 \end{bmatrix}$
ROW	+	–	$\begin{bmatrix} 4, & 7, & 3, & 6, & 5 \\ 3, & 5, & 7, & 9, & 11 \end{bmatrix}$	$\begin{bmatrix} 1, & 1, & 1, & 1, & 1 \\ 1, & 2, & 4, & 6, & 9 \end{bmatrix}$	$\begin{bmatrix} +1.1166, & 0, & 0, & 0, & +1.1166 \\ -1.1166, & 0, & 0, & 0, & -1.1166 \end{bmatrix}$
ROW	–	+	$\begin{bmatrix} 4, & 7, & 3, & 6, & 5 \\ 3, & 5, & 7, & 9, & 11 \end{bmatrix}$	$\begin{bmatrix} 1, & 1, & 1, & 1, & 1 \\ 9, & 6, & 4, & 2, & 1 \end{bmatrix}$	$\begin{bmatrix} -1.5777, & 0, & 0, & 0, & -1.5777 \\ +1.5777, & 0, & 0, & 0, & +1.5777 \end{bmatrix}$
ROW	–	–	$\begin{bmatrix} 4, & 7, & 3, & 6, & 5 \\ 3, & 5, & 7, & 9, & 11 \end{bmatrix}$	$\begin{bmatrix} 1, & 1, & 1, & 1, & 1 \\ 9, & 6, & 4, & 2, & 1 \end{bmatrix}$	$\begin{bmatrix} +1.5777, & 0, & 0, & 0, & +1.5777 \\ -1.5777, & 0, & 0, & 0, & -1.5777 \end{bmatrix}$
COL	Null	Null	$\begin{bmatrix} 4, & 7, & 3, & 6, & 5 \\ 3, & 5, & 7, & 9, & 11 \end{bmatrix}$	$\begin{bmatrix} 1, & 1, & 1, & 1, & 1 \\ 1, & 1, & 1, & 1, & 1 \end{bmatrix}$	$\begin{bmatrix} -0.7422, & 0, & 0, & 0, & +0.7422 \\ -0.7422, & 0, & 0, & 0, & +0.7422 \end{bmatrix}$
COL	+	+	$\begin{bmatrix} 4, & 7, & 3, & 6, & 5 \\ 3, & 5, & 7, & 9, & 11 \end{bmatrix}$	$\begin{bmatrix} 1, & 1, & 1, & 1, & 1 \\ 1, & 2, & 4, & 6, & 9 \end{bmatrix}$	$\begin{bmatrix} -0.9803, & 0, & 0, & 0, & +0.9803 \\ -0.9803, & 0, & 0, & 0, & +0.9803 \end{bmatrix}$
COL	+	–	$\begin{bmatrix} 4, & 7, & 3, & 6, & 5 \\ 3, & 5, & 7, & 9, & 11 \end{bmatrix}$	$\begin{bmatrix} 1, & 1, & 1, & 1, & 1 \\ 1, & 2, & 4, & 6, & 9 \end{bmatrix}$	$\begin{bmatrix} +0.9803, & 0, & 0, & 0, & -0.9803 \\ +0.9803, & 0, & 0, & 0, & -0.9803 \end{bmatrix}$
COL	–	+	$\begin{bmatrix} 4, & 7, & 3, & 6, & 5 \\ 3, & 5, & 7, & 9, & 11 \end{bmatrix}$	$\begin{bmatrix} 1, & 1, & 1, & 1, & 1 \\ 9, & 6, & 4, & 2, & 1 \end{bmatrix}$	$\begin{bmatrix} +1.0895, & 0, & 0, & 0, & -1.0895 \\ +1.0895, & 0, & 0, & 0, & -1.0895 \end{bmatrix}$
COL	–	–	$\begin{bmatrix} 4, & 7, & 3, & 6, & 5 \\ 3, & 5, & 7, & 9, & 11 \end{bmatrix}$	$\begin{bmatrix} 1, & 1, & 1, & 1, & 1 \\ 9, & 6, & 4, & 2, & 1 \end{bmatrix}$	$\begin{bmatrix} -1.0895, & 0, & 0, & 0, & +1.0895 \\ -1.0895, & 0, & 0, & 0, & +1.0895 \end{bmatrix}$
R × C	Null	Null	$\begin{bmatrix} 4, & 7, & 3, & 6, & 5 \\ 3, & 5, & 7, & 9, & 11 \end{bmatrix}$	$\begin{bmatrix} 1, & 1, & 1, & 1, & 1 \\ 1, & 1, & 1, & 1, & 1 \end{bmatrix}$	$\begin{bmatrix} +0.7422, & 0, & 0, & 0, & -0.7422 \\ -0.7422, & 0, & 0, & 0, & +0.7422 \end{bmatrix}$
R × C	+	+	$\begin{bmatrix} 4, & 7, & 3, & 6, & 5 \\ 3, & 5, & 7, & 9, & 11 \end{bmatrix}$	$\begin{bmatrix} 1, & 1, & 1, & 1, & 1 \\ 1, & 2, & 4, & 6, & 9 \end{bmatrix}$	$\begin{bmatrix} +0.9803, & 0, & 0, & 0, & -0.9803 \\ -0.9803, & 0, & 0, & 0, & +0.9803 \end{bmatrix}$
R × C	+	–	$\begin{bmatrix} 4, & 7, & 3, & 6, & 5 \\ 3, & 5, & 7, & 9, & 11 \end{bmatrix}$	$\begin{bmatrix} 1, & 1, & 1, & 1, & 1 \\ 1, & 2, & 4, & 6, & 9 \end{bmatrix}$	$\begin{bmatrix} -0.9803, & 0, & 0, & 0, & +0.9803 \\ +0.9803, & 0, & 0, & 0, & -0.9803 \end{bmatrix}$
R × C	–	+	$\begin{bmatrix} 4, & 7, & 3, & 6, & 5 \\ 3, & 5, & 7, & 9, & 11 \end{bmatrix}$	$\begin{bmatrix} 1, & 1, & 1, & 1, & 1 \\ 9, & 6, & 4, & 2, & 1 \end{bmatrix}$	$\begin{bmatrix} -1.0895, & 0, & 0, & 0, & +1.0895 \\ +1.0895, & 0, & 0, & 0, & -1.0895 \end{bmatrix}$
R × C	–	–	$\begin{bmatrix} 4, & 7, & 3, & 6, & 5 \\ 3, & 5, & 7, & 9, & 11 \end{bmatrix}$	$\begin{bmatrix} 1, & 1, & 1, & 1, & 1 \\ 9, & 6, & 4, & 2, & 1 \end{bmatrix}$	$\begin{bmatrix} +1.0895, & 0, & 0, & 0, & -1.0895 \\ -1.0895, & 0, & 0, & 0, & +1.0895 \end{bmatrix}$

Note: VS = variation sources of interest; R (N/V) = relationship between the size of the cells of the 2 × 5 factorial design and the size of the variances; R (M/V) = relationship between the size of the means and the size of the variances; ROW = rows; COL = columns; R × C = rows (A) and columns (B) interaction.

4. Error Rates Associated with the Sum of Squares Type II of the 2 × 5 Factorial Design

			Normal			Laplace			Exponential			Extremely skewed		
HP	N	R(N/V)	H_R	H_C	H_I	H_R	H_C	H_I	H_R	H_C	H_I	H_R	H_C	H_I
Type-Box														
HP_1	60	=	4.67	4.02	4.29	4.55	3.88	4.09	4.75	3.42	3.38	2.80	**1.09**	**0.96**
HP_1	120	=	4.84	4.54	4.48	4.98	4.20	4.53	4.88	3.88	3.51	3.89	**1.66**	**1.78**
HP_2	60	+	4.91	4.20	3.99	4.71	3.99	3.89	5.08	2.56	2.73	4.70	**1.14**	**1.18**
HP_2	60	–	4.97	5.58	6.00	4.45	5.29	5.48	5.28	5.26	5.43	4.17	**1.86**	**2.14**
HP_2	120	+	5.03	4.49	4.38	4.99	4.45	4.24	5.23	3.31	3.66	5.17	**1.86**	**2.08**
HP_2	120	–	5.00	5.52	5.83	4.90	4.57	5.08	5.47	5.17	6.00	5.05	3.38	2.69
Welch-James														
HP_1	60	=	4.67	4.22	4.87	4.55	4.07	4.08	4.75	6.48	4.22	2.80	**1.62**	**0.56**
HP_1	120	=	4.84	4.28	4.77	4.98	4.62	4.55	4.88	7.13	3.66	3.89	3.90	**1.72**
HP_2	60	+	4.91	4.70	4.56	4.71	4.08	4.23	5.08	5.29	4.07	4.70	**2.24**	**1.84**
HP_2	60	–	4.97	6.38	6.52	4.45	6.07	5.88	5.28	**12.33**	**10.67**	4.17	**9.38**	5.69
HP_2	120	+	5.03	5.15	4.74	4.99	4.61	4.58	5.23	6.20	4.04	5.17	3.97	**2.49**
HP_2	120	–	5.00	5.39	5.49	4.90	4.81	4.62	5.47	**10.06**	**9.34**	5.05	**11.06**	**8.00**
Proc Mixed														
HP_1	60	=	4.67	3.94	4.16	4.54	3.49	4.02	4.74	5.24	2.54	2.82	**1.08**	**0.47**
HP_1	120	=	4.84	4.50	4.68	4.98	4.98	4.12	4.80	6.14	2.90	3.89	4.07	**1.53**
HP_2	60	+	4.91	3.90	3.54	4.72	3.56	3.18	5.10	4.32	3.82	4.80	**1.58**	**1.36**
HP_2	60	–	4.97	5.20	4.90	4.45	4.78	4.68	5.28	**10.38**	7.28	4.14	6.94	4.21
HP_2	120	+	5.03	5.22	4.90	5.00	4.74	4.50	5.23	5.32	5.02	5.21	3.49	2.50
HP_2	120	–	5.00	5.72	5.30	4.90	4.84	4.86	5.47	**9.64**	**8.54**	5.08	**9.09**	7.02
Proc GLM														
HP_1	60	=	5.04	5.34	5.24	5.07	5.09	4.98	4.89	4.90	5.02	4.30	4.49	5.20
HP_1	120	=	4.98	4.92	4.67	5.01	5.04	5.19	5.03	4.99	5.04	4.62	4.27	5.52
HP_2	60	+	**1.69**	3.32	**0.56**	**1.64**	2.95	**0.71**	2.83	3.50	**1.12**	4.09	3.03	**1.93**
HP_2	60	–	6.49	**13.19**	**12.74**	6.16	**12.08**	**12.19**	6.68	**11.17**	**10.67**	6.68	**8.96**	**9.24**
HP_2	120	+	**1.64**	3.34	**0.66**	**1.69**	3.07	**0.54**	**2.29**	3.10	**0.67**	3.07	3.01	**1.20**
HP_2	120	–	5.99	**12.82**	**12.23**	6.06	**11.09**	**12.05**	6.40	**10.72**	**11.00**	6.48	**9.58**	**9.52**

Note: Normal distribution = ($\gamma_1 = 0$ & $\gamma_2 = 0$); Laplace distribution = ($\gamma_1 = 0$ & $\gamma_2 = 3$); exponential distribution = ($\gamma_1 = 2$ & $\gamma_2 = 6$); extremely skewed distribution = ($\gamma_1 = 4$ & $\gamma_2 = 42$); γ_1 = skewness index; γ_2 = kurtosis index. N = sample size; HP_1 = homogeneous pattern; HP_2 = heterogeneous pattern; H_R = hypothesis rows; H_C = hypothesis columns; H_I = hypothesis interaction; R(N/V) = relationship between the size of the cells and the size of the variances; Numbers in bold denote values outside interval 0.025 – 0.075.

5. SAS/IML Macro to implement the modified Type-Box procedure

```
*************************************************************************/
/* MODIFIED TYPE-BOX TEST FOR ANALYZING UNIVARIATE AND MULTIVARIATE   */
/*                                FACTORIAL DESIGNS (VALLEJO 2007)                */
/*************************************************************************/

/*---------------------------------------------------------------------- */
/* This SAS/IML program calculates the F ratio and associated p-values */
/* for omnibus tests as well as F ratios, the individual p-values, and */
/* the Hochberg adjusted p-values for all pairwise comparisons of the  */
/* marginal means and all possible product interaction contrasts, for a*/
/* variety of univariate and multivariate factorial designs            */
/*---------------------------------------------------------------------- */
/*---------------------------------------------------------------------*/
/*-----------------Required Arguments on First Use---------------------*/
/*---------------------------------------------------------------------*/
/* NDV = number of dependent variables
*/
/* NIV = number of independent variables                                          */
/* NA = number of levels of the factor A                                          */
/* NB = number of levels of factor B                                              */
/* NC = number of levels of the factor C                                          */
/*---------------------------------------------------------------------*/

/*---------------------------------------------------------------------*/
/*-------------------Optional Arguments--------------------------------*/
/*---------------------------------------------------------------------*/
/*TESTOMNI =1, where value is either 1 or 0. If TESTOMNI=1, then the F */
/*tests for the main and interaction effects are computed. Default = 1 */
/*TESTFACTOR A=1, where value is either 1 or 0. If TESTFACTOR A =1,then*/
/*all pairwise contrasts among levels of A are computed. Default = 1   */
/*TESTFACTOR B=1, where value is either 1 or 0. If TESTFACTOR B =1,then*/
/*all pairwise contrasts among levels of B are computed. Default = 1   */
*TESTINTER AB=1,where value is either 1 or 0.If TESTINTER AB=1,then all*/
/*possible product interaction contrasts are computed. Default = 1     */
/*TESTFACTOR C=1, where value is either 1 or 0. If TESTFACTOR C =1,then*/
/*all pairwise contrasts among levels of C are computed. Default = 1   */
*TESTINTER AC=1,where value is either 1 or 0.If TESTINTER AC=1,then all*/
/*possible product interaction contrasts are computed. Default = 1     */
*TESTINTER BC=1,where value is either 1 or 0.If TESTINTER BC=1,then all*/
/*possible product interaction contrasts are computed. Default = 1     */
*TESTINTER ABC=1, where value is either 1/0.If TESTINTER ABC=1,then all*/
/*possible product interaction contrasts are computed. Default = 1     */
/*TESTDEPVAR =1, where value is either 1 or 0. If TESTDEPVAR =1, then  */
/*multivariate omnibus tests with multiple post hoc contrasts are      */
/*computed. Also are computed omnibus tests for each dependent outcome */
/*as well as multiple comparison hypotheses related to these effects.  */
/*Default =o                                                           */
/*---------------------------------------------------------------------*/
;DATA MBF; INPUT GROUP SEX AGE CLAS Y1 Y2;CARDS;
1 1 1 1 16 2
1 1 1 1 26 3
1 1 1 1 22 4
1 1 1 1 16 5
2 1 1 2 26 6
2 1 1 2 36 7
2 1 1 2 32 8
2 1 1 2 26 9
3 1 1 3 36 2
3 1 1 3 46 3
3 1 1 3 42 4
3 1 1 3 36 5
4 1 2 1 16 6
4 1 2 1 26 7
4 1 2 1 22 8
4 1 2 1 16 9
5 1 2 2 16 3
5 1 2 2 26 4
5 1 2 2 22 5
5 1 2 2 16 6
6 1 2 3 22 7
6 1 2 3 32 8
6 1 2 3 28 9
6 1 2 3 22 1
7 1 3 1 16 2
7 1 3 1 26 3
7 1 3 1 22 4
7 1 3 1 16 5
8 1 3 2 26 1
```

```
8 1 3 2 36 2
8 1 3 2 32 3
8 1 3 2 26 4
9 1 3 3 36 5
9 1 3 3 46 1
9 1 3 3 42 2
10 2 1 1 16 3
10 2 1 1 26 4
10 2 1 1 22 5
10 2 1 1 16 0
11 2 1 2 26 9
11 2 1 2 36 8
11 2 1 2 32 7
11 2 1 2 26 6
12 2 1 3 36 5
12 2 1 3 46 4
12 2 1 3 42 3
12 2 1 3 36 2
13 2 2 1 36 1
13 2 2 1 36 1
14 2 2 2 16 2
14 2 2 2 26 3
14 2 2 2 22 4
14 2 2 2 16 5
15 2 2 3 16 6
15 2 2 3 26 7
15 2 2 3 22 8
15 2 2 3 16 9
16 2 3 1 22 0
16 2 3 1 32 8
16 2 3 1 28 7
16 2 3 1 22 6
17 2 3 2 16 5
17 2 3 2 26 4
17 2 3 2 22 3
17 2 3 2 16 2
18 2 3 3 26 3
18 2 3 3 36 4
18 2 3 3 22 5
;

PROC IML SYMSIZE=2000;
TESTOMNI=1;
TESTFACTOR A =1;
TESTFACTOR B =1;
TESTINTER AB =1;
TESTFACTOR_C_=1;
TESTINTER AC =1;
TESTINTER BC =1;
TESTINTER ABC_=1;
TESTDEPVAR=1;
NDV=2;NIV=3;
NA=2;NB=3;NC=3;

OPT=1;

IF OPT=0 THEN DO;
  NI=NA*NB;NAB=NI;
  RGA=(J(NA-1,1,1)||(-I(NA-1)))@(J(1,NB,1));
  RGB=(J(1,NA,1))@(J(NB-1,1,1)||(-I(NB-1)));
  RGI=(T(HDIR(RGA`,RGB`)));
 END;

IF OPT=1 THEN DO;
  NI=NA*NB*NC;NAB=NI;NAC=NI;NBC=NI;NABC=NI;
  RGA=(J(NA-1,1,1)||(-I(NA-1)))@((J(1,NB,1))@(J(1,NC,1)));
  RGB=((J(1,NA,1))@(J(NB-1,1,1)||(-I(NB-1))))@(J(1,NC,1));
  RGI=(T(HDIR(RGA`,RGB`)));
  RGC=((J(1,NA,1))@(J(1,NB,1))@(J(NC-1,1,1)||(-I(NC-1))));
  RGK=(T(HDIR(RGA`,RGC`)));
  RGL=(T(HDIR(RGB`,RGC`)));
  RGN=(T(HDIR(RGI`,RGC`)));
END;

USE MBF;
START MBF(TESTDV, CJ, NJ, RGJ, DFJ1, DFJ2, FVALJ, PVALJ) GLOBAL(NDV, NIV);
GROUP1=-1; GROUP2=-1;TNDV=NDV;
        IF ((GROUP1=-1)&(GROUP2=-1)) THEN READ ALL INTO TEMPY;     /*TESTING PAIRWISE
GROUPS/INTERACTION */
                ELSE  DO;
                        READ ALL WHERE ((GROUP=GROUP1)|(GROUP=GROUP2))INTO TEMPY;
```

```
                DO I=1 TO (NROW(TEMPY));
                        IF TEMPY [I,1] = GROUP1 THEN TEMPY[I,1]=1;
                        IF TEMPY [I,1] = GROUP2 THEN TEMPY[I,1]=2;
                END;
        END;

COLUMNS=NCOL(TEMPY);
ROWS=NROW(TEMPY);
TEMPY=TEMPY[,1]||TEMPY[,2+NIV:COLUMNS];

IF (TESTDV) THEN DO;
        DO I=1 TO TNDV;
                FLEP=TEMPY[,1]||TEMPY[,2+TESTDV-1];
        END;
        TEMPY=FLEP;
        TNDV=1;
END;

CONU =I(TNDV);
NG=NCOL(UNION(TEMPY[,1]));
DF=J(NG,1,0);
AF=J(NG,1,0);
DO I=1 TO NG;
        NOBS=0;
        DO J=1 TO ROWS;
                IF TEMPY [J,1] = I THEN DO;
                        NOBS = NOBS + 1;
                END;
        END;
        DF(|I|)=NOBS-1;
        AF(|I|)=NOBS-1;IF AF(|I|)=0 THEN DO;AF(|I|)=1;END;
END;
DFF=DF+1;

Y=TEMPY[,2];
IF NCOL(TEMPY)> 2 THEN DO;
        DO TEMP=3 TO NCOL(TEMPY);
                Y=Y||TEMPY[,TEMP];
        END;
END;
NTOT=NROW(Y);

DO I=1 TO NG;
        TEMP=J(DFF[I],1,I);
        IF I=1 THEN DO;
                XX=TEMP;
        END;
        ELSE DO;
                XX=XX//TEMP;
        END;
END;
X = DESIGN(XX);

LJ=J(1,NJ,1);
MJ=J(1,NJ,-1);
NJ1=NCOL(LJ);
COMJ=(NJ1*(NJ1-1))/2;
CJ=J(COMJ,NJ1,0);
K=1;
L=1;
M=NJ1-1;
J=1;
DO WHILE (K<=M);
        I=1;
        DO WHILE (I<NJ1);
                CJ[L,J]=LJ[1,J];
                CJ[L,J+I]=MJ[1,J+I];
                L=L+1;
                I=I+1;
        END;
        J=J+1;
        NJ1=NJ1-1;
        K=K+1;
END;

BTB = GINV(X`*X)*X`*Y;
DO I=1 TO NG;
        HJ=NTOT*((RGJ*BTB*CONU`)`*GINV(RGJ*RGJ`)*(RGJ*BTB*CONU`));
END;

M=(RGJ`*(GINV(RGJ*RGJ`))*RGJ)@CONU;
```

```
        DM=DIAG((RGJ`*(GINV(RGJ*RGJ`))*RGJ)@CONU);
        SGK=J(NG#TNDV,NG#TNDV,0);
        DO I=1 TO NG;
                GL=(GRL//(GINV(DIAG(DF))))@CONU;
                SG=(NTOT/(AF[I]+1))*(CONU*((T(Y#X[,I]-X[,I]*BTB[I,])*(Y#X[,I]-
X[,I]*BTB[I,]))/(AF[I]))*CONU`);
                F=I#TNDV-(TNDV-1);F=I#TNDV-(TNDV-1);IF TNDV=1 THEN DO; F=I;END;
                L=I#TNDV;
                SGK[F:L,F:L]=SG;
        END;

        VEG1=((TRACE(DM*SGK))**2);
        VEG2=(TRACE((DM*SGK)*(DM*SGK)*GL));
        VH=(TRACE((M*SGK)*(M*SGK)));
        DF1=VEG1/VH;
        DF2=VEG1/VEG2;
        ERJ=TRACE(DM*SGK);
        SGG=(DM*SGK);
        EJ=J(TNDV,TNDV,0);
                DO I=1 TO NG;SKG=0;
                F=I#TNDV-(TNDV-1);
                        L=I#TNDV;
                SK=SGG(|F:L,F:L|);
                        EJ=EJ+SK;
                END;

        MJ=ROUND(TRACE(GINV(EJ)*EJ));
        SJ=((MJ##2*DF1##2-4)/(MJ##2+DF1##2-5))##.5;IF SJ=. THEN DO; SJ=1;END;
        DFJ1=MJ*DF1;                                                    /*DF1*/
        DFJ2=(DF2-(MJ-DF1+1)/2)*SJ-(MJ*DF1-2)/2;                  /*DF2*/
        LMDJ=(DET(EJ*(DF2/DF1)))/DET(HJ+EJ*(DF2/DF1));
        FVALJ=((1-LMDJ##(1/SJ))/LMDJ##(1/SJ))*(DFJ2/DFJ1);  /*FVALUE*/
        PVALJ=1-PROBF(FVALJ,DFJ1,DFJ2);                                 /*PVALUE*/
FINISH;

START OMNIRESULTS ;
        IF OPT=0 THEN DO;
                CALL MBF(TESTDV, CA, NA, RGA, DFA1, DFA2, FVALA, PVALA);
                CALL MBF(TESTDV, CB, NB, RGB, DFB1, DFB2, FVALB, PVALB);
                CALL MBF(TESTDV, CI, NI, RGI, DFI1, DFI2, FVALI, PVALI);
                RESET NONAME; RESET CENTER;   PRINT '';
                PRINT 'MODIFIED TYPE BOX OMNIBUS TEST RESULTS';
                IF (TESTDV) THEN DO; PRINT ''; PRINT 'UNIVARIATE RESULTS FOR DEPENDANT VARIABLE '
TESTDV; END;
                RESET NOCENTER;
                PRINT '                                          DF1             DF2          F-VALUE
P-VALUE';
                PRINT "FACTOR A                       " '' DFA1 ' | ' DFA2 '  |  ' FVALA '  |  '
PVALA;
                PRINT "FACTOR B                       " '' DFB1 ' | ' DFB2 '  |  ' FVALB '  |  '
PVALB;
                PRINT "INTERACCIÓN AxB" '' DFI1 ' | ' DFI2 '  |  ' FVALI '  |  ' PVALI;
        END;

        IF OPT=1 THEN DO;
                CALL MBF(TESTDV, CA, NA, RGA, DFA1, DFA2, FVALA, PVALA);
                CALL MBF(TESTDV, CB, NB, RGB, DFB1, DFB2, FVALB, PVALB);
                CALL MBF(TESTDV, CI, NI, RGI, DFI1, DFI2, FVALI, PVALI);
                CALL MBF(TESTDV, CC, NC, RGC, DFC1, DFC2, FVALC, PVALC);
                CALL MBF(TESTDV, CK, NI, RGK, DFK1, DFK2, FVALK, PVALK);
                CALL MBF(TESTDV, CL, NI, RGL, DFL1, DFL2, FVALL, PVALL);
                CALL MBF(TESTDV, CN, NI, RGN, DFN1, DFN2, FVALN, PVALN);
                RESET NONAME; RESET CENTER;   PRINT '';
                PRINT 'MODIFIED TYPE BOX OMNIBUS TEST RESULTS';
                IF (TESTDV) THEN DO; PRINT ''; PRINT 'UNIVARIATE RESULTS FOR DEPENDANT VARIABLE '
TESTDV; END;
                RESET NOCENTER;
                PRINT '                                          DF1             DF2          F-VALUE
P-VALUE';
                PRINT "FACTOR A                       " '' DFA1 ' | ' DFA2 '  |  ' FVALA '  |  '
PVALA;
                PRINT "FACTOR B                       " '' DFB1 ' | ' DFB2 '  |  ' FVALB '  |  '
PVALB;
                PRINT "INTERACCIÓN AxB" '' DFI1 ' | ' DFI2 '  |  ' FVALI '  |  ' PVALI;
                PRINT "FACTOR C                  " '' DFC1 ' | ' DFC2 '  |  ' FVALC '  |  ' PVALC;
                PRINT "INTERACCIÓN AxC" '' DFK1 ' | ' DFK2 '  |  ' FVALK '  |  ' PVALK;
                PRINT "INTERACCIÓN BxC" '' DFL1 ' | ' DFL2 '  |  ' FVALL '  |  ' PVALL;
                PRINT "INTERACCIÓN AxBxC" '' DFN1 ' | ' DFN2 '  |  ' FVALN '  |  ' PVALN;
        END;
FINISH;
```

```
START FACTOR_A_TEST;
        CM=CA`;
        F=1;
        M=0;
        DO J=1 TO NCOL(NA);
                L=M+NA[J];
        END;

        COMBA=((NA*(NA-1))/2);
        PVA1=J(COMBA,COMBA,0);PVA2=J(COMBA,COMBA,0);PVA3=J(COMBA,COMBA,0);PVA4=J(COMBA,COMBA,0);
        DO K=1 TO NCOL(CM);
                CT=CM[F:L,K];
                A=CT`;
        IF OPT=0 THEN DO;
                RGJ=A@(J(1,NB,1));
        END;
        IF OPT=1 THEN DO;
                RGJ=A@(J(1,NB,1))@(J(1,NC,1));
        END;

        IF ((PVALA<(0.05))&(NA>2)) THEN DO;RUN MBF(TESTDV, CJ, NA, RGJ, DFJ1, DFJ2, FVALJ, PVALJ)
;
                IF K>=1 THEN DO;
                        R=K#1;T=K#1;
                        PVA1[R:T,R:T]=DFJ1;
                        PVA2[R:T,R:T]=DFJ2;
                        PVA3[R:T,R:T]=FVALJ;
                        PVA4[R:T,R:T]=PVALJ;
                        END;
                END;
        END;

        IF ((PVALA<(0.05))&(NA>2)) THEN DO;RUN MBF(TESTDV, CJ, NA, RGJ, DFJ1, DFJ2, FVALJ, PVALJ)
;
                GROUPA=REPEAT(0,COMBA,2);
                DO I=1 TO NA-1;
                        DO J=I+1 TO NA;
                                GROUPA[COMBA,1]=I;
                                GROUPA[COMBA,2]=J;
                                IF NA>1 THEN DO;
                                        JA1=(JA1||I);
                                        JA2=(JA2||J);
                                END;
                        END;
                END;
                JA11=JA1[1:COMBA];
                JA22=JA2[1:COMBA];
                GROUPA=REPEAT(0,COMBA,6);

        PVA=(JA11||JA22||(VECDIAG(PVA1))||(VECDIAG(PVA2))||(VECDIAG(PVA3))||(VECDIAG(PVA4)));
                DO I=1 TO NROW(PVA);
                        J=PVA`[1,I];
                        K=PVA`[2,I];
                        PA1=PVA`[3,I];
                        PA2=PVA`[4,I];
                        PA3=PVA`[5,I];
                        PA4=PVA`[6,I];
                        GROUPA[COMBA,1]=J;
                        GROUPA[COMBA,2]=K;
                        GROUPA[COMBA,3]=PA1;
                        GROUPA[COMBA,4]=PA2;
                        GROUPA[COMBA,5]=PA3;
                        GROUPA[COMBA,6]=PA4;
                        COMBA=COMBA-1;
                END;
                DO I=1 TO (NROW(GROUPA)-1);
                DO J=1 TO (NROW(GROUPA)-I);
                        IF ((GROUPA[J,6])>(GROUPA[J+1,6])) THEN DO;
                                TEMP=GROUPA[J,]; GROUPA[J,]=GROUPA[J+1,]; GROUPA[J+1,]=TEMP;
                                END;
                        END;
                END;
        END;

        IF ((PVALA<(0.05))&(NA>2)) THEN DO;
                PRINT ''; PRINT 'PAIRWISE COMPARISONS AMONG ALL LEVELS OF FACTOR_A WITH
HOCHBERG''''S H-ADJ-VALUES';
                IF (TESTDV) THEN DO; PRINT 'UNIVARIATE RESULTS FOR DEPENDANT VARIABLE ' TESTDV;
END;
                TEMP=0;
                DO I=1 TO (NROW(GROUPA));
```

```
                        GROUP1=GROUPA[I,1];GROUP2=GROUPA[I,2];
                        DF1=GROUPA[I,3];DF2=GROUPA[I,4];
                        FVALUE=GROUPA[I,5];PVALUE=GROUPA[I,6];
                        ADJUSTEDP=GROUPA[I,6]*(NROW(GROUPA)+1-I);
                        IF (ADJUSTEDP>0.05) THEN TEMP=1;
                        IF (TEMP) THEN ADJUSTEDP=GROUPA[NROW(GROUPA),6];
                        IF I=1 THEN PRINT GROUP1 [format=2.0] '' GROUP2 [format=2.0] [LABEL='TEST']
'|' DF1 [LABEL='DF1'] [format=5.3] ' '
                        DF2 [format=5.3] [LABEL='DF2'] '|' FVALUE [format=5.4][LABEL='F VALUE'] '|'
PVALUE [LABEL='P VALUE'] '|' ADJUSTEDP [LABEL='H-ADJ'];
                        ELSE PRINT GROUP1 [format=2.0] '' GROUP2 [format=4.0]
                        '|' DF1 [format=5.3] ' ' DF2 [format=5.3] '|' FVALUE [format=6.4] ' |'
PVALUE '|' ADJUSTEDP;
                END;
        END;
FINISH;

START FACTOR B_TEST;
        CM=CB`;
        F=1;
        M=0;
        DO J=1 TO NCOL(NB);
                L=M+NB[J];
        END;
        COMBB=((NB*(NB-1))/2);
        PVB1=J(COMBB,COMBB,0);PVB2=J(COMBB,COMBB,0);PVB3=J(COMBB,COMBB,0);PVB4=J(COMBB,COMBB,0);
        DO K=1 TO NCOL(CM);
                CT=CM[F:L,K];
                B=CT`;
        IF OPT=0 THEN DO;
                RGJ=(J(1,NA,1))@B;;
        END;
        IF OPT=1 THEN DO;
                RGJ=(J(1,NA,1))@B@(J(1,NC,1));
        END;

        IF ((PVALB<(0.05))&(NB>2)) THEN DO;RUN MBF(TESTDV, CJ, NA, RGJ, DFJ1, DFJ2, FVALJ, PVALJ)
;
                IF K>=1 THEN DO;
                        R=K#1;T=K#1;
                        PVB1[R:T,R:T]=DFJ1;
                        PVB2[R:T,R:T]=DFJ2;
                        PVB3[R:T,R:T]=FVALJ;
                        PVB4[R:T,R:T]=PVALJ;
                        END;
                END;
        END;

        IF ((PVALB<(0.05))&(NB>2)) THEN DO;RUN MBF(TESTDV, CJ, NA, RGJ, DFJ1, DFJ2, FVALJ, PVALJ)
;
                GROUPB=REPEAT(0,COMBB,2);
                DO I=1 TO NB-1;
                        DO J=I+1 TO NB;
                                GROUPB[COMBB,1]=I;
                                GROUPB[COMBB,2]=J;
                                IF NB>1 THEN DO;
                                        JB1=(JB1||I);
                                        JB2=(JB2||J);
                                END;
                        END;
                END;
                JB11=JB1[1:COMBB];
                JB22=JB2[1:COMBB];
                GROUPB=REPEAT(0,COMBB,6);

        PVB=(JB11||JB22||(VECDIAG(PVB1))||(VECDIAG(PVB2))||(VECDIAG(PVB3))||(VECDIAG(PVB4)));
                DO I=1 TO NROW(PVB);
                        J=PVB`[1,I];
                        K=PVB`[2,I];
                        PB1=PVB`[3,I];
                        PB2=PVB`[4,I];
                        PB3=PVB`[5,I];
                        PB4=PVB`[6,I];
                        GROUPB[COMBB,1]=J;
                        GROUPB[COMBB,2]=K;
                        GROUPB[COMBB,3]=PB1;
                        GROUPB[COMBB,4]=PB2;
                        GROUPB[COMBB,5]=PB3;
                        GROUPB[COMBB,6]=PB4;
                        COMBB=COMBB-1;
                END;
```

```
                DO I=1 TO (NROW(GROUPB)-1);
                        DO J=1 TO (NROW(GROUPB)-I);
                                IF ((GROUPB[J,6])>(GROUPB[J+1,6])) THEN DO;
                                        TEMP=GROUPB[J,]; GROUPB[J,]=GROUPB[J+1,]; GROUPB[J+1,]=TEMP;
                                END;
                        END;
                END;
        END;

        IF (PVALB<(0.05))&(NB>2) THEN DO;
                PRINT ''; PRINT 'PAIRWISE COMPARISONS AMONG ALL LEVELS OF FACTOR_B WITH
HOCHBERG''''S H-ADJ-VALUES';
                IF (TESTDV) THEN DO; PRINT 'UNIVARIATE RESULTS FOR DEPENDANT VARIABLE ' TESTDV;
END;
                TEMP=0;
                DO I=1 TO (NROW(GROUPB));
                        GROUP1=GROUPB[I,1];GROUP2=GROUPB[I,2];
                        DF1=GROUPB[I,3];DF2=GROUPB[I,4];
                        FVALUE=GROUPB[I,5];PVALUE=GROUPB[I,6];
                        ADJUSTEDP=GROUPB[I,6]*(NROW(GROUPB)+1-I);
                        IF (ADJUSTEDP>0.05) THEN TEMP=1;
                        IF (TEMP) THEN ADJUSTEDP=GROUPB[NROW(GROUPB),6];
                        IF I=1 THEN PRINT GROUP1 [format=2.0] '' GROUP2 [format=2.0] [LABEL='TEST']
'|' DF1 [LABEL='DF1'] [format=5.3] ' '
                        DF2 [format=5.3] [LABEL='DF2'] '|' FVALUE [format=5.4][LABEL='F VALUE'] '|'
PVALUE [LABEL='P VALUE'] '|' ADJUSTEDP [LABEL='H-ADJ'];
                        ELSE PRINT GROUP1 [format=2.0] '' GROUP2 [format=4.0]
                        '|' DF1 [format=5.3] ' ' DF2 [format=5.3] '|' FVALUE [format=6.4] ' |'
PVALUE '|' ADJUSTEDP;
                END;
        END;
FINISH;

START INTER AB TEST;
        IF OPT=0 THEN DO;
                AG=CA@(J(1,NB,1));
                BG=(J(1,NA,1))@CB;
        END;
        IF OPT=1 THEN DO;
                AG=CA@(J(1,NB,1))@(J(1,NC,1));
                BG=(J(1,NA,1))@CB@(J(1,NC,1));
        END;
        RG=T(HDIR(AG`,BG`));
        CAB=RG`;
        F=1;
        M=0;
        DO J=1 TO NCOL(NAB);
                L=M+NAB[J];
        END;
        COMBI=((NA*(NA-1))/2)*((NB*(NB-1))/2);
        PVI1=J(COMBI,COMBI,0);PVI2=J(COMBI,COMBI,0);PVI3=J(COMBI,COMBI,0);PVI4=J(COMBI,COMBI,0);
        DO K=1 TO NCOL(CAB);
                CTAB=CAB[F:L,K];
                AB=CTAB`;
                RGJ=AB;
                IF ((PVALI<(0.05))&(NAB>4)) THEN DO;RUN MBF(TESTDV, CJ, NI, RGJ, DFJ1, DFJ2, FVALJ,
PVALJ) ;
                        IF K>=1 THEN DO;
                                R=K#1;T=K#1;
                                PVI1[R:T,R:T]=DFJ1;
                                PVI2[R:T,R:T]=DFJ2;
                                PVI3[R:T,R:T]=FVALJ;
                                PVI4[R:T,R:T]=PVALJ;
                        END;
                END;
        END;

        IF ((PVALI<(0.05))&(NAB>4)) THEN DO;RUN MBF(TESTDV, CJ, NI, RGJ, DFJ1, DFJ2, FVALJ, PVALJ)
;
                INTERACV=REPEAT(0,COMBI,4);
                DO I=1 TO (NA-1);
                        DO J=I+1 TO NA;
                                DO K=1 TO (NB-1);
                                        DO L=K+1 TO NB;
                                                INTERACV[COMBI,1]=I;
                                                INTERACV[COMBI,2]=J;
                                                INTERACV[COMBI,3]=K;
                                                INTERACV[COMBI,4]=L;
                                                IF NB>1 THEN DO;
                                                        JI1=(JI1||I);
                                                        JI2=(JI2||J);
```

```
                                                        JI3=(JI3||K);
                                                        JI4=(JI4||L);
                                                END;
                                        END;
                                END;
                        END;
                END;
                JI11=JI1[1:COMBI];
                JI22=JI2[1:COMBI];
                JI33=JI3[1:COMBI];
                JI44=JI4[1:COMBI];
                INTERACV=REPEAT(0,COMBI,8);

        PVI=(JI11||JI22||JI33||JI44||(VECDIAG(PVI1))||(VECDIAG(PVI2))||(VECDIAG(PVI3))||(VECDIAG(P
VI4)));
                DO I=1 TO NROW(PVI);
                        J=PVI`[1,I];
                        K=PVI`[2,I];
                        L=PVI`[3,I];
                        M=PVI`[4,I];
                        PI1=PVI`[5,I];
                        PI2=PVI`[6,I];
                        PI3=PVI`[7,I];
                        PI4=PVI`[8,I];
                        INTERACV[COMBI,1]=J;
                        INTERACV[COMBI,2]=K;
                        INTERACV[COMBI,3]=L;
                        INTERACV[COMBI,4]=M;
                        INTERACV[COMBI,5]=PI1;
                        INTERACV[COMBI,6]=PI2;
                        INTERACV[COMBI,7]=PI3;
                        INTERACV[COMBI,8]=PI4;
                        COMBI=COMBI-1;
                END;
                DO I=1 TO (NROW(INTERACV)-1);
                        DO J=1 TO (NROW(INTERACV)-I);
                                IF ((INTERACV[J,8])>(INTERACV[J+1,8])) THEN DO;
                                        TEMP=INTERACV[J,]; INTERACV[J,]=INTERACV[J+1,];
INTERACV[J+1,]=TEMP;
                                END;
                        END;
                END;
        END;

        IF ((PVALI<(0.05))&(NAB>4)) THEN DO;
                PRINT '' ; PRINT 'INTERACTION A×B PAIRWISE COMPARISONS WITH HOCHBERG'''S H-ADJ-
VALUES';
                IF (TESTDV) THEN DO; PRINT ''; PRINT 'UNIVARIATE RESULTS FOR DEPENDANT VARIABLE '
TESTDV; END;
                TEMP=0;
                DO I=1 TO (NROW(INTERACV));
                        GROUP1=INTERACV[I,1];GROUP2=INTERACV[I,2];
                        TIME1=INTERACV[I,3]; TIME2=INTERACV[I,4];
                        DF1=INTERACV[I,5];DF2=INTERACV[I,6];
                        FVALUE=INTERACV[I,7];PVALUE=INTERACV[I,8];
                        ADJUSTEDP=INTERACV[I,8]*(NROW(INTERACV)+1-I);
                        IF ((ADJUSTEDP>0.05)&(TEMP=0)) THEN TEMP=1; IF(TEMP) THEN
ADJUSTEDP=INTERACV[NROW(INTERACV),8];
                        IF I=1 THEN PRINT GROUP1 [format=1.9] '' GROUP2 [format=1.0]
[LABEL='FACT A'] '|' TIME1 [format=1.0] '' TIME2[format=1.0][LABEL='FACT_B'] '|'
                        DF1 [format=5.3] [LABEL='DF1']
                        ' ' DF2 [format=5.3][LABEL='DF2'] '|' FVALUE [format=7.3] [LABEL='F VALUE']
'|' PVALUE [LABEL='P VALUE'] '|' ADJUSTEDP [LABEL='H-ADJ'];
                        ELSE PRINT GROUP1 [format=2.0] '' GROUP2 [format=6.0] '|' TIME1 [format=2.0]
'' TIME2 [format=4.0] '|' DF1 [format=5.3]
                        ' ' DF2 [format=5.3] '|' FVALUE [format=7.3] '|' PVALUE '|' ADJUSTEDP;
                END;
        END;
FINISH;

START FACTOR_C_TEST;
        CM=CC`;
        F=1;
        M=0;
        DO J=1 TO NCOL(NC);
                L=M+NC[J];
        END;
        COMBC=((NC*(NC-1))/2);
        PVC1=J(COMBC,COMBC,0);PVC2=J(COMBC,COMBC,0);PVC3=J(COMBC,COMBC,0);PVC4=J(COMBC,COMBC,0);
        DO K=1 TO NCOL(CM);
                CT=CM[F:L,K];
```

```
                C=CT`;
                RGJ=(J(1,NA,1))@(J(1,NB,1))@C;
                IF ((PVALC<(0.05))&(NC>2)) THEN DO;RUN MBF(TESTDV, CJ, NC, RGJ, DFJ1, DFJ2, FVALJ,
PVALJ);
                        IF K>=1 THEN DO;
                                R=K#1;T=K#1;
                                PVC1[R:T,R:T]=DFJ1;
                                PVC2[R:T,R:T]=DFJ2;
                                PVC3[R:T,R:T]=FVALJ;
                                PVC4[R:T,R:T]=PVALJ;
                        END;
                 END;
         END;

        IF ((PVALC<(0.05))&(NC>2)) THEN DO;RUN MBF(TESTDV, CJ, NC, RGJ, DFJ1, DFJ2, FVALJ, PVALJ);
                GROUPC=REPEAT(0,COMBC,2);
                DO I=1 TO NC-1;
                        DO J=I+1 TO NC;
                                GROUPC[COMBC,1]=I;
                                GROUPC[COMBC,2]=J;
                                IF NC>1 THEN DO;
                                        JC1=(JC1||I);
                                        JC2=(JC2||J);
                                END;
                        END;
                END;

                JC11=JC1[1:COMBC];
                JC22=JC2[1:COMBC];
                GROUPC=REPEAT(0,COMBC,6);

        PVC=(JC11||JC22||(VECDIAG(PVC1))||(VECDIAG(PVC2))||(VECDIAG(PVC3))||(VECDIAG(PVC4)));
                DO I=1 TO NROW(PVC);
                        J=PVC`[1,I];
                        K=PVC`[2,I];
                        PC1=PVC`[3,I];
                        PC2=PVC`[4,I];
                        PC3=PVC`[5,I];
                        PC4=PVC`[6,I];
                        GROUPC[COMBC,1]=J;
                        GROUPC[COMBC,2]=K;
                        GROUPC[COMBC,3]=PC1;
                        GROUPC[COMBC,4]=PC2;
                        GROUPC[COMBC,5]=PC3;
                        GROUPC[COMBC,6]=PC4;
                        COMBC=COMBC-1;
                END;
                DO I=1 TO (NROW(GROUPC)-1);
                        DO J=1 TO (NROW(GROUPC)-I);
                                IF ((GROUPC[J,6])>(GROUPC[J+1,6])) THEN DO;
                                        TEMP=GROUPC[J,]; GROUPC[J,]=GROUPC[J+1,]; GROUPC[J+1,]=TEMP;
                                END;
                        END;
                END;
        END;

        IF (PVALC<(0.05))&(NC>2) THEN DO;
                PRINT ''; PRINT 'PAIRWISE COMPARISONS AMONG ALL LEVELS OF FACTOR_C WITH
HOCHBERG''''S H-ADJ-VALUES';
                IF (TESTDV) THEN DO; PRINT 'UNIVARIATE RESULTS FOR DEPENDANT VARIABLE ' TESTDV;
END;
                TEMP=0;
                DO I=1 TO (NROW(GROUPC));
                        GROUP1=GROUPC[I,1];GROUP2=GROUPC[I,2];
                        DF1=GROUPC[I,3];DF2=GROUPC[I,4];
                        FVALUE=GROUPC[I,5];PVALUE=GROUPC[I,6];
                        ADJUSTEDP=GROUPC[I,6]*(NROW(GROUPC)+1-I);
                        IF (ADJUSTEDP>0.05) THEN TEMP=1;
                        IF (TEMP) THEN ADJUSTEDP=GROUPC[NROW(GROUPC),6];
                        IF I=1 THEN PRINT GROUP1 [format=2.0] '' GROUP2 [format=2.0] [LABEL='TEST']
'|' DF1 [LABEL='DF1'] [format=5.3] ' '
                        DF2 [format=5.3] [LABEL='DF2'] '|' FVALUE [format=5.4][LABEL='F VALUE'] '|'
PVALUE [LABEL='P VALUE'] '|' ADJUSTEDP [LABEL='H-ADJ'];
                        ELSE PRINT GROUP1 [format=2.0] '' GROUP2 [format=4.0]
                        '|' DF1 [format=5.3] ' ' DF2 [format=5.3] '|' FVALUE [format=6.4] ' |'
PVALUE '|' ADJUSTEDP;
                END;
        END;
FINISH;

START INTER_AC_TEST;
```

```
        AG=CA@(J(1,NB,1))@(J(1,NC,1));
        CG=(J(1,NA,1))@(J(1,NB,1))@CC;
        RG=T(HDIR(AG`,CG`));
        CAC=RG`;
        F=1;
        M=0;
        DO J=1 TO NCOL(NAC);
                L=M+NAC[J];
        END;
        COMBK=((NA*(NA-1))/2)*((NC*(NC-1))/2);
        PVK1=J(COMBK,COMBK,0);PVK2=J(COMBK,COMBK,0);PVK3=J(COMBK,COMBK,0);PVK4=J(COMBK,COMBK,0);
        DO K=1 TO NCOL(CAC);
                CTAC=CAC[F:L,K];
                AC=CTAC`;
                RGJ=AC;
                IF ((PVALK<(0.05))&(NAC>4)) THEN DO;RUN MBF(TESTDV, CJ, NI, RGJ, DFJ1, DFJ2, FVALJ,
PVALJ);
                        IF K>=1 THEN DO;
                                R=K#1;T=K#1;
                                PVK1[R:T,R:T]=DFJ1;
                                PVK2[R:T,R:T]=DFJ2;
                                PVK3[R:T,R:T]=FVALJ;
                                PVK4[R:T,R:T]=PVALJ;
                        END;
                END;
        END;

        IF ((PVALK<(0.05))&(NAC>4)) THEN DO;RUN MBF(TESTDV, CJ, NI, RGJ, DFJ1, DFJ2, FVALJ,
PVALJ);
                INTERACV=REPEAT(0,COMBK,4);
                DO I=1 TO (NA-1);
                        DO J=I+1 TO NA;
                                DO K=1 TO (NC-1);
                                        DO L=K+1 TO NC;
                                                INTERACV[COMBK,1]=I;
                                                INTERACV[COMBK,2]=J;
                                                INTERACV[COMBK,3]=K;
                                                INTERACV[COMBK,4]=L;
                                                IF NC>1 THEN DO;
                                                        JK1=(JK1||I);
                                                        JK2=(JK2||J);
                                                        JK3=(JK3||K);
                                                        JK4=(JK4||L);
                                                END;
                                        END;
                                END;
                        END;
                END;
                JK11=JK1[1:COMBK];
                JK22=JK2[1:COMBK];
                JK33=JK3[1:COMBK];
                JK44=JK4[1:COMBK];
                INTERACV=REPEAT(0,COMBK,8);

        PVK=(JK11||JK22||JK33||JK44||(VECDIAG(PVK1))||(VECDIAG(PVK2))||(VECDIAG(PVK3))||(VECDIAG(P
VK4)));
                DO I=1 TO NROW(PVK);
                        J=PVK`[1,I];
                        K=PVK`[2,I];
                        L=PVK`[3,I];
                        M=PVK`[4,I];
                        PK1=PVK`[5,I];
                        PK2=PVK`[6,I];
                        PK3=PVK`[7,I];
                        PK4=PVK`[8,I];
                        INTERACV[COMBK,1]=J;
                        INTERACV[COMBK,2]=K;
                        INTERACV[COMBK,3]=L;
                        INTERACV[COMBK,4]=M;
                        INTERACV[COMBK,5]=PK1;
                        INTERACV[COMBK,6]=PK2;
                        INTERACV[COMBK,7]=PK3;
                        INTERACV[COMBK,8]=PK4;
                        COMBK=COMBK-1;
                END;
                DO I=1 TO (NROW(INTERACV)-1);
                        DO J=1 TO (NROW(INTERACV)-I);
                                IF ((INTERACV[J,8])>(INTERACV[J+1,8])) THEN DO;
                                        TEMP=INTERACV[J,]; INTERACV[J,]=INTERACV[J+1,];
INTERACV[J+1,]=TEMP;
                                END;
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                        END;
                END;
        END;

        IF ((PVALK<(0.05))&(NAC>4)) THEN DO;
                PRINT '' ; PRINT 'INTERACTION A×C PAIRWISE COMPARISONS WITH HOCHBERG''''S H-ADJ-
VALUES';
                IF (TESTDV) THEN DO; PRINT ''; PRINT 'UNIVARIATE RESULTS FOR DEPENDANT VARIABLE '
TESTDV; END;
                TEMP=0;
                DO I=1 TO (NROW(INTERACV));
                        GROUP1=INTERACV[I,1];GROUP2=INTERACV[I,2];
                        TIME1=INTERACV[I,3]; TIME2=INTERACV[I,4];
                        DF1=INTERACV[I,5];DF2=INTERACV[I,6];
                        FVALUE=INTERACV[I,7];PVALUE=INTERACV[I,8];
                        ADJUSTEDP=INTERACV[I,8]*(NROW(INTERACV)+1-I);
                        IF ((ADJUSTEDP>0.05)&(TEMP=0)) THEN TEMP=1; IF(TEMP) THEN
ADJUSTEDP=INTERACV[NROW(INTERACV),8];
                        IF I=1 THEN PRINT GROUP1 [format=1.9] '' GROUP2 [format=1.0]
[LABEL='FACT A'] '|' TIME1 [format=1.0] '' TIME2[format=1.0][LABEL='FACT_C'] '|'
                        DF1 [format=5.3] [LABEL='DF1']
                        ' ' DF2 [format=5.3][LABEL='DF2'] '|' FVALUE [format=7.3] [LABEL='F VALUE']
'|' PVALUE [LABEL='P VALUE'] '|' ADJUSTEDP [LABEL='H-ADJ'];
                        ELSE PRINT GROUP1 [format=2.0] '' GROUP2 [format=6.0] '|' TIME1 [format=2.0]
'' TIME2 [format=4.0] '|' DF1 [format=5.3]
                        ' ' DF2 [format=5.3] '|' FVALUE [format=7.3] '|' PVALUE '|' ADJUSTEDP;
                END;
        END;
FINISH;

START INTER BC TEST;
        BG=(J(1,NA,1))@CB@(J(1,NC,1));
        CG=(J(1,NA,1))@(J(1,NB,1))@CC;
        RG=T(HDIR(BG`,CG`));
        CBC=RG`;
        F=1;
        M=0;
        DO J=1 TO NCOL(NBC);
                L=M+NBC[J];
        END;
        COMBL=((NB*(NB-1))/2)*((NC*(NC-1))/2);
        PVL1=J(COMBL,COMBL,0);PVL2=J(COMBL,COMBL,0);PVL3=J(COMBL,COMBL,0);PVL4=J(COMBL,COMBL,0);
        DO K=1 TO NCOL(CBC);
                CTBC=CBC[F:L,K];
                BC=CTBC`;
                RGJ=BC;
                IF ((PVALL<(0.05))&(NBC>4)) THEN DO;RUN MBF(TESTDV,CJ, NI, RGJ, DFJ1, DFJ2, FVALJ,
PVALJ);
                        IF K>=1 THEN DO;
                                R=K#1;T=K#1;
                                PVL1[R:T,R:T]=DFJ1;
                                PVL2[R:T,R:T]=DFJ2;
                                PVL3[R:T,R:T]=FVALJ;
                                PVL4[R:T,R:T]=PVALJ;
                        END;
                END;
        END;

        IF ((PVALL<(0.05))&(NBC>4)) THEN DO;RUN MBF(TESTDV,CJ, NI, RGJ, DFJ1, DFJ2, FVALJ, PVALJ);
                COMBL=((NB*(NB-1))/2)*((NC*(NC-1))/2);
                INTERACV=REPEAT(0,COMBL,4);
                DO I=1 TO (NB-1);
                        DO J=I+1 TO NB;
                                DO K=1 TO (NC-1);
                                        DO L=K+1 TO NC;
                                                INTERACV[COMBL,1]=I;
                                                INTERACV[COMBL,2]=J;
                                                INTERACV[COMBL,3]=K;
                                                INTERACV[COMBL,4]=L;
                                                IF NC>1 THEN DO;
                                                        JL1=(JL1||I);
                                                        JL2=(JL2||J);
                                                        JL3=(JL3||K);
                                                        JL4=(JL4||L);
                                                END;
                                        END;
                                END;
                        END;
                END;
                JL11=JL1[1:COMBL];
                JL22=JL2[1:COMBL];
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                JL33=JL3[1:COMBL];
                JL44=JL4[1:COMBL];
                INTERACV=REPEAT(0,COMBL,8);

        PVL=(JL11||JL22||JL33||JL44||(VECDIAG(PVL1))||(VECDIAG(PVL2))||(VECDIAG(PVL3))||(VECDIAG(P
VL4)));
                DO I=1 TO NROW(PVL);
                        J=PVL`[1,I];
                        K=PVL`[2,I];
                        L=PVL`[3,I];
                        M=PVL`[4,I];
                        PL1=PVL`[5,I];
                        PL2=PVL`[6,I];
                        PL3=PVL`[7,I];
                        PL4=PVL`[8,I];
                        INTERACV[COMBL,1]=J;
                        INTERACV[COMBL,2]=K;
                        INTERACV[COMBL,3]=L;
                        INTERACV[COMBL,4]=M;
                        INTERACV[COMBL,5]=PL1;
                        INTERACV[COMBL,6]=PL2;
                        INTERACV[COMBL,7]=PL3;
                        INTERACV[COMBL,8]=PL4;
                        COMBL=COMBL-1;
                        END;
                DO I=1 TO (NROW(INTERACV)-1);
                        DO J=1 TO (NROW(INTERACV)-I);
                                IF ((INTERACV[J,8])>(INTERACV[J+1,8])) THEN DO;
                                        TEMP=INTERACV[J,]; INTERACV[J,]=INTERACV[J+1,];
INTERACV[J+1,]=TEMP;
                                END;
                        END;
                END;
        END;

        IF ((PVALL<(0.05))&(NBC>4)) THEN DO;
                PRINT '' ; PRINT 'INTERACTION B×C PAIRWISE COMPARISONS WITH HOCHBERG''''S H-ADJ-
VALUES';
                IF (TESTDV) THEN DO; PRINT ''; PRINT 'UNIVARIATE RESULTS FOR DEPENDANT VARIABLE '
TESTDV; END;
                TEMP=0;
                DO I=1 TO (NROW(INTERACV));
                        GROUP1=INTERACV[I,1];GROUP2=INTERACV[I,2];
                        TIME1=INTERACV[I,3]; TIME2=INTERACV[I,4];
                        DF1=INTERACV[I,5];DF2=INTERACV[I,6];
                        FVALUE=INTERACV[I,7];PVALUE=INTERACV[I,8];
                        ADJUSTEDP=INTERACV[I,8]*(NROW(INTERACV)+1-I);
                        IF ((ADJUSTEDP>0.05)&(TEMP=0)) THEN TEMP=1; IF(TEMP) THEN
ADJUSTEDP=INTERACV[NROW(INTERACV),8];
                        IF I=1 THEN PRINT GROUP1 [format=1.9] '' GROUP2 [format=1.0]
[LABEL='FACT B'] '|' TIME1 [format=1.0] '' TIME2[format=1.0][LABEL='FACT_C'] '|'
                        DF1 [format=5.3] [LABEL='DF1']
                        ' ' DF2 [format=5.3][LABEL='DF2'] '|' FVALUE [format=7.3] [LABEL='F VALUE']
'|' PVALUE [LABEL='P VALUE'] '|' ADJUSTEDP [LABEL='H-ADJ'];
                        ELSE PRINT GROUP1 [format=2.0] '' GROUP2 [format=6.0] '|' TIME1 [format=2.0]
'' TIME2 [format=4.0] '|' DF1 [format=5.3]
                        ' ' DF2 [format=5.3] '|' FVALUE [format=7.3] '|' PVALUE '|' ADJUSTEDP;
                END;
        END;
FINISH;

START INTER ABC TEST;
        AG=CA@(J(1,NB,1))@(J(1,NC,1));
        BG=(J(1,NA,1))@CB@(J(1,NC,1));
        CG=(J(1,NA,1))@(J(1,NB,1))@CC;
        GAB=T(HDIR(AG`,BG`));
        RG=T(HDIR(GAB`,CG`));
        CABC=RG`;
        F=1;
        M=0;
        DO J=1 TO NCOL(NABC);
                L=M+NABC[J];
        END;
        COMBN=((NA*(NA-1))/2)*((NB*(NB-1))/2)*((NC*(NC-1))/2);
        PVN1=J(COMBN,COMBN,0);PVN2=J(COMBN,COMBN,0);PVN3=J(COMBN,COMBN,0);PVN4=J(COMBN,COMBN,0);
        DO K=1 TO NCOL(CABC);
                CTABC=CABC[F:L,K];
                ABC=CTABC`;
                RGJ=ABC;
                IF ((PVALN<(0.05))&(NABC>4)) THEN DO;RUN MBF(TESTDV, CJ, NI, RGJ, DFJ1, DFJ2,
FVALJ, PVALJ);
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                        IF K>=1 THEN DO;
                                R=K#1;T=K#1;
                                PVN1[R:T,R:T]=DFJ1;
                                PVN2[R:T,R:T]=DFJ2;
                                PVN3[R:T,R:T]=FVALJ;
                                PVN4[R:T,R:T]=PVALJ;
                        END;
                END;
        END;

        IF ((PVALN<(0.05))&(NABC>4)) THEN DO;RUN MBF(TESTDV, CJ, NI, RGJ, DFJ1, DFJ2, FVALJ,
PVALJ);
                INTERACV=REPEAT(0,COMBN,6);
                DO I=1 TO (NA-1);
                        DO J=I+1 TO NA;
                                DO K=1 TO (NB-1);
                                        DO L=K+1 TO NB;
                                                DO M=1 TO (NC-1);
                                                        DO N=M+1 TO NC;
                                                                INTERACV[COMBN,1]=I;
                                                                INTERACV[COMBN,2]=J;
                                                                INTERACV[COMBN,3]=K;
                                                                INTERACV[COMBN,4]=L;
                                                                INTERACV[COMBN,5]=M;
                                                                INTERACV[COMBN,6]=N;
                                                                        IF NC>1 THEN DO;
                                                                                JN1=(JN1||I);
                                                                                JN2=(JN2||J);
                                                                                JN3=(JN3||K);
                                                                                JN4=(JN4||L);
                                                                                JN5=(JN5||M);
                                                                                JN6=(JN6||N);
                                                                        END;
                                                                END;
                                                        END;
                                                END;
                                        END;
                                END;
                        END;
                 JN11=JN1[1:COMBN];
                 JN22=JN2[1:COMBN];
                 JN33=JN3[1:COMBN];
                 JN44=JN4[1:COMBN];
                 JN55=JN5[1:COMBN];
                 JN66=JN6[1:COMBN];
                 INTERACV=REPEAT(0,COMBN,10);

PVN=(JN11||JN22||JN33||JN44||JN55||JN66||(VECDIAG(PVN1))||(VECDIAG(PVN2))||(VECDIAG(PVN3))||(VECDI
AG(PVN4)));
                 DO I=1 TO NROW(PVN);
                        J=PVN`[1,I];
                        K=PVN`[2,I];
                        L=PVN`[3,I];
                        M=PVN`[4,I];
                        N=PVN`[5,I];
                        P=PVN`[6,I];
                        PN1=PVN`[7,I];
                        PN2=PVN`[8,I];
                        PN3=PVN`[9,I];
                        PN4=PVN`[10,I];
                        INTERACV[COMBN,1]=J;
                        INTERACV[COMBN,2]=K;
                        INTERACV[COMBN,3]=L;
                        INTERACV[COMBN,4]=M;
                        INTERACV[COMBN,5]=N;
                        INTERACV[COMBN,6]=P;
                        INTERACV[COMBN,7]=PN1;
                        INTERACV[COMBN,8]=PN2;
                        INTERACV[COMBN,9]=PN3;
                        INTERACV[COMBN,10]=PN4;
                        COMBN=COMBN-1;
                END;
                DO I=1 TO (NROW(INTERACV)-1);
                        DO J=1 TO (NROW(INTERACV)-I);
                                IF ((INTERACV[J,10])>(INTERACV[J+1,10])) THEN DO;
                                        TEMP=INTERACV[J,]; INTERACV[J,]=INTERACV[J+1,];
INTERACV[J+1,]=TEMP;
                                END;
                        END;
                END;
        END;
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        IF ((PVALN<(0.05))&(NABC>4)) THEN DO;
                PRINT '' ; PRINT 'INTERACTION A×B×C PAIRWISE COMPARISONS WITH HOCHBERG''''S H-ADJ-
VALUES';
                IF (TESTDV) THEN DO; PRINT ''; PRINT 'UNIVARIATE RESULTS FOR DEPENDANT VARIABLE '
TESTDV; END;
                TEMP=0;
                DO I=1 TO (NROW(INTERACV));
                        GROUP1=INTERACV[I,1];GROUP2=INTERACV[I,2];
                        TIME1=INTERACV[I,3]; TIME2=INTERACV[I,4];
                        TIME3=INTERACV[I,5]; TIME4=INTERACV[I,6];
                        DF1=INTERACV[I,7];DF2=INTERACV[I,8];
                        FVALUE=INTERACV[I,9];PVALUE=INTERACV[I,10];
                        ADJUSTEDP=INTERACV[I,10]*(NROW(INTERACV)+1-I);
                        IF ((ADJUSTEDP>0.05)&(TEMP=0)) THEN TEMP=1; IF(TEMP) THEN
ADJUSTEDP=INTERACV[NROW(INTERACV),10];
                        IF I=1 THEN PRINT GROUP1 [format=1.9] '' GROUP2 [format=1.0]
[LABEL='FACT A'] '|' TIME1 [format=1.0] '' TIME2[format=1.0][LABEL='FACT B'] '|'
                        TIME3 [format=1.0] '' TIME4[format=1.0][LABEL='FACT_C'] '|' DF1 [format=5.3]
[LABEL='DF1']
                        ' ' DF2 [format=5.3][LABEL='DF2'] '|' FVALUE [format=7.3] [LABEL='F VALUE']
'|' PVALUE [LABEL='P VALUE'] '|' ADJUSTEDP [LABEL='H-ADJ'];
                        ELSE PRINT GROUP1 [format=2.0] '' GROUP2 [format=6.0] '|' TIME1 [format=2.0]
'' TIME2 [format=4.0] '|' TIME3 [format=2.0] '' TIME4 [format=4.0] '|' DF1 [format=5.3]
                        ' ' DF2 [format=5.3] '|' FVALUE [format=7.3] '|' PVALUE '|' ADJUSTEDP;
                END;
        END;
FINISH;

START DEPVARTEST;
        DO TESTDV=1 TO NDV;
                IF (NDV>1) THEN DO;
                        RUN OMNIRESULTS;
                        RUN FACTOR A TEST;
                        RUN FACTOR B TEST;
                        RUN INTER AB TEST;
                        RUN FACTOR C TEST;
                        RUN INTER AC TEST;
                        RUN INTER BC TEST;
                        RUN INTER_ABC_TEST;
                END;
        END;
FINISH;

IF TESTOMNI=1 THEN RUN OMNIRESULTS;
IF TESTFACTOR A =1 THEN RUN FACTOR A TEST;
IF TESTFACTOR_B_=1 THEN RUN FACTOR_B_TEST;
IF TESTINTER AB =1 THEN RUN INTER AB TEST;
IF TESTFACTOR C =1 THEN RUN FACTOR C TEST;
IF TESTINTER AC =1 THEN RUN INTER AC TEST;
IF TESTINTER BC =1 THEN RUN INTER BC TEST;
IF TESTINTER ABC =1 THEN RUN INTER ABC_TEST;
IF TESTDEPVAR=1 THEN RUN DEPVARTEST;
PROC PRINT;
```