

# Multivariate analysis of covariance on the bunny data

```
/* mvbunnylec.sas */
title 'Multivariate analysis of covariance on the bunny data';
options linesize=79 noovp formdlim='- ' nodate;

data implant;
  infile 'bunnies.data';
  input id $ day drug stiff force preload;
  time = day/3;
  drugtime = 10*drug + time;
  /* Indicators for all eight treatment combinations */
  if drugtime = 1 then dt01=1; else dt01=0;
  if drugtime = 2 then dt02=1; else dt02=0;
  if drugtime = 3 then dt03=1; else dt03=0;
  if drugtime = 4 then dt04=1; else dt04=0;
  if drugtime = 11 then dt11=1; else dt11=0;
  if drugtime = 12 then dt12=1; else dt12=0;
  if drugtime = 13 then dt13=1; else dt13=0;
  if drugtime = 14 then dt14=1; else dt14=0;

proc freq;
  tables drugtime;

proc glm;
  class day drug;
  model force stiff = preload day|drug;
  lsmeans day|drug;
  manova h=_all_;

proc reg;
  title2 'Proc reg with cell means coding: No intercept';
  model force stiff = preload dt01--dt14 / noint;
  preload: mtest preload=0;
  /* Lambda = 0.65085324 */
  day: mtest dt01+dt11=dt02+dt12,
        dt02+dt12=dt03+dt13,
        dt03+dt13=dt04+dt14;
  /* Lambda = 0.53445846 */
  drug: mtest dt01+dt02+dt03+dt04=dt11+dt12+dt13+dt14;
  /* Lambda = 0.70538200 */
  inter: mtest dt01-dt11=dt02-dt12,
             dt02-dt12=dt03-dt13,
             dt03-dt13=dt04-dt14;
  /* Lambda = 0.78862025 */
  drug12: mtest dt04-dt14; /* Multivariate Drug effect just at day 12 */
  uni12: test dt04-dt14; /* Univariate Drug effects just at day 12 */

/*
proc freq;
  tables drugtime * (dt01--dt14) / norow nocol nopercnt;
```

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The FREQ Procedure

drugtime	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	5	12.50	5	12.50
2	5	12.50	10	25.00
3	5	12.50	15	37.50
4	5	12.50	20	50.00
11	5	12.50	25	62.50
12	5	12.50	30	75.00
13	5	12.50	35	87.50
14	5	12.50	40	100.00

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The GLM Procedure

Class Level Information

Class	Levels	Values
day	4	3 6 9 12
drug	2	0 1

Number of Observations Read 40  
Number of Observations Used 40

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The GLM Procedure

Dependent Variable: force

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	252224.1570	31528.0196	4.73	0.0007
Error	31	206548.5980	6662.8580		
Corrected Total	39	458772.7550			

R-Square Coeff Var Root MSE force Mean  
0.549780 77.35260 81.62633 105.5250

Source	DF	Type I SS	Mean Square	F Value	Pr > F
preload	1	9491.7128	9491.7128	1.42	0.2417
day	3	119358.7565	39786.2522	5.97	0.0025
drug	1	79975.5589	79975.5589	12.00	0.0016
day*drug	3	43398.1288	14466.0429	2.17	0.1114

Source	DF	Type III SS	Mean Square	F Value	Pr > F
preload	1	7397.0980	7397.0980	1.11	0.3002
day	3	119356.1002	39785.3667	5.97	0.0025
drug	1	78094.6857	78094.6857	11.72	0.0018
day*drug	3	43398.1288	14466.0429	2.17	0.1114

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The GLM Procedure

Dependent Variable: stiff

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	189364.7156	23670.5894	3.42	0.0062
Error	31	214322.8844	6913.6414		
Corrected Total	39	403687.6000			

R-Square	Coeff Var	Root MSE	stiff Mean
0.469087	43.90090	83.14831	189.4000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
preload	1	14635.3828	14635.3828	2.12	0.1557
day	3	110969.4228	36989.8076	5.35	0.0044
drug	1	23966.1732	23966.1732	3.47	0.0721
day*drug	3	39793.7368	13264.5789	1.92	0.1471

Source	DF	Type III SS	Mean Square	F Value	Pr > F
preload	1	22619.5156	22619.5156	3.27	0.0802
day	3	110762.0466	36920.6822	5.34	0.0044
drug	1	23424.6791	23424.6791	3.39	0.0753
day*drug	3	39793.7368	13264.5789	1.92	0.1471

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The GLM Procedure  
Least Squares Means

day	force LSMEAN	stiff LSMEAN
3	49.707978	120.450371
6	63.213945	154.765158
9	121.306808	237.835025
12	187.871269	244.549447

drug	force LSMEAN	stiff LSMEAN
0	149.975057	213.744363
1	61.074943	165.055637

day	drug	force LSMEAN	stiff LSMEAN
3	0	58.621332	103.800833
3	1	40.794624	137.099909
6	0	79.780433	158.486232
6	1	46.647456	151.044083
9	0	183.631197	292.200460
9	1	58.982420	183.469590
12	0	277.867267	300.489927
12	1	97.875271	188.608967

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The GLM Procedure  
Multivariate Analysis of Variance

Characteristic Roots and Vectors of: E Inverse \* H, where  
H = Type III SSCP Matrix for preload  
E = Error SSCP Matrix

Characteristic Root	Percent	Characteristic Vector force	V'EV=1 stiff
0.53644469	100.00	-0.00298767	0.00316138
0.00000000	0.00	0.00147859	0.00084555

MANOVA Test Criteria and Exact F Statistics for  
the Hypothesis of No Overall preload Effect  
H = Type III SSCP Matrix for preload  
E = Error SSCP Matrix

S=1 M=0 N=14

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.65085324	8.05	2	30	0.0016
Pillai's Trace	0.34914676	8.05	2	30	0.0016
Hotelling-Lawley Trace	0.53644469	8.05	2	30	0.0016
Roy's Greatest Root	0.53644469	8.05	2	30	0.0016

Characteristic Roots and Vectors of: E Inverse \* H, where  
H = Type III SSCP Matrix for day  
E = Error SSCP Matrix

Characteristic Root	Percent	Characteristic Vector force	V'EV=1 stiff
0.60583567	78.58	0.00149839	0.00082454
0.16515834	21.42	-0.00297779	0.00316693

MANOVA Test Criteria and F Approximations for  
the Hypothesis of No Overall day Effect  
H = Type III SSCP Matrix for day  
E = Error SSCP Matrix

S=2 M=0 N=14

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.53445846	3.68	6	60	0.0035
Pillai's Trace	0.51901882	3.62	6	62	0.0038
Hotelling-Lawley Trace	0.77099401	3.80	6	38.273	0.0046
Roy's Greatest Root	0.60583567	6.26	3	31	0.0019

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

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The GLM Procedure  
Multivariate Analysis of Variance

Characteristic Roots and Vectors of: E Inverse \* H, where  
H = Type III SSCP Matrix for drug  
E = Error SSCP Matrix

Characteristic Root	Percent	Characteristic Vector force	V'EV=1 stiff
0.41767157	100.00	0.00286435	-0.00100737
0.00000000	0.00	-0.00170525	0.00311360

MANOVA Test Criteria and Exact F Statistics  
for the Hypothesis of No Overall drug Effect  
H = Type III SSCP Matrix for drug  
E = Error SSCP Matrix

S=1 M=0 N=14

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.70538200	6.27	2	30	0.0053
Pillai's Trace	0.29461800	6.27	2	30	0.0053
Hotelling-Lawley Trace	0.41767157	6.27	2	30	0.0053
Roy's Greatest Root	0.41767157	6.27	2	30	0.0053

Characteristic Roots and Vectors of: E Inverse \* H, where  
H = Type III SSCP Matrix for day\*drug  
E = Error SSCP Matrix

Characteristic Root	Percent	Characteristic Vector force	V'EV=1 stiff
0.22229546	85.59	0.00148371	0.00084013
0.03742301	14.41	-0.00298513	0.00316283

MANOVA Test Criteria and F Approximations for  
the Hypothesis of No Overall day\*drug Effect  
H = Type III SSCP Matrix for day\*drug  
E = Error SSCP Matrix

S=2 M=0 N=14

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.78862025	1.26	6	60	0.2891
Pillai's Trace	0.21794026	1.26	6	62	0.2872
Hotelling-Lawley Trace	0.25971847	1.28	6	38.273	0.2899
Roy's Greatest Root	0.22229546	2.30	3	31	0.0970

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

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Proc reg with cell means coding: No intercept

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The REG Procedure  
Model: MODEL1  
Dependent Variable: force

Number of Observations Read 40  
Number of Observations Used 40

NOTE: No intercept in model. R-Square is redefined.

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	697645	77516	11.63	<.0001
Error	31	206549	6662.85800		
Uncorrected Total	40	904194			

Root MSE 81.62633 R-Square 0.7716  
Dependent Mean 105.52500 Adj R-Sq 0.7052  
Coeff Var 77.35260

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr >  t
preload	1	-0.49258	0.46750	-1.05	0.3002
dt01	1	108.03952	61.24780	1.76	0.0876
dt02	1	129.19862	66.46119	1.94	0.0610
dt03	1	233.04938	53.95932	4.32	0.0001
dt04	1	327.28545	60.94790	5.37	<.0001
dt11	1	90.21281	62.60723	1.44	0.1596
dt12	1	96.06564	55.07031	1.74	0.0910
dt13	1	108.40060	50.74518	2.14	0.0407
dt14	1	147.29346	65.68187	2.24	0.0322

The REG Procedure  
 Model: MODEL1  
 Dependent Variable: stiff

Number of Observations Read 40  
 Number of Observations Used 40

NOTE: No intercept in model. R-Square is redefined.

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	1624259	180473	26.10	<.0001
Error	31	214323	6913.64143		
Uncorrected Total	40	1838582			

Root MSE 83.14831 R-Square 0.8834  
 Dependent Mean 189.40000 Adj R-Sq 0.8496  
 Coeff Var 43.90090

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr >  t
preload	1	0.86137	0.47621	1.81	0.0802
dt01	1	17.38412	62.38981	0.28	0.7824
dt02	1	72.06952	67.70040	1.06	0.2953
dt03	1	205.78375	54.96543	3.74	0.0007
dt04	1	214.07321	62.08431	3.45	0.0016
dt11	1	50.68320	63.77459	0.79	0.4328
dt12	1	64.62737	56.09713	1.15	0.2581
dt13	1	97.05288	51.69136	1.88	0.0699
dt14	1	102.19225	66.90655	1.53	0.1368



Multivariate analysis of covariance on the bunny data  
 Proc reg with cell means coding: No intercept

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The REG Procedure  
 Model: MODEL1  
 Multivariate Test: preload

Multivariate Statistics and Exact F Statistics

	S=1	M=0	N=14			
Statistic	Value	F Value	Num DF	Den DF	Pr > F	
Wilks' Lambda	0.65085324	8.05	2	30	0.0016	
Pillai's Trace	0.34914676	8.05	2	30	0.0016	
Hotelling-Lawley Trace	0.53644469	8.05	2	30	0.0016	
Roy's Greatest Root	0.53644469	8.05	2	30	0.0016	

The REG Procedure  
 Model: MODEL1  
 Multivariate Test: day

Multivariate Statistics and F Approximations

	S=2	M=0	N=14			
Statistic	Value	F Value	Num DF	Den DF	Pr > F	
Wilks' Lambda	0.53445846	3.68	6	60	0.0035	
Pillai's Trace	0.51901882	3.62	6	62	0.0038	
Hotelling-Lawley Trace	0.77099401	3.80	6	38.273	0.0046	
Roy's Greatest Root	0.60583567	6.26	3	31	0.0019	

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

The REG Procedure  
 Model: MODEL1  
 Multivariate Test: drug

Multivariate Statistics and Exact F Statistics

	S=1	M=0	N=14			
Statistic	Value	F Value	Num DF	Den DF	Pr > F	
Wilks' Lambda	0.70538200	6.27	2	30	0.0053	
Pillai's Trace	0.29461800	6.27	2	30	0.0053	
Hotelling-Lawley Trace	0.41767157	6.27	2	30	0.0053	
Roy's Greatest Root	0.41767157	6.27	2	30	0.0053	

Multivariate analysis of covariance on the bunny data  
 Proc reg with cell means coding: No intercept

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The REG Procedure  
 Model: MODEL1  
 Multivariate Test: inter

Multivariate Statistics and F Approximations

S=2 M=0 N=14

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.78862025	1.26	6	60	0.2891
Pillai's Trace	0.21794026	1.26	6	62	0.2872
Hotelling-Lawley Trace	0.25971847	1.28	6	38.273	0.2899
Roy's Greatest Root	0.22229546	2.30	3	31	0.0970

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

The REG Procedure  
 Model: MODEL1  
 Multivariate Test: drug12

Multivariate Statistics and Exact F Statistics

S=1 M=0 N=14

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.71178812	6.07	2	30	0.0061
Pillai's Trace	0.28821188	6.07	2	30	0.0061
Hotelling-Lawley Trace	0.40491247	6.07	2	30	0.0061
Roy's Greatest Root	0.40491247	6.07	2	30	0.0061

Multivariate analysis of covariance on the bunny data  
 Proc reg with cell means coding: No intercept

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The REG Procedure  
 Model: MODEL1

Test uni12 results

Dependent Variable	Source	DF	Mean Square	F Value	Pr > F
force	Numerator	1	79984	12.00	0.0016
	Denominator	31	6662.85800		
stiff	Numerator	1	30904	4.47	0.0426
	Denominator	31	6913.64143		