One Between, One Within (Multivariate)

```
/* monkey1.sas */
options linesize=79 pagesize=100 noovp formdlim='_' nodate;
title 'Primate hippocampal function: Zola-Morgan and Squire, 1990';
/* Science, Vol. 250 (12 Oct. 1990) , Pages 288-290 */
title2 'Multivariate approach to repeated measures (within-cases)';

data memory;
     infile 'monkey.data' firstobs=2;     input monkey $ treatmnt $ week2 week4 week8
week12 week16;
proc means mean;
     class treatmnt;
     var week2 -- week16;
proc glm;
     class treatmnt;
     model week2 -- week16 = treatmnt;
     repeated time profile /  short summary nouni mean;
proc glm;
     title3 'Replicate test for main effect of treatment: F=8.08, p=0.0118';
     class treatmnt;
     model week2 -- week16 = treatmnt;
     manova H = treatmnt
            M = week2+week4+week8+week12+week16 / short;
     /* M is a matrix of coefficients for transforming the DVs */
proc glm;
     title3 'Replicate tests for main effect of time: Lambda=0.84009249';
     title4 'And time by treatment interaction: Lambda=0.44106117';
     class treatmnt;
     model week2 -- week16 = treatmnt;
     manova H = intercept treatmnt
            M = week2-week4, week4-week8, week8-week12, week12-week16
               / short;

/* But the real point is that the treatment only affects recent memories, not
older ones. A basic MANOVA is really more to the point. Follow up with
Bonferroni. */

proc glm;
     title3 'MANOVA, no repeated measures';
     class treatmnt;
     model week2 -- week16 = treatmnt;
     manova h = treatmnt;
```

The MEANS Procedure

treatmnt	N Obs	Variable	Mean
CONTROL	7	week2	78.5714286
		week4	82.1428571
		week8	70.7142857
		week12	62.1428571
		week16	70.0000000
TREATED	11	week2	62.2727273
		week4	64.0909091
		week8	65.4545455
		week12	72.2727273
		week16	67.2727273

The GLM Procedure

Class Level Information

Class	Levels	Values
treatmnt	2	CONTROL TREATED

Number of Observations Read	18
Number of Observations Used	18

The GLM Procedure

Dependent Variable: week2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1136.381674	1136.381674	10.37	0.0054
Error	16	1753.896104	109.618506		
Corrected Total	17	2890.277778			

R-Square	Coeff Var	Root MSE	week2 Mean
0.393174	15.25975	10.46989	68.61111

Source	DF	Type I SS	Mean Square	F Value	Pr > F
treatmnt	1	1136.381674	1136.381674	10.37	0.0054

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treatmnt	1	1136.381674	1136.381674	10.37	0.0054

The GLM Procedure

Dependent Variable: week4

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1394.011544	1394.011544	17.37	0.0007
Error	16	1283.766234	80.235390		
Corrected Total	17	2677.777778			

R-Square	Coeff Var	Root MSE	week4 Mean
0.520585	12.59637	8.957421	71.11111

Source	DF	Type I SS	Mean Square	F Value	Pr > F
treatmnt	1	1394.011544	1394.011544	17.37	0.0007

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treatmnt	1	1394.011544	1394.011544	17.37	0.0007

The GLM Procedure

Dependent Variable: week8

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	118.344156	118.344156	1.15	0.2991
Error	16	1644.155844	102.759740		
Corrected Total	17	1762.500000			

R-Square	Coeff Var	Root MSE	week8 Mean
0.067146	15.01785	10.13705	67.50000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
treatmnt	1	118.3441558	118.3441558	1.15	0.2991

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treatmnt	1	118.3441558	118.3441558	1.15	0.2991

The GLM Procedure

Dependent Variable: week12

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	438.961039	438.961039	4.50	0.0499
Error	16	1561.038961	97.564935		
Corrected Total	17	2000.000000			

R-Square	Coeff Var	Root MSE	week12 Mean
0.219481	14.45487	9.877496	68.33333

Source	DF	Type I SS	Mean Square	F Value	Pr > F
treatmnt	1	438.9610390	438.9610390	4.50	0.0499

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treatmnt	1	438.9610390	438.9610390	4.50	0.0499

The GLM Procedure

Dependent Variable: week16

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	31.818182	31.818182	0.31	0.5826
Error	16	1618.181818	101.136364		
Corrected Total	17	1650.000000			

R-Square	Coeff Var	Root MSE	week16 Mean
0.019284	14.71706	10.05666	68.33333

Source	DF	Type I SS	Mean Square	F Value	Pr > F
treatmnt	1	31.81818182	31.81818182	0.31	0.5826

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treatmnt	1	31.81818182	31.81818182	0.31	0.5826

The GLM Procedure
Repeated Measures Analysis of Variance

Repeated Measures Level Information

Dependent Variable	week2	week4	week8	week12	week16
Level of time	1	2	3	4	5

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

S=1 M=1 N=5.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.84009249	0.62	4	13	0.6571
Pillai's Trace	0.15990751	0.62	4	13	0.6571
Hotelling-Lawley Trace	0.19034512	0.62	4	13	0.6571
Roy's Greatest Root	0.19034512	0.62	4	13	0.6571

MANOVA Test Criteria and Exact F Statistics for
the Hypothesis of no time*treatmnt Effect
H = Type III SSCP Matrix for time*treatmnt
E = Error SSCP Matrix

S=1 M=1 N=5.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.44106117	4.12	4	13	0.0227
Pillai's Trace	0.55893883	4.12	4	13	0.0227
Hotelling-Lawley Trace	1.26725921	4.12	4	13	0.0227
Roy's Greatest Root	1.26725921	4.12	4	13	0.0227

The GLM Procedure
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treatmnt	1	887.503608	887.503608	8.08	0.0118
Error	16	1758.051948	109.878247		

Need to investigate, but first look at the rest of the output from this `proc glm`.

The GLM Procedure
Repeated Measures Analysis of Variance
Analysis of Variance of Contrast Variables

time_N represents the nth successive difference in time

Contrast Variable: time_1

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Mean	1	124.260462	124.260462	0.66	0.4275
treatmnt	1	13.149351	13.149351	0.07	0.7945
Error	16	2999.350649	187.459416		

Contrast Variable: time_2

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Mean	1	433.351371	433.351371	2.08	0.1689
treatmnt	1	700.018038	700.018038	3.35	0.0858
Error	16	3340.259740	208.766234		

Contrast Variable: time_3

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Mean	1	13.149351	13.149351	0.08	0.7797
treatmnt	1	1013.149351	1013.149351	6.24	0.0238
Error	16	2599.350649	162.459416		

Contrast Variable: time_4

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Mean	1	34.920635	34.920635	0.33	0.5736
treatmnt	1	707.142857	707.142857	6.68	0.0199
Error	16	1692.857143	105.803571		

The GLM Procedure
Repeated Measures Analysis of Variance

Means of Within Subjects Effects

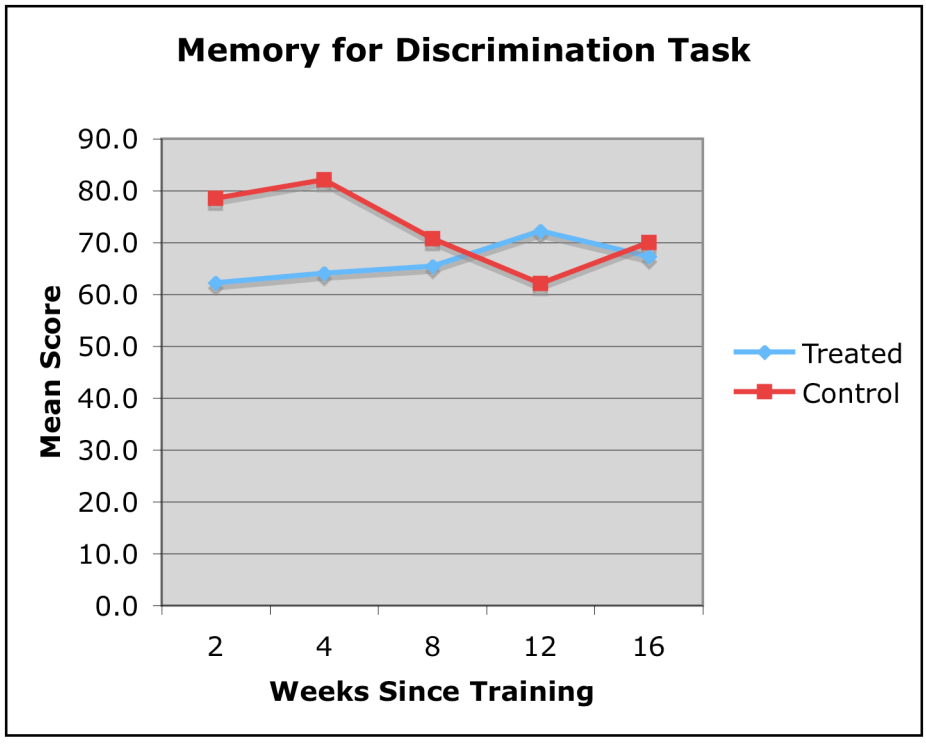
Level of time	N	Mean	Std Dev
1	18	68.61111111	13.03903140
2	18	71.11111111	12.55055138
3	18	67.50000000	10.18216434
4	18	68.33333333	10.84652289
5	18	68.33333333	9.85184366

	2	4	8	12	16	
Treated	62.3	64.1	65.5	72.3	67.3	66.3
Control	78.6	82.1	70.7	62.1	70.0	72.7
	70.4	73.1	68.1	67.2	68.6	69.5

Moral of the story: Watch out! When there are between-cases factors with unequal cell sample sizes, single degree of freedom tests on the within-cases factors are no longer the same as matched *t*-tests. For example, a matched *t* on Week 2 versus 4 gives a p-value of 0.4366, while on the preceding page, the correct test of

$$H_0 : \frac{1}{2}(\mu_{1,1} + \mu_{2,1}) = \frac{1}{2}(\mu_{1,2} + \mu_{2,2})$$

gives a p-value of 0.4275



The GLM Procedure

Class Level Information

Class	Levels	Values
treatmnt	2	CONTROL TREATED

Number of Observations Read	18
Number of Observations Used	18

This time we will skip the 5 sets of univariate output.

M Matrix Describing Transformed Variables

	week2	week4	week8	week12	week16
MVAR1	1	1	1	1	1

MANOVA Test Criteria and Exact F Statistics for
the Hypothesis of No Overall treatmnt Effect
on the Variables Defined by the M Matrix Transformation
H = Type III SSCP Matrix for treatmnt
E = Error SSCP Matrix

S=1 M=-0.5 N=7

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.66453035	8.08	1	16	0.0118
Pillai's Trace	0.33546965	8.08	1	16	0.0118
Hotelling-Lawley Trace	0.50482217	8.08	1	16	0.0118
Roy's Greatest Root	0.50482217	8.08	1	16	0.0118

Skipping univariate output again ...

The GLM Procedure
Multivariate Analysis of Variance

M Matrix Describing Transformed Variables

	week2	week4	week8	week12	week16
MVAR1	1	-1	0	0	0
MVAR2	0	1	-1	0	0
MVAR3	0	0	1	-1	0
MVAR4	0	0	0	1	-1

The GLM Procedure
Multivariate Analysis of Variance

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

Variables have been transformed by the M Matrix

Characteristic Root	Percent	Characteristic Vector V'EV=1 MVAR1	MVAR2	MVAR3	MVAR4
0.19034512	100.00	0.00273242	0.02066960	0.01326881	0.00197175
0.00000000	0.00	0.00913639	0.01141182	0.00864049	0.02826829
0.00000000	0.00	0.02176348	0.01048946	0.00668528	0.00000000
0.00000000	0.00	-0.00026861	-0.00324662	0.01781228	0.00000000

Replicate tests for main effect of time: Lambda=0.84009249
And time by treatment interaction: Lambda=0.44106117

MANOVA Test Criteria and Exact F Statistics for
the Hypothesis of No Overall Intercept Effect
on the Variables Defined by the M Matrix Transformation
H = Type III SSCP Matrix for Intercept
E = Error SSCP Matrix

S=1 M=1 N=5.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.84009249	0.62	4	13	0.6571
Pillai's Trace	0.15990751	0.62	4	13	0.6571
Hotelling-Lawley Trace	0.19034512	0.62	4	13	0.6571
Roy's Greatest Root	0.19034512	0.62	4	13	0.6571

MANOVA Test Criteria and Exact F Statistics for
the Hypothesis of No Overall treatmnt Effect
on the Variables Defined by the M Matrix Transformation
H = Type III SSCP Matrix for treatmnt
E = Error SSCP Matrix

S=1 M=1 N=5.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.44106117	4.12	4	13	0.0227
Pillai's Trace	0.55893883	4.12	4	13	0.0227
Hotelling-Lawley Trace	1.26725921	4.12	4	13	0.0227
Roy's Greatest Root	1.26725921	4.12	4	13	0.0227

The GLM Procedure

Class Level Information

Class	Levels	Values
treatmnt	2	CONTROL TREATED

Number of Observations Read 18
Number of Observations Used 18

The GLM Procedure

Dependent Variable: week2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1136.381674	1136.381674	10.37	0.0054
Error	16	1753.896104	109.618506		
Corrected Total	17	2890.277778			

R-Square	Coeff Var	Root MSE	week2 Mean
0.393174	15.25975	10.46989	68.61111

Source	DF	Type I SS	Mean Square	F Value	Pr > F
treatmnt	1	1136.381674	1136.381674	10.37	0.0054

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treatmnt	1	1136.381674	1136.381674	10.37	0.0054

Dependent Variable: week4

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treatmnt	1	1394.011544	1394.011544	17.37	0.0007

Dependent Variable: week8

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treatmnt	1	118.3441558	118.3441558	1.15	0.2991

Dependent Variable: week12

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treatmnt	1	438.9610390	438.9610390	4.50	0.0499

Dependent Variable: week16

Source	DF	Type III SS	Mean Square	F Value	Pr > F
treatmnt	1	31.81818182	31.81818182	0.31	0.5826

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

S=1 M=1.5 N=5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.30021681	5.59	5	12	0.0069
Pillai's Trace	0.69978319	5.59	5	12	0.0069
Hotelling-Lawley Trace	2.33092613	5.59	5	12	0.0069
Roy's Greatest Root	2.33092613	5.59	5	12	0.0069