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 week4 week8 week12 week16	78.5714286 82.1428571 70.7142857 62.1428571 70.0000000
TREATED	11	week2 week4 week8 week12 week16	62.2727273 64.0909091 65.4545455 72.2727273 67.2727273

Primate hippocampal function: Zola-Morgan and Squire, 1990 Multivariate approach to repeated measures (within-cases)

The GLM Procedure

Class Level Information

Class	Levels	Values
51035	Пелета	Varues

treatmnt	2	CONTROL	TREATED
or ou onni o	-	CONTINOT	TICDITTDD

Number of Observations Read18Number of Observations Used18

Primate hippocampal function: Zola-Morgan and Squire, 1990 Multivariate approach to repeated measures (within-cases)

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			

2

3

Page 2 of 13

	R-Square	Coeff	Var Ro	oot MSE	week2	Mean	
	0.393174	15.2	5975 10	.46989	68.0	51111	
Source		DF	Type I SS	5 Mean	Square	F Value	Pr > F
treatmnt		1	1136.381674	1136	.381674	10.37	0.0054
Source		DF	Type III S	6 Mean	Square	F Value	Pr > F
treatmnt		1	1136.381674	1136	.381674	10.37	0.0054
	Primate hippo Multivariate	campal fu approach	nction: Zola to repeated	a-Morgan 1 measure	and Squi s (with	ire, 1990 in-cases)	4
		Т	he GLM Proce	edure			
Dependent	Variable: wee	k4					
Source		DF	Sum of Squares	f 8 Mean	Square	F Value	Pr > F
Model		1	1394.011544	1394	.011544	17.37	0.0007
Error		16	1283.766234	1 80	.235390		
Corrected	Total	17	2677.77778	3			
	R-Square	Coeff	Var Ro	oot MSE	week4	Mean	
	0.520585	12.5	9637 8.	957421	71.1	11111	
Source		DF	Type I SS	6 Mean	Square	F Value	Pr > F
treatmnt		1	1394.011544	1394	.011544	17.37	0.0007

5

Pr > F

0.0007

The GLM Procedure

Type III SS

1394.011544

Mean Square

1394.011544

F Value

17.37

 DF

1

Source

treatmnt

Dependent Variable: week8

Source		DF	Sur Squa	n of ares	Mean	Square	F Value	Pr > F
Model		1	118.34	4156	118.	344156	1.15	0.2991
Error		16	1644.15	5844	102.	759740		
Corrected To	tal	17	1762.50	0000				
	R-Square	Coef	f Var	Root	MSE	week8	Mean	
	0.067146	15.	01785	10.13	3705	67.5	0000	
Source		DF	Туре 1	I SS	Mean	Square	F Value	Pr > F
treatmnt		1	118.344	1558	118.3	441558	1.15	0.2991
Source		DF	Type II:	I SS	Mean	Square	F Value	Pr > F
treatmnt		1	118.344	1558	118.3	441558	1.15	0.2991
Dependent Va	riable: week1	12	The GLM P	rocedu	re			
L			Sur	m of				
Source		DF	Squa	ares	Mean	Square	F Value	Pr > F
Model		1	438.96	1039	438.	961039	4.50	0.0499
Error		16	1561.03	8961	97.	564935		
Corrected To	tal	17	2000.000	0000				
	R-Square	Coef	f Var	Root	MSE	week12	Mean	
	0.219481	14.	45487	9.87	7496	68.	33333	
Source		DF	Туре 1	I SS	Mean	Square	F Value	Pr > F
treatmnt		1	438.961	0390	438.9	610390	4.50	0.0499
Source		DF	Type II:	I SS	Mean	Square	F Value	Pr > F
treatmnt		1	438.961	0390	438.9	610390	4.50	0.0499

The GLM Procedure

Dependent Variable: week16

Source		DF	Sum	OI PS	Mean	Square	F Value	Pr > F
bource		DI	bquui		neun	bquure	i vuiue	11 / 1
Model		1	31.8181	82	31.	818182	0.31	0.5826
Error		16	1618.1818	818	101.	136364		
Corrected Tot	al	17	1650.0000	000				
	R-Square	Coeff	Var	Root M	4SE	week16	Mean	
	0.019284	14.71	L706	10.056	566	68.3	33333	
Source		DF	Туре І	SS	Mean	Square	F Value	Pr > F
Source treatmnt		DF 1	Type I 31.818181	SS 82	Mean 31.81	Square .818182	F Value 0.31	Pr > F 0.5826
Source treatmnt		DF 1	Type I 31.818181	SS 82	Mean 31.81	Square .818182	F Value 0.31	Pr > F 0.5826
Source treatmnt Source		DF 1 DF	Type I 31.818181 Type III	SS .82 SS	Mean 31.81 Mean	Square 818182 Square	F Value 0.31 F Value	Pr > F 0.5826 Pr > F
Source treatmnt Source treatmnt		DF 1 DF 1	Type I 31.818181 Type III 31.818181	SS .82 SS .82	Mean 31.81 Mean 31.81	Square .818182 Square .818182	F Value 0.31 F Value 0.31	Pr > F 0.5826 Pr > F 0.5826

Primate hippocampal function: Zola-Morgan and Squire, 1990 Multivariate approach to repeated measures (within-cases) 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 N = 5.5S=1 M=1Statistic Value F Value Num DF Den DF Pr > FWilks' Lambda 0.84009249 0.62 0.6571 4 13 Pillai's Trace 0.6571 0.15990751 0.62 4 13 Hotelling-Lawley Trace 0.19034512 0.62 0.6571 4 13 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=1N = 5.5Statistic Value F Value Num DF Den DF Pr > FWilks' Lambda 0.44106117 4.12 4 13 0.0227 Pillai's Trace 0.55893883 4.12 4 13 0.0227 Hotelling-Lawley Trace 4.12 13 0.0227 1.26725921 4 4.12 4 0.0227 Roy's Greatest Root 1.26725921 13 Primate hippocampal function: Zola-Morgan and Squire, 1990 9 Multivariate approach to repeated measures (within-cases) The GLM Procedure Repeated Measures Analysis of Variance Tests of Hypotheses for Between Subjects Effects Mean Square Source DFType III SS F Value Pr > F

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

887.503608

1758.051948

887.503608

109.878247

8.08

0.0118

1

16

treatmnt

Error

Primate hippocampal function: Zola-Morgan and Squire, 1990 Multivariate approach to repeated measures (within-cases)					
		The GLM Procedu	ire		
Repea Analysi	ted M s of '	easures Analysis Variance of Cont	of Variance rast Variables		
time_N represents the nth	succ	essive differenc	e 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		

11

The GLM Procedure Repeated Measures Analysis of Variance

Level of						
time	N		Mea	in	Std Dev	
1	18	68	.6111111	.1	13.03903140	
2	18	71	.1111111	.1	12.55055138	
3	18	67	.5000000	0	10.18216434	
4	18	68	.3333333	33	10.84652289	
5	18	68	.3333333	33	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



Primate hippocampal function: Zola-Morgan and Squire, 1990 Multivariate approach to repeated measures (within-cases) Replicate test for main effect of treatment: F=8.08, p=0.0118

The GLM Procedure

Class Level Information

Class Levels Values

treatmnt 2 CONTROL TREATED

Number of Observations Read18Number of Observations Used18

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

	M Matı	ix Describing	Transformed	Variables	
	week2	week4	week8	week12	week16
MVAR1	1	1	1	1	1

Primate hippocampal function: Zola-Morgan and Squire, 1990 Multivariate approach to repeated measures (within-cases) Replicate test for main effect of treatment: F=8.08, p=0.0118

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

M- 0 5

NI – 7

C = 1

5-1 M0	•.5 N-7			
Value	F Value	Num DF	Den DF	Pr > F
0.66453035	8.08	1	16	0.0118
0.33546965	8.08	1	16	0.0118
0.50482217	8.08	1	16	0.0118
0.50482217	8.08	1	16	0.0118
	Value 0.66453035 0.33546965 0.50482217 0.50482217	Value F Value 0.66453035 8.08 0.33546965 8.08 0.50482217 8.08 0.50482217 8.08	Value F Value Num DF 0.66453035 8.08 1 0.33546965 8.08 1 0.50482217 8.08 1 0.50482217 8.08 1	Value F Value Num DF Den DF 0.66453035 8.08 1 16 0.33546965 8.08 1 16 0.50482217 8.08 1 16 0.50482217 8.08 1 16

12

19

Primate hippocampal function: Zola-Morgan and Squire, 1990 Multivariate approach to repeated measures (within-cases) Replicate tests for main effect of time: Lambda=0.84009249 And time by treatment interaction: Lambda=0.44106117

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

Primate hippocampal function: Zola-Morgan and Squire, 1990 Multivariate approach to repeated measures (within-cases) Replicate tests for main effect of time: Lambda=0.84009249 And time by treatment interaction: Lambda=0.44106117

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		Characteristic	c Vector V'EV=	-1	
Root	Percent	MVAR1	MVAR2	MVAR3	MVAR4
0.19034512	100.00	0.00273242	0.02066960	0.01326881	0.00197175
0.0000000	0.00	0.00913639	0.01141182	0.00864049	0.02826829
0.0000000	0.00	0.02176348	0.01048946	0.00668528	0.0000000
0.00000000	0.00	-0.00026861	-0.00324662	0.01781228	0.0000000

21

27

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			
Value	F Value	Num DF	Den DF	Pr > F
0.44106117	4.12	4	13	0.0227
0.55893883	4.12	4	13	0.0227
1.26725921	4.12	4	13	0.0227
1.26725921	4.12	4	13	0.0227
	S=1 M=1 Value 0.44106117 0.55893883 1.26725921 1.26725921	S=1 M=1 N=5.5 Value F Value 0.44106117 4.12 0.55893883 4.12 1.26725921 4.12 1.26725921 4.12	S=1 M=1 N=5.5 Value F Value Num DF 0.44106117 4.12 4 0.55893883 4.12 4 1.26725921 4.12 4 1.26725921 4.12 4	S=1 M=1 N=5.5 Value F Value Num DF Den DF 0.44106117 4.12 4 13 0.55893883 4.12 4 13 1.26725921 4.12 4 13 1.26725921 4.12 4 13

Primate hippocampal function: Zola-Morgan and Squire, 1990 Multivariate approach to repeated measures (within-cases) MANOVA, no repeated measures

The GLM Procedure

Class Level Information

Class Levels Values

treatmnt 2 CONTROL TREATED

Number of Observations Read18Number of Observations Used18

Primate hippocampal function: Zola-Morgan and Squire, 1990 Multivariate approach to repeated measures (within-cases) MANOVA, no repeated measures

```
The GLM Procedure
```

Dependent Variable: week2

Source		DF	Sum Squa	of res	Mean	Square	F Value	Pr > F
Model		1	1136.381	674	1136.	381674	10.37	0.0054
Error		16	1753.896	104	109.	618506		
Corrected To	otal	17	2890.277	778				
	R-Square	Coef	f Var	Root	MSE	week2	Mean	
	0.393174	15.	25975	10.4	6989	68.6	51111	
Source		DF	Туре І	SS	Mean	Square	F Value	Pr > F
treatmnt		1	1136.381	674	1136.	381674	10.37	0.0054
Source		DF	Type III	SS	Mean	Square	F Value	Pr > F
treatmnt		1	1136.381	674	1136.	381674	10.37	0.0054

29

Dependent Variable:	week4				
Source	DI	Type II	I SS Mean Squar	e F Value	Pr > F
treatmnt	:	1394.011	1394.01154	4 17.37	0.0007
Dependent Variable:	week8				
Source	DI	Type II	I SS Mean Squar	e F Value	Pr > F
treatmnt	:	118.3441	1558 118.344155	8 1.15	0.2991
Dependent Variable:	week12				
Source	DI	Type II	I SS Mean Squar	e F Value	Pr > F
treatmnt	:	438.9610	438.961039	0 4.50	0.0499
Dependent Variable:	week16				
Source	DI	Type III	I SS Mean Squar	e F Value	Pr > F
treatmnt		31.81818	3182 31.8181818	2 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