Within-cases analysis of the Monkey Data

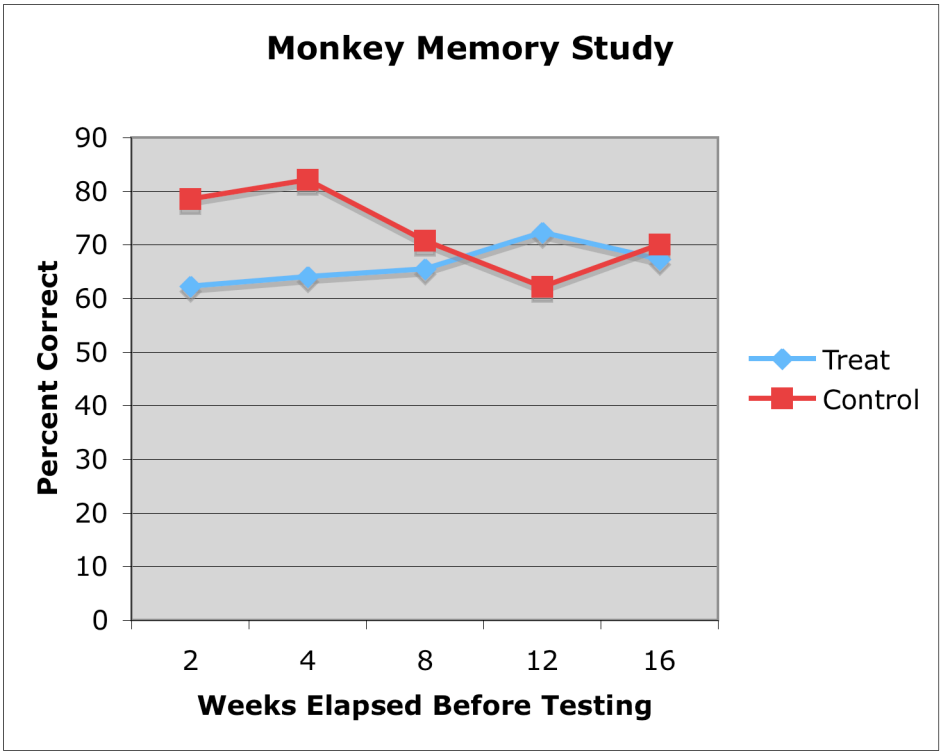
MONKEY	TREATMENT	WEEK2	WEEK4	WEEK8	WEEK12	WEEK16
Spank	CONTROL	95	75	80	65	70
Chim	CONTROL	85	75	55	75	85
Chak	CONTROL	75	95	60	40	45
Alf	CONTROL	85	80	70	45	80
Poet	CONTROL	65	80	75	65	65
Jessie	CONTROL	70	90	85	75	75
Phil	CONTROL	75	80	70	70	70
Irv	TREATED	75	50	70	75	75
Edy	TREATED	85	85	60	70	70
Allen	TREATED	60	70	70	75	70
Poe	TREATED	60	65	70	70	60
Joey	TREATED	65	60	80	70	60
Just	TREATED	55	70	60	65	75
Junior	TREATED	60	55	75	70	50
Andy	TREATED	55	65	45	70	65
Sport	TREATED	60	70	70	85	70
Cornelius	TREATED	45	60	65	65	70
Duncan	TREATED	65	55	55	80	75

```
/* monkey1.sas */
options linesize=79 pagesize=100 noovp formdlim='_';
title 'Primate hippocampal function: Zola-Morgan and Squire, 1990';
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;

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



First we get univariate analyses of all the dependent variables – before the transformations that make time a within-cases factor. Often you ignore these, but here they're interesting.

Primate hippocampal function: Zola-Morgan and Squire, 1990 2
Multivariate approach to repeated measures (within-cases)

The GLM Procedure

Class Level Information

Class	Levels	Values
treatmnt	2	CONTROL TREATED

Number of Observations Read	18
Number of Observations Used	18

Primate hippocampal function: Zola-Morgan and Squire, 1990 3
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			

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

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

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

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

Now the tests for main effect and interactions

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		

The `profile` option on the `repeated` statement yields these successive difference variables. Default is contrast with the last category.

Multivariate approach to repeated measures (within-cases)

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		

Now get the tests for main effects and interactions a different way, by specifying the **M** matrix for transforming the dependent variables. The output starts with tests on the untransformed dependent variables, but we've already seen those, so they are omitted. For the first run, we use a single linear combination of the dependent variables: their sum.

Primate hippocampal function: Zola-Morgan and Squire, 1990 17
Multivariate approach to repeated measures (within-cases)
Replicate test for main effect of treatment: F=8.08, p=0.0118

The GLM Procedure
Multivariate Analysis of Variance

M Matrix Describing Transformed Variables

	week2	week4	week8	week12	week16
MVAR1	1	1	1	1	1

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Multivariate approach to repeated measures (within-cases)
Replicate test for main effect of treatment: F=8.08, p=0.0118

The GLM Procedure
Multivariate Analysis of Variance

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

Variables have been transformed by the M Matrix

Characteristic Root	Percent	Characteristic Vector MVAR1	V'EV=1
0.50482217	100.00	0.01066594	

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

Now we transform the 5 dependent variables into 4 linear combinations: successive differences (changes over time). Test of the "intercept" is a simultaneous test of whether the four population mean differences equal zero. If this null hypothesis were true, there would be no change in recall as a function of elapsed time – averaging across treatment and control conditions. Test of treatment is for whether the set of changes depend on treatment; this is the treatment by time interaction. Once again we skip all the univariate tests on the untransformed variables. We start with the transformation matrix, which is a set of contrasts, in this case.

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

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 the "Characteristic Roots and Vectors" part ...

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

But the real point is that the treatment only affects recent memories, not older ones. A basic MANOVA is really more to the point. taking the output of the last `proc glm` out of order, we start by verifying that the treatment has an effect on the 5 recall variables considered simultaneously.

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

Now let's look at the 5 univariate tests for treatment, with a Bonferroni correction. Summarizing output we have already examined ...

Elapsed Time until testing, in weeks	F	p	Significant by Bonferroni?
2	10.37	0.0054	Yes
4	17.37	0.0007	Yes
8	1.15	0.2991	No
12	4.50	0.0499	No
16	0.31	0.5826	No

Conclusion: Blocking hippocampal function impaired the monkeys' average performance on tasks learned two and four weeks before the procedure, but there was no evidence of an effect for tasks learned eight, twelve or sixteen weeks before the procedure. This supports the idea that the hippocampus is involved more in short-term memory than in long-term memory.