```
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';
/* 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 = treatment  /* H says what hypotheses to test */
            M = week2+week4+week8+week12+week16 / short;
     /* M is a matrix of coefficients for defining new 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 may be what we want. Follow up with
Bonferroni. */

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

The MEANS Procedure

| | N | | |
treatmnt	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

| | | Sum of Squares | Mean Square | F Value | Pr > F |
Source	DF				
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

```
         Primate hippocampal function: Zola-Morgan and Squire, 1990            8
          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


                     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
```

```
         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

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.

```
         Primate hippocampal function: Zola-Morgan and Squire, 1990           10
          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
```

_____

```
          Primate hippocampal function: Zola-Morgan and Squire, 1990          11
             Multivariate approach to repeated measures (within-cases)


                               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

One 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
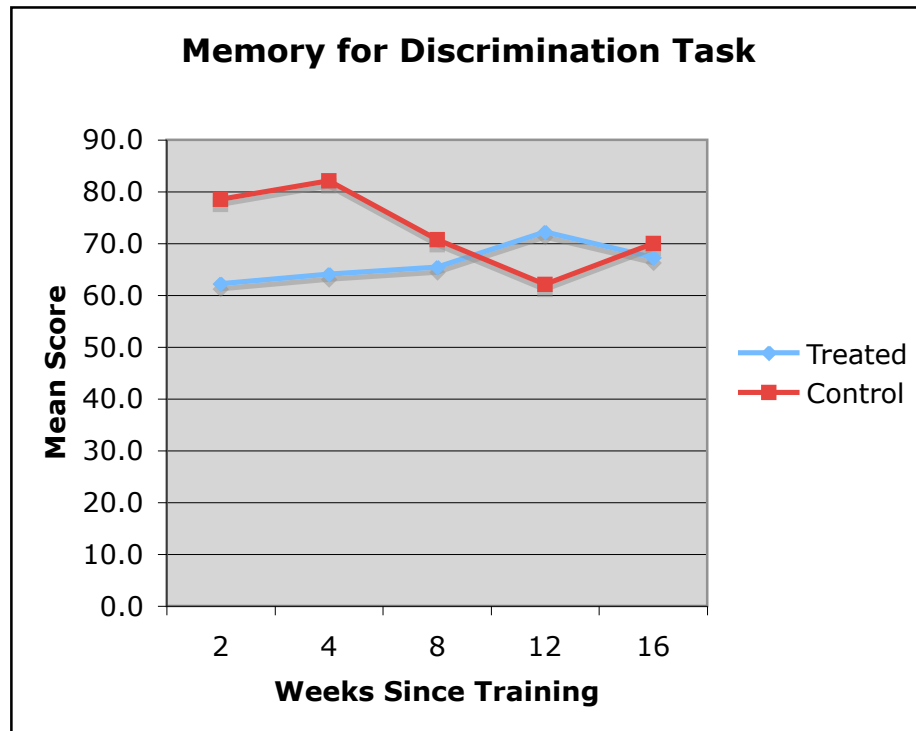
Primate hippocampal function: Zola-Morgan and Squire, 1990   12
        Multivariate approach to repeated measures (within-cases)
        Replicate test for main effect of treatment: F=8.08, p=0.0118

The GLM Procedure

Class Level Information

Class	Levels	Values
treatmnt	2	CONTROL TREATED

Number of Observations 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

_____

Primate hippocampal function: Zola-Morgan and Squire, 1990   19
        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

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

Primate hippocampal function: Zola-Morgan and Squire, 1990   21
    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   27
    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 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
```

Primate hippocampal function: Zola-Morgan and Squire, 1990   28
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 Read   18
Number of Observations Used   18

Primate hippocampal function: Zola-Morgan and Squire, 1990   29
Multivariate approach to repeated measures (within-cases)
MANOVA, no repeated measures

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