REPEATED MEASURES DATA AND SAS:

What SAS does and does not do

Ravi Khattree
Department of Epidemiology and Data Coordinating Center

Michigan State University

Nov. 3, 2005

What are repeated measures data?

1. Sleeping Dog Data

4 treatments applied successively on 19 dogs

Treatment			
1	**2**	**3**	**4**
426	609	556	600
253	236	392	395
359	433	349	357
432	431	522	600
405	426	513	513
324	438	507	539
310	312	410	456
326	326	350	504
375	447	547	548
286	286	403	422
349	382	473	497
429	410	488	547
348	377	447	514
412	473	472	446
347	326	455	468
434	458	637	524
364	367	432	469
420	395	508	531
397	556	645	625

2. Six volunteers were observed for blood glucose levels over a period of time after meal.

Measurements: 15 minutes before meal, immediately before meal, then every half hour for 2 hours, hourly measurements thereafter.

Experiment repeated for several days for each volunteer.

```
/* GLUCOSE DATA SET: glucose.dat */

  1  g1   4.90  4.50  7.84   5.46   5.08  4.32  3.91  3.99  4.15  4.41
  2  g1   4.61  4.65  7.90   6.13   4.45  4.17  4.96  4.36  4.26  4.13
  3  g1   5.37  5.35  7.94   5.64   5.06  5.49  4.77  4.48  4.39  4.45
  4  g1   5.10  5.22  7.20   4.95   4.45  3.88  3.65  4.21  4.38  4.44
  5  g1   5.34  4.91  5.69   8.21   2.97  4.30  4.18  4.93  5.16  5.54
  6  g1   5.24  5.04  8.72   4.85   5.57  6.33  4.81  4.55  4.48  5.15
  7  g2   4.91  4.18  9.00   9.74   6.95  6.92  4.66  3.45  4.20  4.63
  8  g2   4.16  3.42  7.09   6.98   6.13  5.36  6.13  3.67  4.37  4.31
  9  g2   4.95  4.40  7.00   7.80   7.78  7.30  5.82  5.14  3.59  4.00
 10  g2   3.82  4.00  6.56   6.48   5.66  7.74  4.45  4.07  3.73  3.58
 11  g2   3.76  4.70  6.76   4.98   5.02  5.95  4.90  4.79  5.25  5.42
 12  g2   4.13  3.95  5.53   8.55   7.09  5.34  5.56  4.23  3.95  4.29
 13  g3   4.22  4.92  8.09   6.74   4.30  4.28  4.59  4.49  5.29  4.95
 14  g3   4.52  4.22  8.46   9.12   7.50  6.02  4.66  4.69  4.26  4.29
 15  g3   4.47  4.47  7.95   7.21   6.35  5.58  4.57  3.90  3.44  4.18
 16  g3   4.27  4.33  6.61   6.89   5.64  4.85  4.82  3.82  4.31  3.81
 17  g3   4.81  4.85  6.08   8.28   5.73  5.68  4.66  4.62  4.85  4.69
 18  g3   4.61  4.68  6.01   7.35   6.38  6.16  4.41  4.96  4.33  4.54
 19  g4   4.05  3.78  8.71   7.12   6.17  4.22  4.31  3.15  3.64  3.88
 20  g4   3.94  4.14  7.82   8.68   6.22  5.10  5.16  4.38  4.22  4.27
 21  g4   4.19  4.22  7.45   8.07   6.84  6.86  4.79  3.87  3.60  4.92
 22  g4   4.31  4.45  7.34   6.75   7.55  6.42  5.75  4.56  4.30  3.92
 23  g4   4.30  4.71  7.44   7.08   6.30  6.50  4.50  4.36  4.83  4.50
 24  g4   4.45  4.12  7.14   5.68   6.07  5.96  5.20  4.83  4.50  4.71
 25  g5   5.03  4.99  9.10  10.03   9.20  8.31  7.92  4.86  4.63  3.52
 26  g5   4.51  4.50  8.74   8.80   7.10  8.20  7.42  5.79  4.85  4.94
 27  g5   4.87  5.12  6.32   9.48   9.88  6.28  5.58  5.26  4.10  4.25
 28  g5   4.55  4.44  5.56   8.39   7.85  7.40  6.23  4.59  4.31  3.96
 29  g5   4.79  4.82  9.29   8.99   8.15  5.71  5.24  4.95  5.06  5.24
```

```
30   g5    4.33  4.48  8.06   8.49   4.50  7.15  5.91  4.27  4.78  5.72
31   g6    4.60  4.72  9.53  10.02  10.25  9.29  5.45  4.82  4.09  3.52
32   g6    4.33  4.10  4.36   6.92   9.06  8.11  5.69  5.91  5.65  4.58
33   g6    4.42  4.07  5.48   9.05   8.04  7.19  4.87  5.40  4.35  4.51
34   g6    4.38  4.54  8.86  10.01  10.47  9.91  6.11  4.37  3.38  4.02
35   g6    5.06  5.04  8.86   9.97   8.45  6.58  4.74  4.28  4.04  4.34
36   g6    4.43  4.75  6.95   6.64   7.72  7.03  6.38  5.17  4.71  5.14

/*
The data are ID, group, y1-y10 (the observations taken at the time points
-15 0 30 60 90 120 180 240 300 and 360  minutes.
From Crowder and Hand (1990) page 14.
*/
```

3. Cork measurements on the four sides of each of the 28 trees (C.R. Rao, 1948).

/*CORK DATA SET: cork.dat*/

N	E	S	W
72	66	76	77
60	53	66	63
56	57	64	58
41	29	36	38
32	32	35	36
30	35	34	26
39	39	31	27
42	43	31	25
37	40	31	25
33	29	27	36
32	30	34	28
63	45	74	63
54	46	60	52
47	51	52	43
91	79	100	75
56	68	47	50
79	65	70	61
81	80	68	58
78	55	67	60
46	38	37	38
39	35	34	37
32	30	30	32
60	50	67	54
35	37	48	39
39	36	39	31
50	34	37	40
43	37	39	50
48	54	57	43

4. Comparison of two hearing implants (A and B). Scores on hearing test were recorded.

/* AUDIOLOGY DATA SET: audiology.dat */

	Months			
	1	**9**	**18**	**30**
a	28.57	53.00	57.83	59.22
a	.	13.00	21.00	26.50
a	60.37	86.41	.	.
a	33.87	55.60	61.06	.
a	26.04	61.98	67.28	.
a	.	59.00	66.80	83.20
a	11.29	38.02	.	.
a	.	35.10	37.79	54.80
a	16.00	33.00	45.39	40.09
a	40.55	50.69	41.70	52.07
a	3.90	11.06	4.15	14.90
a	.00	17.74	44.70	48.85
a	64.75	84.50	92.40	95.39
a	38.25	81.57	89.63	.
a	67.50	91.47	92.86	.
a	45.62	58.00	.	.
a	.00	.00	37.00	.
a	51.15	66.13	.	.
a	.00	48.16	.	.
b	8.76	24.42	.	.
b	.00	20.79	27.42	31.80
b	2.30	12.67	28.80	24.42
b	12.90	28.34	.	.
b	.	45.50	43.32	36.80
b	68.00	96.08	97.47	99.00
b	20.28	41.01	51.15	61.98
b	65.90	81.30	71.20	70.00
b	.00	8.76	16.59	14.75
b	9.22	14.98	9.68	.
b	11.29	44.47	62.90	68.20
b	30.88	29.72	.	.
b	29.72	41.40	64.00	.
b	.00	43.55	48.16	.
b	8.76	60.00	.	.
b	8.00	25.00	30.88	55.53

/* Nunez-Anton and Woodworth (1994).
Biometrics, 50,445-456). */

- Observations taken on the same subject or same unit.

  Over time or over any other variable (e.g. spatial data).

- Observations are correlated.

- Observations may be unequally spaced.

- Observations may be missing.

- Observations may be continuous, discrete, ordinal or binary.

- Observations may correspond to same treatment (e.g. in clinical trials) or to different treatments (e.g. in crossover trials or experiments such as sleeping dog data).

- There are within-subject as well as between-subjects variability present.

Q. How do we analyze these data?

A. (For continuous data, assuming normality), you can use multivariate models since you have correlated data

OR

You can use univariate models using certain covariance structure assumptions.

Data on a single subject over time for *p* time points

$$\mathbf{y} = (y_1, y_2, \cdots, y_p)', \text{Cov}(\mathbf{y}) = \Sigma$$

1. $\Sigma = \sigma^2 \mathbf{I}$ (VC)
2. $\Sigma = \sigma_1^2 \mathbf{11}' + \sigma_2^2 \mathbf{I}$ (CS)
3. Σ Unstructured (UN)
4. $\Sigma = diag(\sigma_1^2, \ldots, \sigma_p^2)$: Banded Main diagonal (UN(1))
5. $$\Sigma = \sigma^2 \begin{bmatrix} 1 & \rho & \cdots & \rho^{p-1} \\ \rho & 1 & \cdots & \rho^{p-2} \\ \vdots & & & \\ \rho^{p-1} & \rho^{p-2} & \cdots & 1 \end{bmatrix}$$: Autoregressive of order 1 (AR(1))
6. $$\Sigma = \begin{bmatrix} \sigma_0 & \sigma_1 & \cdots & \sigma_{p-1} \\ \sigma_1 & \sigma_0 & \cdots & \sigma_{p-2} \\ \vdots & & & \\ \sigma_{p-1} & \sigma_{p-2} & \cdots & \sigma_0 \end{bmatrix}$$: Toeplitz (TOEP)
7. $$\Sigma = \begin{bmatrix} \sigma_0 & \sigma_1 & 0 & 0 & \cdots & 0 \\ \sigma_1 & \sigma_0 & \sigma_1 & 0 & \cdots & 0 \\ \vdots & & & & & \\ 0 & \cdots & \cdots & 0 & \sigma_1 & \sigma_0 \end{bmatrix}$$: Two Bands Toeplitz (TOEP(2))
8. $\Sigma = \sigma^2 \left(\rho_{ij}^{dij}\right), \rho_{ii} = 1$: Spatial Power or Markov (SP(POW)(c))
9. $\Sigma = \left(\sigma_{ij}\right), \sigma_{ij} = \dfrac{\sigma_{ii} + \sigma_{jj}}{2} - \lambda, \text{if } i \neq j$: Huynh–Feldt (HF)

Linear Structures

$$\Sigma = c_1 \mathbf{A}_1 + \cdots + c_k \mathbf{A}_k ,$$

Where $\mathbf{A}_1,\ldots,\mathbf{A}_k$ are known matrices but the scalars $c_1,\ldots,c_k$ are all unknown and are functionally unrelated to each other.

For example, the matrix

$$\Sigma = \begin{bmatrix} \sigma_1^2+\sigma_2^2 & \sigma_1^2 & \sigma_1^2 \\ \sigma_1^2 & \sigma_1^2+\sigma_2^2 & \sigma_1^2 \\ \sigma_1^2 & \sigma_2^2 & \sigma_1^2+\sigma_2^2 \end{bmatrix} = \sigma_1^2 \begin{bmatrix} 111 \\ 111 \\ 111 \end{bmatrix} + \sigma_2^2 \begin{bmatrix} 100 \\ 010 \\ 001 \end{bmatrix}.$$

• If $\Sigma = \sigma_1^2 \begin{bmatrix} 111 \\ 111 \\ 111 \end{bmatrix} + \sigma_2^2 \begin{bmatrix} 100 \\ 010 \\ 001 \end{bmatrix}$

or Σ has Huynh-Feldt structure, then analysis can be performed as (univariate) analysis of variance and F-tests can be used to see the significance. (PROC GLM)

- If Σ is not of the above form but one of the previous forms then ANOVA or F-tests are not valid.

One may use PROC MIXED to do the analysis based on large sample theory, while assuming the “appropriate” covariance structure.

What is an “appropriate” structure?

No one knows!!

We will get back to this issue soon.

Example 1:
Heart Data:

- 3 drugs to be compared for their effects on human heart rate.
- Data on each subject at 4 time points 5 minutes apart.
- Data on same subject are correlated.

/* HEART RATE DATA: heart.dat */

ax23	72	86	81	77
ax23	78	83	88	82
ax23	71	82	81	75
ax23	72	83	83	69
ax23	66	79	77	66
ax23	74	83	84	77
ax23	62	73	78	70
ax23	69	75	76	70
bww9	85	86	83	80
bww9	82	86	80	84
bww9	71	78	70	75
bww9	83	88	79	81
bww9	86	85	76	76
bww9	85	82	83	80
bww9	79	83	80	81
bww9	83	84	78	81
control	69	73	72	74
control	66	62	67	73
control	84	90	88	87
control	80	81	77	72
control	72	72	69	70
control	65	62	65	61
control	75	69	69	68
control	71	70	65	65

/* Source: Spector (1987, pp. 1174-1177). "Strategies for Repeated Measures Analysis of Variance", SUGI 1987. */

Program

```
title2 ‘Analysis of Heart Rate Data’’
data heart;
inifile ‘heart.dat’;
Input drug $ y1 y2 y3 y4;

proc glm data=heart;
class drug;
model y1-y4=drug/nouni;
repeated time 4;
run;
data split;
set heart;
array t{4} y1-y4;
subject+1;
do time=1 to 4;
y=t{time};
output;
end;
drop y1-y4;
run;
* AR(1) Covariance Structure;
proc mixed data = split covtest method = reml;
class drug subject time;
model y =  drug time time*drug;
repeated /type = ar(1) subject = subject r ;
title3 'AR(1) Covariance Structure';
run;
*Compound Symmetry Structure;
proc mixed data = split covtest method = reml;
class drug subject time;
model y =  drug time time*drug;
repeated /type = cs subject = subject r ;
title3 'Compound Symmetry Structure';
*Unstructured Covariance;
proc mixed data = split covtest method = reml;
class drug subject time;
model y =  drug time time*drug;
repeated /type = un subject = subject r ;
title3 'Unstructured Covariance';
run;
```

Analysis of Heart Data:

Analysis of Heart Rate Data

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
drug	2	1314.812500	657.406250	5.92	0.0092
Error	21	2332.812500	111.086310		

Analysis of Heart Rate Data

The GLM Procedure
Repeated Measures Analysis of Variance
Univariate Tests of Hypotheses for Within Subject Effects

						Adj Pr > F	
Source	DF	Type III SS	Mean Square	F Value	Pr > F	G - G	H - F
time	3	279.2083333	93.0694444	12.68	<.0001	<.0001	<.0001
time*drug	6	528.3541667	88.0590278	12.00	<.0001	<.0001	<.0001
Error(time)	63	462.4375000	7.3402778				

Greenhouse-Geisser Epsilon 0.7947
Huynh-Feldt Epsilon 0.9887

Example 2:

Audiology Data:

Implant types are denoted by A and B respectively. There are 19 subjects in group A and 16 subjects in group B. The hearing tests are administered 1, 9, 18, and 30 months after the implantation of the devices. The objective of the study is

(i) to determine if there is any difference between the two cochlear implants and also

(ii) to determine the average improvement curves as functions of the length of time since implantation. The raw data have several missing values and are observed at equally spaced time points.

Suppose we decide to fit two different quadratic functions for different groups, as functions of time since implantation, for the scores on the hearing tests. For the *u*th individual in the *i*th group, i = 1, 2, we consider the following model relating the improvement as a function of TIME.

$$y_{iu} = \beta_0 + \beta_{0i} + 2\beta_1 time + \beta_{1i} time + \beta_2 time^2 + \beta_{2i} time^2 + \varepsilon_{iu}$$

$i = 1,2; u = 1,\ldots,n_i, n_1 = 19, n_2 = 16$. We assume that ε_{iu} are all independently distributed as $N(0, \sigma^2), \beta_{0i}$

are all independently distributed as $N(0, \sigma_\beta^2)$ and that ε_{iu} and $\beta_{0i'}$ are also independent of each other for $i = 1, 2; u = 1,\ldots,n_i$. The coefficients β_{1i} and $\beta_{2i}, i = 1, 2$ allow the curves for the two groups to be different in their linear and quadratic time components.

We also assume that the variance covariance matrix of the P_{iu} repeated measurements, collected on a given subject over time since the implantation of the hearing device, is given by

$$\sigma^2 \mathbf{R}_{iu} = \sigma^2 \begin{bmatrix} 1 & \rho^{t_2 - t_1} & \rho^{t_3 - t_1} & \rho^{t_4 - t_1} \\ \rho^{t_2 - t_1} & 1 & \rho^{t_3 - t_2} & \rho^{t_4 - t_2} \\ \rho^{t_3 - t_1} & \rho^{t_3 - t_2} & 1 & \rho^{t_4 - t_3} \\ \rho^{t_4 - t_1} & \rho^{t_4 - t_2} & \rho^{t_4 - t_2} & 1 \end{bmatrix}$$

where for our data t_1 = 1, t_2 = 9, t_3 = 18, and t_4 = 30.

SAS Program:

```
data aud_n;
set aud;
array t{4} y1-y4;
subject+1;
do i=1 to 4;
if (i=1) then time=1;
if (i=2) then time=9;
if (i=3) then time=18;
if (i=4) then time=30;
time1=time;
y=t{i};
output;
end;
drop i y1-y4;
run;
title2 'Fit Different Quadratic Curves for Groups A and B';
proc mixed data=aud_n method=reml covtest;
class gp subject;
model y= gp time time*gp time*time time*time*gp/htype=1;
repeated/type=sp(pow)(time1) subject=subject r;
run;
title2 'Common Quadratic Term for Groups A and B';
proc mixed data=aud_n method=reml covtest;
class gp subject;
model y= gp time time*gp time*time;
repeated/type=sp(pow)(time1) subject=subject r;
run;
title2 'Common Linear and Quadratic Terms for Groups A and B';
proc mixed data=aud_n method=reml covtest;
class gp subject;
model y= gp time time*time/s;
repeated/type=sp(pow)(time1) subject=subject r;
run;
title2 'Common Quadratic Curve for Groups A and B';
proc mixed data=aud_n method=reml covtest;
class gp subject;
model y= time time*time/s;
repeated/type=sp(pow)(time1) subject=subject r;
run;
```

SAS Output:

Fit Different Quadratic Curves for Groups A and B
The Mixed Procedure

Type 1 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
gp	1	33	2.23	0.1453
time	1	71	64.20	0.0001
time*gp	1	71	0.20	0.6533
time*time	1	71	33.43	0.0001
time*time*gp	1	71	0.04	0.8508

Common Quadratic Term for Groups A and B
The Mixed Procedure

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
gp	1	33	1.32	0.2581
time	1	72	85.48	0.0001
time*gp	1	72	0.19	0.6649
time*time	1	72	33.85	0.0001

Q. How do we test for covariance structure?

- There is no direct "PROC" in SAS for doing it (SPSS does have it).

- One can do it indirectly by using "PROC MIXED."

Idea:
Log likelihood ratio test statistic

$$-2\ln L = -2\left\{ \ln\left[\begin{matrix}\max \\ \text{null hyp}\end{matrix} \quad g(\Sigma \mid data)\right] - \ln\left[\begin{matrix}\max \\ \text{unrestricted}\end{matrix} \quad g(\Sigma \mid data)\right]\right\}$$

Thus, the second term is computed by a run of "PROC MIXED" under unrestricted covariance structure.

The first term is computed by using assumed covariance structure.

Example: Cork Data:

Cork deposit collected from the 4 sides of the tree:

N, E, S, W

Q. Does Σ have a circulant covariance structure?

$$\Sigma = \begin{bmatrix} \sigma_0 & \sigma_1 & \sigma_2 & \sigma_1 \\ \sigma_1 & \sigma_0 & \sigma_1 & \sigma_2 \\ \sigma_2 & \sigma_1 & \sigma_0 & \sigma_1 \\ \sigma_1 & \sigma_2 & \sigma_1 & \sigma_0 \end{bmatrix} ?$$

$$\Sigma = \sigma_0 \begin{bmatrix} 1&0&0&0 \\ 0&1&0&0 \\ 0&0&1&0 \\ 0&0&0&1 \end{bmatrix} + \sigma_1 \begin{bmatrix} 1&0&0&1 \\ 1&0&1&0 \\ 0&1&0&1 \\ 1&0&1&0 \end{bmatrix} + \sigma_2 \begin{bmatrix} 0&0&1&0 \\ 0&0&0&1 \\ 1&0&0&0 \\ 0&1&0&0 \end{bmatrix}$$

$$= c_1^* \mathbf{A}_1^* + c_2^* \mathbf{A}_2^* + c_3^* \mathbf{A}_3^*$$

or as

$$\Sigma = \sigma_2 \begin{bmatrix} 1&1&1&1 \\ 1&1&1&1 \\ 1&1&1&1 \\ 1&1&1&1 \end{bmatrix} + (\sigma_1 - \sigma_2) \begin{bmatrix} 1&1&0&1 \\ 1&1&1&0 \\ 0&1&1&1 \\ 1&0&1&1 \end{bmatrix} + (\sigma_2 - \sigma_1) \begin{bmatrix} 1&0&0&0 \\ 0&1&0&0 \\ 0&0&1&0 \\ 0&0&0&1 \end{bmatrix}$$

$$= c_1^* \mathbf{A}_1^* + c_2^* \mathbf{A}_2^* + c_3^* \mathbf{A}_3^*$$

SAS PROGRAM:

```
data cork1;
set cork;
array t{4} n e s w;
tree+1;
do dir = 1 to 4;
dir1 = dir;
y = t{dir};
output;
end;
drop n e s w;
run;
data circ;
input parm row col1-col4;
datalines;
1 1 1 0 0 0
1 2 0 1 0 0
1 3 0 0 1 0
1 4 0 0 0 1
2 1 0 1 0 1
2 2 1 0 1 0
2 3 0 1 0 1
2 4 1 0 1 0
3 1 0 0 1 0
3 2 0 0 0 1
3 3 1 0 0 0
3 4 0 1 0 0
;
proc mixed data =cork1 method = ml;
class tree dir;
model y =dir;
repeated/ type =un subject = tree;
title3 'Unstructured Covariance';
run;
proc mixed data = cork1 method = ml;
class tree dir;
model y = dir;
repeated/type = lin(3) ldata = circ subject = tree;
parms (190) (30) (70);
title3 'Circulant';
run;
```

Output:

Fit Statistics

-2 Log Likelihood	791.4
AIC (smaller is better)	819.4
AICC (smaller is better)	823.7
BIC (smaller is better)	838.1

Null Model Likelihood Ratio Test

DF	Chi-Square	Pr > ChiSq
9	150.03	<.0001

Fit Statistics

-2 Log Likelihood	811.2
AIC (smaller is better)	825.2
AICC (smaller is better)	826.2
BIIC (smaller is better)	834.5

PARMS Model Likelihood Ratio Test

DF	Chi-Square	Pr > ChiSq
3	78.05	<.0001

$\chi^2 = -2\ln L = 811.2 - 791.4 = 19.8$

degrees of freedom 9 – 3 = 6

Reject the null hypothesis of circulant.

<u>Multivariate Repeated Measures Data</u>

Data on BP, pulse rate and heart rate

Collected over six weeks

3 response variables (multivariate): Cov. Matrix $\sum$

6 repeated measures (again multivariate): Cov. Matrix V

18 measurements on each subject

$$Cov.\,Matrix\;\Omega_{18\times 18} = V_{6\times 6} \otimes \Sigma_{3\times 3}$$

$\otimes$: Kronecker Product

$$\begin{bmatrix} v_{11}\, v_{12} \cdots v_{16} \\ v_{21}\, v_{22} \cdots \\ v_{61} \cdots \cdots v_{66} \end{bmatrix} \otimes \begin{bmatrix} \sigma_{11}\; \sigma_{12}\; \sigma_{13} \\ \sigma_{21}\; \sigma_{22}\; \sigma_{23} \\ \sigma_{31}\; \sigma_{32}\; \sigma_{33} \end{bmatrix} = \begin{bmatrix} \left. \begin{matrix} V_{11}\sigma_{11}\; V_{11}\sigma_{12} \cdots \\ V_{11}\sigma_{21}\; V_{11}\sigma_{22} \cdots \\ . \quad . \quad . \quad . \end{matrix} \right| & \Big| \cdots \\ V_{21}\sigma_{11}\; V_{21}\sigma_{22} \cdots & \\ V_{21}\sigma_{21}\; V_{21}\sigma_{22} \cdots & \\ . \quad . \quad . \quad . & \end{bmatrix}$$

Q. 1. Can we test if the covariance matrix is of the above form?

2. Can we test if the repeated measures have auto-correlated covariance structure (that is, correlations decay with time?)

Answer to (1) and (2) both is: Yes, using PROC MIXED.

But,

<u>Often</u> PROC MIXED fails to converge.

Roy and Khattree (2002-2005)

SAS macros have been developed.

The above situation is very important in the context of discriminant analysis.

Two populations:

Healthy vs. diseased

Samples from the two groups are taken.

4 clinical features measured over 6 days.

A new patient is to be classified into one of the two groups based on his 24 measurements.

This is a case of discriminant analysis with repeated measures

SAS PROC DISCRIM does not readily allow the $\sum \otimes V$ type of structure or any other structure.

Extensive SAS MACROS are available for the purpose (Roy and Khattree 2002-2005). But, they are too tedious and slow to converge. Need new SAS options for this purpose.