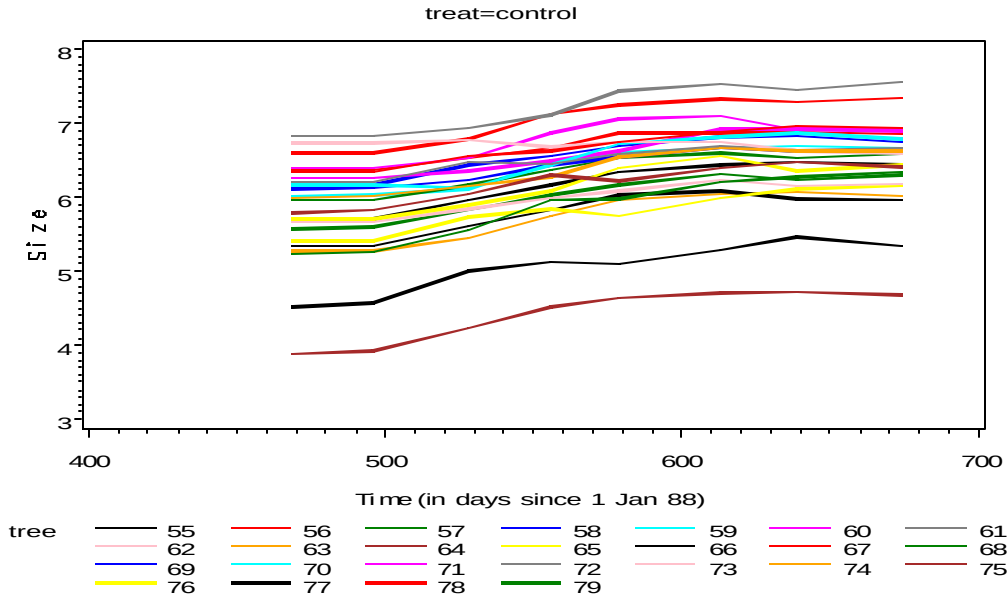


```

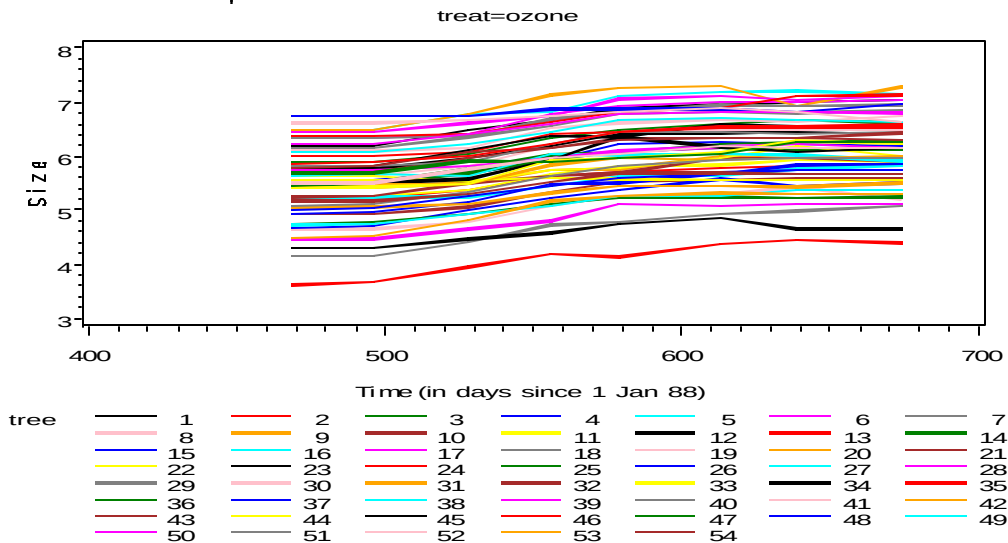
proc sort;
  by treat;
run;
axis1 label=(a=90 h=1.2 'Size');
axis2 label=(h=1.2 'Time (in days since 1 Jan 88)');
symbol1 v=None l=1 w=2 i=join r=27;
symbol2 v=None l=2 i=join r=54;
proc gplot;
  title 'Sitka spruce trees - 54 ozone 25 controls';
  plot size*time=tree / vaxis=axis1 haxis=axis2;
  by treat;
run;

```

Sitka spruce trees — 54 ozone 25 controls



Sitka spruce trees — 54 ozone 25 controls



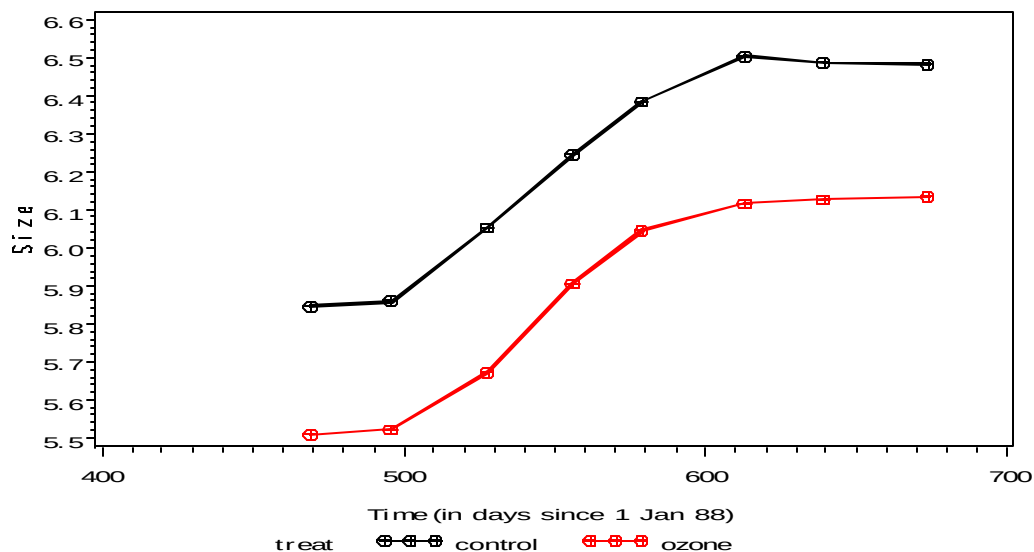
```

proc sort;
  by treat time;

```

```
run;
proc means noprint;
  by treat time;
  var size;
  output out=avg mean=size;
run;
axis1 label=(a=90 h=1.2 'Size');
axis2 label=(h=1.2 'Time (in days since 1 Jan 88)');
symbol1 v=+ i=join; symbol2 v=dot i=join;
proc gplot;
  title 'Sitka spruce trees - 54 ozone 25 controls';
  plot size*time=treat / vaxis=axis1 haxis=axis2;
run;
```

Sitka spruce trees — 54 ozone 25 controls



```
proc glm data=sitka89b;
  title 'MANOVA approach to Sitka89 Repeated Measures data';
  class treat;
  model s1-s8=treat / nouni;
  repeated time 8 (469 496 528 556 579 613 639 674) polynomial / printe summary;
run;
```

MANOVA approach to Sitka89 Repeated Measures data

The GLM Procedure

Class Level Information

Class	Levels	Values
treat	2	control ozone

Number of Observations Read	79
Number of Observations Used	79

Repeated Measures Level Information

Dependent Variable	s1	s2	s3	s4	s5	s6	s7	s8
Level of time	469	496	528	556	579	613	639	674

Partial Correlation Coefficients from the Error SSCP Matrix / Prob > |r|

DF = 77	s1	s2	s3	s4	s5	s6	s7	s8
s1	1.000000	0.999818 <.0001	0.987435 <.0001	0.978336 <.0001	0.969627 <.0001	0.965049 <.0001	0.958844 <.0001	0.954988 <.0001
s2	0.999818 <.0001	1.000000	0.988605 <.0001	0.980156 <.0001	0.971016 <.0001	0.966826 <.0001	0.960807 <.0001	0.956773 <.0001

s3	0.987435 <.0001	0.988605 <.0001	1.000000	0.986348 <.0001	0.975590 <.0001	0.976987 <.0001	0.968464 <.0001	0.968581 <.0001
s4	0.978336 <.0001	0.980156 <.0001	0.986348 <.0001	1.000000	0.988743 <.0001	0.990352 <.0001	0.980814 <.0001	0.982923 <.0001
s5	0.969627 <.0001	0.971016 <.0001	0.975590 <.0001	0.988743 <.0001	1.000000	0.992895 <.0001	0.978713 <.0001	0.981732 <.0001
s6	0.965049 <.0001	0.966826 <.0001	0.976987 <.0001	0.990352 <.0001	0.992895 <.0001	1.000000	0.988348 <.0001	0.990160 <.0001
s7	0.958844 <.0001	0.960807 <.0001	0.968464 <.0001	0.980814 <.0001	0.978713 <.0001	0.988348 <.0001	1.000000	0.992948 <.0001
s8	0.954988 <.0001	0.956773 <.0001	0.968581 <.0001	0.982923 <.0001	0.981732 <.0001	0.990160 <.0001	0.992948 <.0001	1.000000

E = Error SSCP Matrix

time_N represents the nth degree polynomial contrast for time

	time_1	time_2	time_3	time_4	time_5	time_6	time_7
time_1	3.0574277	-0.4531706	-0.3281987	0.2912467	-0.1626463	-0.0736470	0.0843278
time_2	-0.4531706	0.5785267	0.0533850	-0.2944128	-0.0641771	-0.0702961	0.0011899
time_3	-0.3281987	0.0533850	0.2806842	-0.0084585	-0.1329011	0.1312298	0.0314857
time_4	0.2912467	-0.2944128	-0.0084585	0.3508661	0.2001563	-0.0334619	-0.0108714
time_5	-0.1626463	-0.0641771	-0.1329011	0.2001563	0.3447394	-0.0638936	-0.0937355
time_6	-0.0736470	-0.0702961	0.1312298	-0.0334619	-0.0638936	0.2614921	-0.0144420
time_7	0.0843278	0.0011899	0.0314857	-0.0108714	-0.0937355	-0.0144420	0.2346755

Partial Correlation Coefficients from the Error SSCP Matrix of the
Variables Defined by the Specified Transformation / Prob > |r|

DF = 77	time_1	time_2	time_3	time_4	time_5	time_6	time_7
time_1	1.000000	-0.340739 0.0023	-0.354283 0.0015	0.281198 0.0126	-0.158424 0.1659	-0.082366 0.4734	0.099554 0.3858
time_2	-0.340739 0.0023	1.000000	0.132479 0.2476	-0.653468 <.0001	-0.143705 0.2094	-0.180734 0.1133	0.003229 0.9776
time_3	-0.354283 0.0015	0.132479 0.2476	1.000000	-0.026953 0.8148	-0.427242 <.0001	0.484389 <.0001	0.122679 0.2846
time_4	0.281198 0.0126	-0.653468 <.0001	-0.026953 0.8148	1.000000	0.575510 <.0001	-0.110472 0.3356	-0.037886 0.7419
time_5	-0.158424 0.1659	-0.143705 0.2094	-0.427242 <.0001	0.575510 <.0001	1.000000	-0.212805 0.0614	-0.329553 0.0032
time_6	-0.082366 0.4734	-0.180734 0.1133	0.484389 <.0001	-0.110472 0.3356	-0.212805 0.0614	1.000000	-0.058299 0.6122
time_7	0.099554 0.3858	0.003229 0.9776	0.122679 0.2846	-0.037886 0.7419	-0.329553 0.0032	-0.058299 0.6122	1.000000

Sphericity Tests

Variables	DF	Mauchly's Criterion	Chi-Square	Pr > ChiSq
Transformed Variates	27	0.0003544	591.52039	<.0001
Orthogonal Components	27	0.0003544	591.52039	<.0001

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=2.5	N=34.5			
Statistic	Value	F Value	Num DF	Den DF	Pr > F	
Wilks' Lambda	0.07214069	130.46	7	71	<.0001	
Pillai's Trace	0.92785931	130.46	7	71	<.0001	
Hotelling-Lawley Trace	12.86180306	130.46	7	71	<.0001	
Roy's Greatest Root	12.86180306	130.46	7	71	<.0001	

MANOVA Test Criteria and Exact F Statistics for the Hypothesis of no time*treat Effect

H = Type III SSCP Matrix for time*treat

E = Error SSCP Matrix

	S=1	M=2.5	N=34.5			
Statistic	Value	F Value	Num DF	Den DF	Pr > F	
Wilks' Lambda	0.83679550	1.98	7	71	0.0701	
Pillai's Trace	0.16320450	1.98	7	71	0.0701	
Hotelling-Lawley Trace	0.19503511	1.98	7	71	0.0701	
Roy's Greatest Root	0.19503511	1.98	7	71	0.0701	

Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
treat	1	17.1430120	17.1430120	5.30	0.0241	
Error	77	249.1604067	3.2358494			

Univariate Tests of Hypotheses for Within Subject Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F	Adj G - G	Pr > F
time	7	36.22251707	5.17464530	545.99	<.0001	<.0001	<.0001
time*treat	7	0.04369871	0.00624267	0.66	0.7071	0.5389	0.5454
Error(time)	539	5.10841173	0.00947757				

Greenhouse-Geisser Epsilon 0.3276

Huynh-Feldt Epsilon 0.3426

Analysis of Variance of Contrast Variables

time_N represents the nth degree polynomial contrast for time

Contrast Variable: time_1

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
Mean	1	32.28321796	32.28321796	813.04	<.0001	
treat	1	0.00386893	0.00386893	0.10	0.7558	
Error	77	3.05742771	0.03970685			

Contrast Variable: time_2

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
Mean	1	2.08801505	2.08801505	277.91	<.0001	
treat	1	0.00284268	0.00284268	0.38	0.5403	
Error	77	0.57852672	0.00751333			

Contrast Variable: time_3

Source	DF	Type III SS	Mean Square	F Value	Pr > F	
Mean	1	1.24565002	1.24565002	341.72	<.0001	
treat	1	0.00045217	0.00045217	0.12	0.7257	
Error	77	0.28068421	0.00364525			

Contrast Variable: time_4

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Mean	1	0.58568852	0.58568852	128.53	<.0001
treat	1	0.00414691	0.00414691	0.91	0.3431
Error	77	0.35086610	0.00455670		
Contrast Variable: time_5					
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Mean	1	0.01593513	0.01593513	3.56	0.0630
treat	1	0.00057799	0.00057799	0.13	0.7204
Error	77	0.34473936	0.00447713		
Contrast Variable: time_6					
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Mean	1	0.00367160	0.00367160	1.08	0.3017
treat	1	0.03170342	0.03170342	9.34	0.0031
Error	77	0.26149212	0.00339600		
Contrast Variable: time_7					
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Mean	1	0.00033878	0.00033878	0.11	0.7397
treat	1	0.00010661	0.00010661	0.03	0.8521
Error	77	0.23467551	0.00304773		

```
proc glm data=sitka89;
  title 'Split Plot approach to Sitka89 Repeated Measures data';
  class treat tree time;
  model size=treat tree(treat) time treat*time;
  test h=treat e=tree(treat);
run;
```

Split Plot approach to Sitka89 Repeated Measures data					
The GLM Procedure					
Class Level Information					
Class	Levels	Values			
treat	2	control ozone			
tree	79	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28			
		29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53			
		54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78			
		79			
time	8	469 496 528 556 579 613 639 674			
Number of Observations Read				632	
Number of Observations Used				632	
Dependent Variable: size					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	92	307.8860819	3.3465878	353.11	<.0001
Error	539	5.1084117	0.0094776		
Corrected Total	631	312.9944937			
	R-Square	Coeff Var	Root MSE	size Mean	
	0.983679	1.625067	0.097353	5.990696	
Source	DF	Type I SS	Mean Square	F Value	Pr > F
treat	1	17.1430120	17.1430120	1808.80	<.0001
tree(treat)	77	249.1604067	3.2358494	341.42	<.0001
time	7	41.5389646	5.9341378	626.12	<.0001

treat*time	7	0.0436987	0.0062427	0.66	0.7071
Source	DF	Type III SS	Mean Square	F Value	Pr > F
treat	1	17.1430120	17.1430120	1808.80	<.0001
tree(treat)	77	249.1604067	3.2358494	341.42	<.0001
time	7	36.2225171	5.1746453	545.99	<.0001
treat*time	7	0.0436987	0.0062427	0.66	0.7071
Tests of Hypotheses Using the Type III MS for tree(treat) as an Error Term					
Source	DF	Type III SS	Mean Square	F Value	Pr > F
treat	1	17.14301196	17.14301196	5.30	0.0241

```
proc mixed data=sitka89;  
  title 'MIXED approach with CS error structure';  
  class treat tree time;  
  model size=treat time treat*time;  
  repeated / type=cs sub=tree(treat);  
run;
```

MIXED approach with CS error structure														
The Mixed Procedure														
Model Information														
Data Set	WORK.SITKA89													
Dependent Variable	size													
Covariance Structure	Compound Symmetry													
Subject Effect	tree(treat)													
Estimation Method	REML													
Residual Variance Method	Profile													
Fixed Effects SE Method	Model-Based													
Degrees of Freedom Method	Between-Within													
Class Level Information														
Class	Levels	Values												
treat	2	control ozone												
tree	79	1	2	3	4	5	6	7	8	9	10	11	12	13
		14	15	16	17	18	19	20	21	22	23			
		24	25	26	27	28	29	30	31	32	33			
		34	35	36	37	38	39	40	41	42	43			
		44	45	46	47	48	49	50	51	52	53			
		54	55	56	57	58	59	60	61	62	63			
		64	65	66	67	68	69	70	71	72	73			
		74	75	76	77	78	79							
time	8	469	496	528	556	579	613	639						
		674												
Dimensions														
Covariance Parameters	2													
Columns in X	27													
Columns in Z	0													
Subjects	79													
Max Obs Per Subject	8													
Number of Observations														
Number of Observations Read	632													
Number of Observations Used	632													
Number of Observations Not Used	0													
The Mixed Procedure														
Iteration History														
Iteration	Evaluations	-2	Res	Log	Like	Criterion								

0	1	1260.72452373	
1	1	-614.89217445	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
CS	tree(treat)	0.4033
Residual		0.009478

Fit Statistics

-2 Res Log Likelihood	-614.9
AIC (smaller is better)	-610.9
AICC (smaller is better)	-610.9
BIC (smaller is better)	-606.2

Null Model Likelihood Ratio Test

DF	Chi-Square	Pr > ChiSq
1	1875.62	<.0001

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
treat	1	77	5.30	0.0241
time	7	539	545.99	<.0001
treat*time	7	539	0.66	0.7071

```
proc mixed data=sitka89;
  title 'MIXED approach with AR(1) error structure';
  class treat tree time;
  model size=treat time treat*time;
  repeated / type=ar(1) sub=tree(treat);
run;
```

MIXED approach with AR(1) error structure

The Mixed Procedure

Model Information

Data Set	WORK.SITKA89
Dependent Variable	size
Covariance Structure	Autoregressive
Subject Effect	tree(treat)
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Between-Within

Class Level Information

Class	Levels	Values
treat	2	control ozone
tree	79	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79
time	8	469 496 528 556 579 613 639 674

Dimensions

Covariance Parameters	2
-----------------------	---

Columns in X	27
Columns in Z	0
Subjects	79
Max Obs Per Subject	8

Number of Observations	
Number of Observations Read	632
Number of Observations Used	632
Number of Observations Not Used	0

Iteration History				
Iteration	Evaluations	-2 Res Log Like	Criterion	
0	1	1260.72452373		
1	2	-892.46138132	0.00114345	
2	1	-893.74611704	0.00004058	
3	1	-893.78818880	0.00000005	
4	1	-893.78824278	0.00000000	

Convergence criteria met.

Covariance Parameter Estimates		
Cov Parm	Subject	Estimate
AR(1)	tree(treat)	0.9911
Residual		0.4272

Fit Statistics	
-2 Res Log Likelihood	-893.8
AIC (smaller is better)	-889.8
AICC (smaller is better)	-889.8
BIC (smaller is better)	-885.0

Null Model Likelihood Ratio Test		
DF	Chi-Square	Pr > ChiSq
1	2154.51	<.0001

Type 3 Tests of Fixed Effects				
	Num	Den		
Effect	DF	DF	F Value	Pr > F
treat	1	77	5.13	0.0263
time	7	539	135.39	<.0001
treat*time	7	539	2.03	0.0500

```
proc mixed data=sitka89;
  title 'MIXED approach with Unstructured error structure';
  class treat tree time;
  model size=treat time treat*time;
  repeated / type=un sub=tree(treat);
run;
```

MIXED approach with Unstructured error structure

The Mixed Procedure	
Model Information	
Data Set	WORK.SITKA89
Dependent Variable	size
Covariance Structure	Unstructured
Subject Effect	tree(treat)
Estimation Method	REML
Residual Variance Method	None
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Between-Within

Class Level Information

Class	Levels	Values
treat	2	control ozone
tree	79	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79
time	8	469 496 528 556 579 613 639 674

Dimensions

Covariance Parameters	36
Columns in X	27
Columns in Z	0
Subjects	79
Max Obs Per Subject	8

Number of Observations

Number of Observations Read	632
Number of Observations Used	632
Number of Observations Not Used	0

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	1260.72452373	
1	1	-1246.66153301	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Subject	Estimate
UN(1,1)	tree(treat)	0.4486
UN(2,1)	tree(treat)	0.4455
UN(2,2)	tree(treat)	0.4425
UN(3,1)	tree(treat)	0.4189
UN(3,2)	tree(treat)	0.4166
UN(3,3)	tree(treat)	0.4012
UN(4,1)	tree(treat)	0.4080
UN(4,2)	tree(treat)	0.4060
UN(4,3)	tree(treat)	0.3890
UN(4,4)	tree(treat)	0.3877
UN(5,1)	tree(treat)	0.4223
UN(5,2)	tree(treat)	0.4201
UN(5,3)	tree(treat)	0.4019
UN(5,4)	tree(treat)	0.4004
UN(5,5)	tree(treat)	0.4229
UN(6,1)	tree(treat)	0.4119
UN(6,2)	tree(treat)	0.4099
UN(6,3)	tree(treat)	0.3944
UN(6,4)	tree(treat)	0.3930
UN(6,5)	tree(treat)	0.4115
UN(6,6)	tree(treat)	0.4061
UN(7,1)	tree(treat)	0.3986
UN(7,2)	tree(treat)	0.3967
UN(7,3)	tree(treat)	0.3807
UN(7,4)	tree(treat)	0.3790
UN(7,5)	tree(treat)	0.3950
UN(7,6)	tree(treat)	0.3909
UN(7,7)	tree(treat)	0.3851
UN(8,1)	tree(treat)	0.4085
UN(8,2)	tree(treat)	0.4065
UN(8,3)	tree(treat)	0.3918

UN(8,4)	tree(treat)	0.3909
UN(8,5)	tree(treat)	0.4077
UN(8,6)	tree(treat)	0.4030
UN(8,7)	tree(treat)	0.3936
UN(8,8)	tree(treat)	0.4079

Fit Statistics

-2 Res Log Likelihood	-1246.7
AIC (smaller is better)	-1174.7
AICC (smaller is better)	-1170.1
BIC (smaller is better)	-1089.4

Null Model Likelihood Ratio Test

DF	Chi-Square	Pr > ChiSq
35	2507.39	<.0001

Type 3 Tests of Fixed Effects

	Num	Den		
Effect	DF	DF	F Value	Pr > F
treat	1	77	5.30	0.0241
time	7	77	141.48	<.0001
treat*time	7	77	2.15	0.0485