

```

dm'log;clear;output;clear';
options ps=512 ls=99 nocenter nodate nonumber
      nolabel FORMCHAR="|----|+|----+=|-\<>*" ;
ODS LISTING;

*** Table 23.2 *****;
*** Moore, David S. Essential Statistics, 1st Ed. 2010, ***;
*** W. H. Freeman & Co. NY, NY ***;
*** Harvest of rain forest trees in Borneo ***;
*****;

TITLE1 'Analysis of Variance (One-way ANOVA)';

data Rainforest; infile cards missover;
  infile 'Rainforest logging.csv' missover DSD dlm="," firstobs=2;
  TITLE2 'Harvest of rain forest trees';
  LABEL group = '1=Never harvested, 2=1 year ago, 3=8 years ago'
        trees = 'Number of trees'
        Species = 'Number of species represented'
        Richness = 'Number of species / number of trees';
  input Obs Group Trees Species Richness;
datalines;
;
ODS PDF style=minimal body='Rainforest logging boxplot.PDF' ;
proc sort data=Rainforest; by group; run;
proc boxplot data=Rainforest; plot Richness * group; run;

ods PDF close;
ODS HTML style=minimal body='Rainforest logging ANOVA CRD.html' ;

proc print data=Rainforest; var group Richness;
  TITLE3 'Raw data list (unsorted)'; run;

proc mixed data=Rainforest order=data; class group;
  TITLE3 'ANOVA with PROC MIXED';
  model Richness = group / DDFM = KR;
  repeated / group = group;
run; quit;

proc mixed data=Rainforest order=data; class group;
  TITLE3 'ANOVA with PROC MIXED - separate variances';
  model Richness = group / DDFM=KR outp=resids;
  lsmeans group / adjust=tukey pdiff;
  ods output diffs=ppp lsmeans=mmm;
  *ods listing exclude diffs lsmeans; * this line is inactive;
run;
TITLE4 'Post hoc adjustment with macro by Arnold Saxton';
* SAS Macro by Arnold Saxton: Saxton, A.M. 1998. A macro for ;
* converting mean separation output to letter groupings in Proc Mixed. ;
* In Proc. 23rd SAS Users Group Intl., SAS Institute, Cary, NC, pp1243-1246.;
%include 'C:\pdmix800.sas';
%pdmix800(ppp,mmm,alpha=0.05,sort=yes);
run;

proc univariate data=resids normal plot; var resid;
  TITLE4 'Univariate analysis of residuals';
  TITLE5 'Test of normality and plots only';
  ods exclude Moments BasicMeasures ExtremeObs ExtremeValues
        Modes MissingValues Quantiles TestsForLocation;
  histogram resid / normal;
run;

```

```

proc GlimMix data=Rainforest order=data; class group;
  TITLE3 'ANOVA with SAS PROC GlimMix with Poisson distribution';
  model species = group / dist=Poisson;
run;

proc GlimMix data=Rainforest order=data; class group;
  TITLE3 'ANOVA with SAS PROC GlimMix with negative binomial distribution';
  TITLE4 'with post hoc tests';
  model species = group / dist=NegB;
  LSmeans group / adjust=tukey lines;
  LSmeans group / adjust=dunnett diff=control('1');
run;

quit;

ods html close;

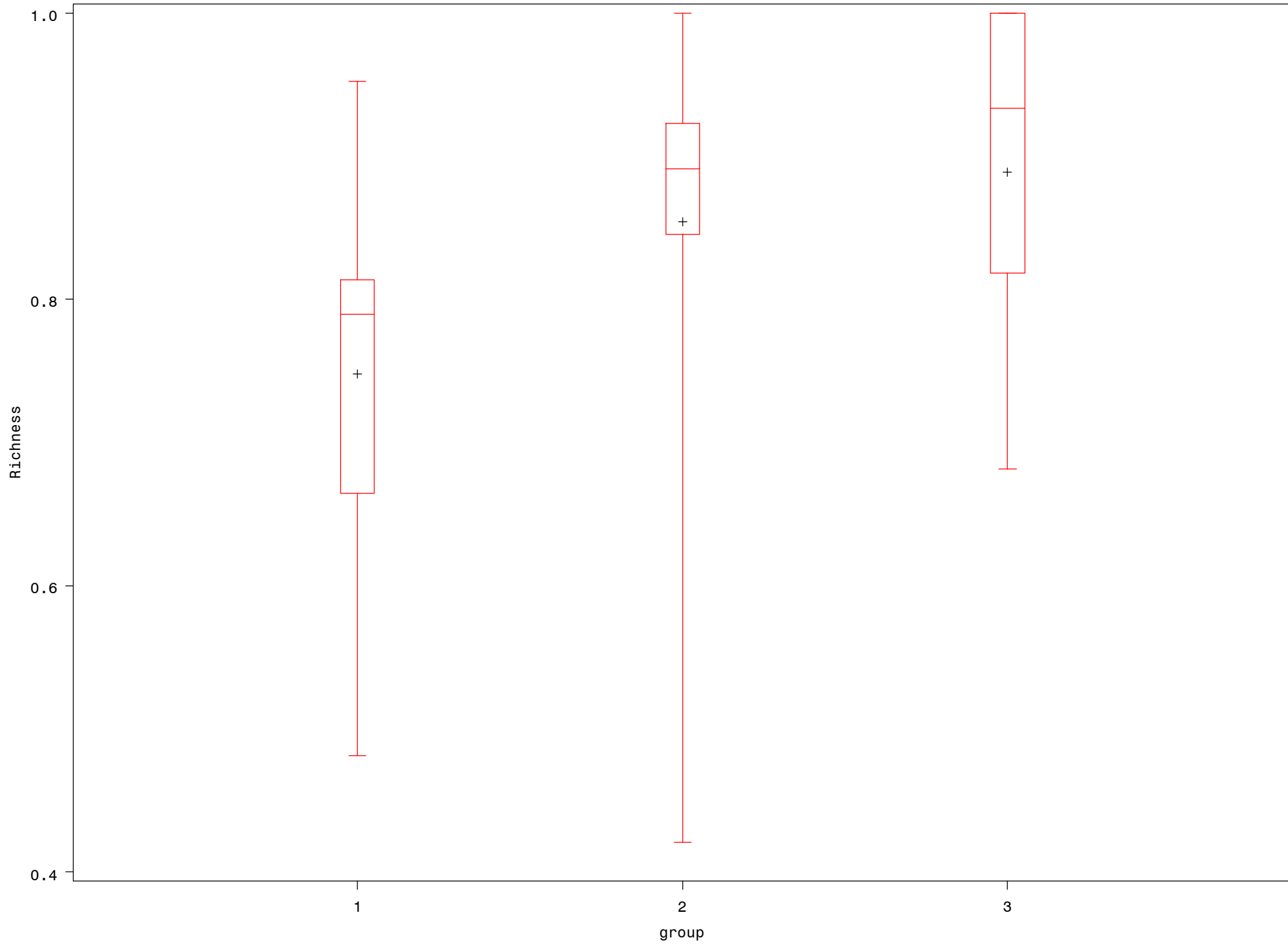
run;
quit;

```

Analysis of Variance (One-way ANOVA)
 Harvest of rain forest trees
 Raw data list (unsorted)

Obs	group	Richness
1	1	0.8148
2	1	0.8182
3	1	0.7586
4	1	0.9524
5	1	0.7895
6	1	0.6364
7	1	0.8125
8	1	0.6500
9	1	0.7917
10	1	0.4815
11	1	0.6786
12	1	0.7895
13	2	0.9167
14	2	0.9167
15	2	0.9333
16	2	0.7778
17	2	0.9000
18	2	0.8333
19	2	0.8824
20	2	0.8571
21	2	0.9286
22	2	1.0000
23	2	0.8824
24	2	0.4211
25	3	0.9444
26	3	1.0000
27	3	0.8182
28	3	0.9333
29	3	1.0000
30	3	0.7895
31	3	0.6818
32	3	0.8333
33	3	1.0000

Analysis of Variance (One-way ANOVA)
Harvest of rain forest trees



Analysis of Variance (One-way ANOVA)
 Harvest of rain forest trees
 ANOVA with PROC MIXED

The Mixed Procedure

Model Information

Data Set	WORK.RAINFOREST
Dependent Variable	Richness
Covariance Structure	Variance Components
Group Effect	group
Estimation Method	REML
Residual Variance Method	None
Fixed Effects SE Method	Kenward-Roger
Degrees of Freedom Method	Kenward-Roger

Class Level Information

Class	Levels	Values
group	3	1 2 3

Dimensions

Covariance Parameters	3
Columns in X	4
Columns in Z	0
Subjects	33
Max Obs Per Subject	1

Number of Observations

Number of Observations Read	33
Number of Observations Used	33
Number of Observations Not Used	0

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	-30.52439823	
1	1	-31.29470017	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Group	Estimate
Residual	group 1	0.01443
Residual	group 2	0.02167
Residual	group 3	0.01287

FitStatistics

-2 Res Log Likelihood	-31.3
AIC (smaller is better)	-25.3
AICC (smaller is better)	-24.4
BIC (smaller is better)	-20.8

Null Model Likelihood Ratio Test

DF	Chi-Square	Pr > ChiSq
2	0.77	0.6803

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
group	2	18.8	4.00	0.0358

Analysis of Variance (One-way ANOVA)
 Harvest of rain forest trees
 ANOVA with PROC MIXED - separate variances

The Mixed Procedure

Model Information

Data Set	WORK.RAINFOREST
Dependent Variable	Richness
Covariance Structure	Diagonal
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Residual

Class Level Information

Class	Levels	Values
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group	3	1 2 3
-------	---	-------

Dimensions

Covariance Parameters	1
Columns in X	4
Columns in Z	0
Subjects	1
Max Obs Per Subject	33

Number of Observations

Number of Observations Read	33
Number of Observations Used	33
Number of Observations Not Used	0

Covariance Parameter

Estimates

Cov Parm	Estimate
Residual	0.01667

FitStatistics

-2 Res Log Likelihood	-30.5
AIC (smaller is better)	-28.5
AICC (smaller is better)	-28.4
BIC (smaller is better)	-27.1

Type 3 Tests of Fixed Effects

Effect	Num	Den	F Value	Pr > F
	DF	DF		
group	2	30	3.55	0.0412

Least Squares Means

Effect	group	Estimate	Standard		t Value	Pr > t
			Error	DF		
group	1	0.7478	0.03727	30	20.06	<.0001
group	2	0.8541	0.03727	30	22.92	<.0001
group	3	0.8889	0.04304	30	20.66	<.0001

Differences of Least Squares Means

Effect	group	_group	Estimate	Standard		t Value	Pr > t	Adjustment	Adj P
				Error	DF				
group	1	2	-0.1063	0.05271	30	-2.02	0.0527	Tukey-Kramer	0.1255
group	1	3	-0.1411	0.05693	30	-2.48	0.0190	Tukey-Kramer	0.0485
group	2	3	-0.03483	0.05693	30	-0.61	0.5453	Tukey-Kramer	0.8148

Analysis of Variance (One-way ANOVA)
 Harvest of rain forest trees
 ANOVA with PROC MIXED - separate variances
 Post hoc adjustment with macro by Arnold Saxton

Effect=group ADJUSTMENT=Tukey-Kramer(P<0.05) bygroup=1

Obs	group	Estimate	StdErr	MSGROUP
1	3	0.8889	0.04304	A
2	2	0.8541	0.03727	AB
3	1	0.7478	0.03727	B

Analysis of Variance (One-way ANOVA)
 Harvest of rain forest trees
 ANOVA with PROC MIXED - separate variances
 Univariate analysis of residuals
 Test of normality and plots only

The UNIVARIATE Procedure
 Variable: Resid

Tests for Normality

Test	--Statistic--	-----p Value-----
Shapiro-Wilk	W 0.865166	Pr < W 0.0007
Kolmogorov-Smirnov	D 0.19556	Pr > D <0.0100
Cramer-von Mises	W-Sq 0.26615	Pr > W-Sq <0.0050
Anderson-Darling	A-Sq 1.48335	Pr > A-Sq <0.0050

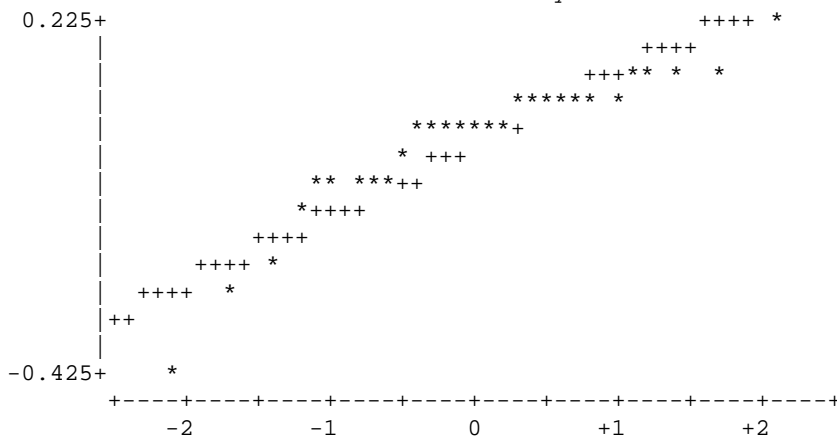
Stem Leaf Boxplot

2 0	1	
1 5	1	
1 111	3	
0 566667778	9	+-----+
0 01334444	8	*---+--*
-0 2	1	
-0 8776	4	+-----+
-1 100	3	
-1		
-2 1	1	
-2 7	1	
-3		
-3		
-4 3	1	0

-----+

Multiply Stem.Leaf by 10**-1

Normal Probability Plot



Analysis of Variance (One-way ANOVA)
 Harvest of rain forest trees
 ANOVA with PROC MIXED - separate variances
 Univariate analysis of residuals
 Test of normality and plots only

The UNIVARIATE Procedure
 Fitted Normal Distribution for Resid

Parameters for Normal Distribution

Parameter	Symbol	Estimate
Mean	Mu	0
Std Dev	Sigma	0.125005

Goodness-of-Fit Tests for Normal Distribution

Test	-----Statistic-----	-----p Value-----
Kolmogorov-Smirnov	D 0.19555980	Pr > D <0.010
Cramer-von Mises	W-Sq 0.26615011	Pr > W-Sq <0.005
Anderson-Darling	A-Sq 1.48334999	Pr > A-Sq <0.005

Quantiles for Normal Distribution

Percent	-----Quantile-----	
	Observed	Estimated
1.0	-0.43302	-0.29081
5.0	-0.26631	-0.20562
10.0	-0.11141	-0.16020
25.0	-0.06921	-0.08431
50.0	0.04169	0.00000
75.0	0.06699	0.08431
90.0	0.11106	0.16020
95.0	0.14588	0.20562
99.0	0.20459	0.29081

Analysis of Variance (One-way ANOVA)
 Harvest of rain forest trees
 ANOVA with SAS PROC GlimMix with Poisson distribution

The GLIMMIX Procedure

Model Information

Data Set	WORK.RAINFOREST
Response Variable	Species
Response Distribution	Poisson
Link Function	Log
Variance Function	Default
Variance Matrix	Diagonal
Estimation Technique	Maximum Likelihood
Degrees of Freedom Method	Residual

Class Level Information

Class	Levels	Values
group	3	1 2 3

Number of Observations Read	33
Number of Observations Used	33

Dimensions

Columns in X	4
Columns in Z	0
Subjects (Blocks in V)	1
Max Obs per Subject	33

Optimization Information

Optimization Technique	Newton-Raphson
Parameters in Optimization	3
Lower Boundaries	0
Upper Boundaries	0
Fixed Effects	Not Profiled

Iteration History

Iteration	Restarts	Evaluations	Objective Function	Change	Max Gradient
0	0	4	95.876743485	.	21.16051
1	0	3	95.290183523	0.58655996	0.563649
2	0	3	95.289616099	0.00056742	0.000567
3	0	3	95.289616098	0.00000000	7.4E-10

Convergence criterion (GCONV=1E-8) satisfied.

FitStatistics

-2 Log Likelihood	190.58
AIC (smaller is better)	196.58
AICC (smaller is better)	197.41
BIC (smaller is better)	201.07
CAIC (smaller is better)	204.07
HQIC (smaller is better)	198.09
Pearson Chi-Square	37.58
Pearson Chi-Square / DF	1.25

Type III Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
group	2	30	7.04	0.0031

Analysis of Variance (One-way ANOVA)
 Harvest of rain forest trees
 ANOVA with SAS PROC GlimMix with negative binomial distribution
 with post hoc tests

The GLIMMIX Procedure

Model Information

Data Set	WORK.RAINFOREST
Response Variable	Species
Response Distribution	Negative Binomial
Link Function	Log
Variance Function	Default
Variance Matrix	Diagonal
Estimation Technique	Maximum Likelihood
Degrees of Freedom Method	Residual

Class Level Information

Class	Levels	Values
group	3	1 2 3

Number of Observations Read	33
Number of Observations Used	33

Dimensions

Covariance Parameters	1
Columns in X	4
Columns in Z	0
Subjects (Blocks in V)	1
Max Obs per Subject	33

Optimization Information

Optimization Technique	Newton-Raphson
Parameters in Optimization	4
Lower Boundaries	1
Upper Boundaries	0
Fixed Effects	Not Profiled

Iteration History

Iteration	Restarts	Evaluations	Objective Function	Change	Max Gradient
0	0	4	200.16501704	.	1.041193
1	0	76	95.270804284	104.89421275	1.796269
2	0	3	95.229112819	0.04169147	0.553487
3	0	3	95.229019783	0.00009304	0.003957
4	0	3	95.229019776	0.00000001	8.746E-7

Convergence criterion (GCONV=1E-8) satisfied.

FitStatistics

-2 Log Likelihood	190.46
AIC (smaller is better)	198.46
AICC (smaller is better)	199.89
BIC (smaller is better)	204.44
CAIC (smaller is better)	208.44
HQIC (smaller is better)	200.47
Pearson Chi-Square	34.19
Pearson Chi-Square / DF	1.14

Type III Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
group	2	30	6.36	0.0050

group Least Squares Means

group	Estimate	Standard Error	DF	t Value	Pr > t
1	2.8622	0.07330	30	39.05	<.0001
2	2.4639	0.08777	30	28.07	<.0001
3	2.6150	0.09458	30	27.65	<.0001

Differences of group Least Squares Means

Adjustment for Multiple Comparisons: Tukey-Kramer

group	_group	Estimate	Standard Error	DF	t Value	Pr > t	Adj P
1	2	0.3983	0.1144	30	3.48	0.0015	0.0043
1	3	0.2472	0.1197	30	2.07	0.0475	0.1141
2	3	-0.1511	0.1290	30	-1.17	0.2508	0.4792

Tukey-Kramer Grouping for group Least Squares Means (Alpha=0.05)

LS-means with the same letter are not significantly different.

group	Estimate	Grouping
1	2.8622	A
		A
3	2.6150	B A
		B
2	2.4639	B

Group Least Squares Means

group	Estimate	Standard Error	DF	t Value	Pr > t
1	2.8622	0.07330	30	39.05	<.0001
2	2.4639	0.08777	30	28.07	<.0001
3	2.6150	0.09458	30	27.65	<.0001

Differences of group Least Squares Means

Adjustment for Multiple Comparisons: Dunnett

group	_group	Estimate	Standard Error	DF	t Value	Pr > t	Adj P
2	1	-0.3983	0.1144	30	-3.48	0.0015	0.0030
3	1	-0.2472	0.1197	30	-2.07	0.0475	0.0880