

```

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

*****;
*** McClave, Benson and Sincich - Statistics for Business and Economics ***;
*** 2005, 9th Ed. Pearson Prentice Hall. Upper Saddle River, NJ          ***;
*****;
*** Golf ball distance with two different clubs and 4 brands of ball     ***;
*****;

TITLE1 'Factorial ANOVA (CRD with factorial treatment arrangement)';

data Golf; length Club $ 10;
        infile 'Golf distance.csv' missover DSD dlm="," firstobs=2;
        TITLE2 'Analysis of Golf ball distance';
input Club $ BallBrand $ Rep Distance;
datalines;
;

ODS PDF style=minimal body='Golf distance.PDF' ;
proc sort data=Golf; by BallBrand; run;
proc boxplot data=Golf; plot Distance * BallBrand; run;
proc sort data=Golf; by Club BallBrand Rep; run;
proc boxplot data=Golf; plot Distance * Club; run;
proc boxplot data=Golf; plot Distance * BallBrand; run;
ods PDF close;

ODS HTML style=minimal body='Golf distance.html' ;

PROC PRINT DATA=Golf; TITLE3 'LISTING OF DATA'; RUN;

PROC MIXED DATA=Golf; CLASS Club BallBrand;
        TITLE3 'Analysis of Variance done with PROC MIXED';
        TITLE3 'Testing for homogeniety of variance';
        MODEL Distance = Club BallBrand Club*BallBrand / ddfm=KR outp=resids;
        repeated / group=Club*BallBrand;
run;
PROC MIXED DATA=Golf; CLASS Club BallBrand;
        TITLE3 'Analysis of Variance done with PROC MIXED';
        MODEL Distance = Club BallBrand Club*BallBrand / ddfm=KR outp=resids;
        LSMEANS Club BallBrand Club*BallBrand / PDIFF ADJUST=TUKEY;
        ods output diffs=ppp lsmeans=mmm;
**ods listing exclude diffs lsmeans; *this is now just a comment;
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=.01,sort=yes);
RUN;
QUIT;

proc univariate data=resids normal plot; var resid;
        TITLE4 'Univariate analysis of RESIDUALS';
        ods exclude Moments BasicMeasures ExtremeObs ExtremeValues
                Modes MissingValues Quantiles TestsForLocation;
        histogram resid / normal;
run;

proc sort data=Golf; by Club BallBrand; run;

```

```

proc means noprint data=Golf; by Club BallBrand; var Distance;
  output out=next1 mean=mean; run;
options ps=45; proc plot data=next1; plot mean*BallBrand=Club;
  TITLE3 'Variance mean plot to examine homogeniety';
run;
options ps=61;

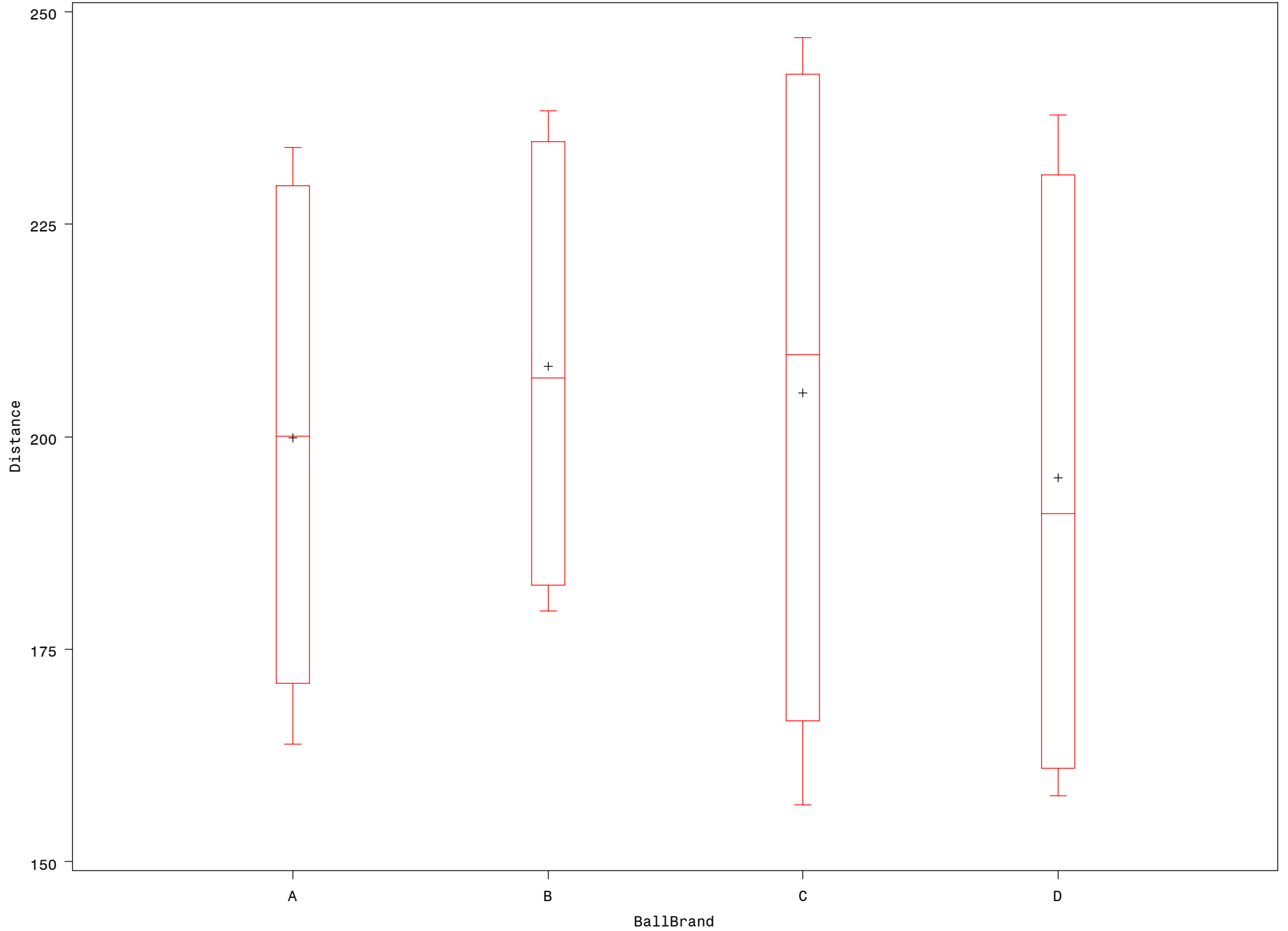
ods html close;
run;
quit;

```

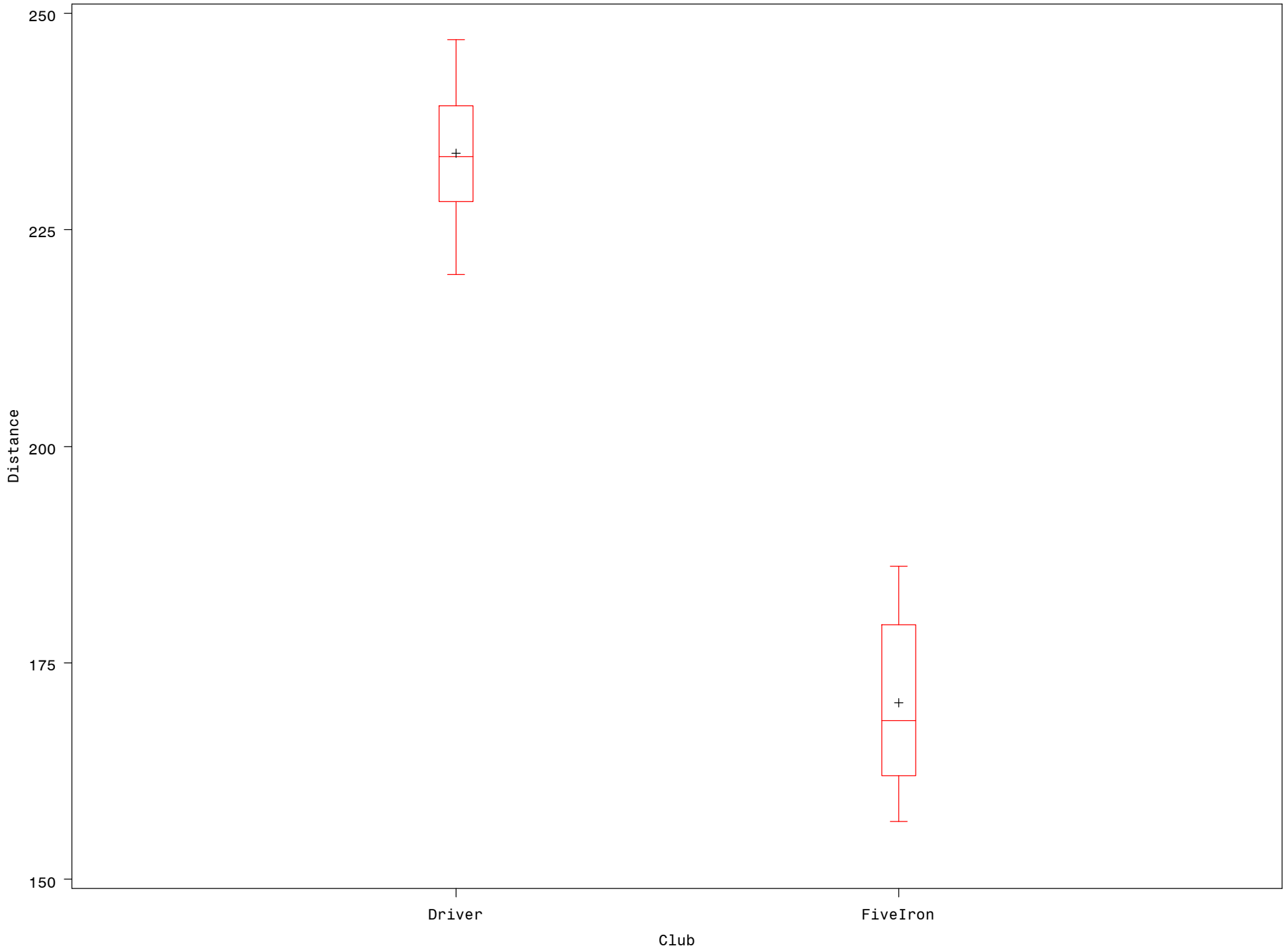
Factorial ANOVA (CRD with factorial treatment arrangement)
 Analysis of Golf ball distance
 LISTING OF DATA

Obs	Club	Ball Brand	Rep	Distance
1	Driver	A	1	226.4
2	Driver	A	2	232.6
3	Driver	A	3	234.0
4	Driver	A	4	220.7
5	Driver	B	1	238.3
6	Driver	B	2	231.7
7	Driver	B	3	227.7
8	Driver	B	4	237.7
9	Driver	C	1	240.5
10	Driver	C	2	246.9
11	Driver	C	3	240.3
12	Driver	C	4	244.7
13	Driver	D	1	219.8
14	Driver	D	2	228.7
15	Driver	D	3	232.9
16	Driver	D	4	237.8
17	FiveIron	A	1	163.8
18	FiveIron	A	2	179.4
19	FiveIron	A	3	168.6
20	FiveIron	A	4	173.4
21	FiveIron	B	1	184.4
22	FiveIron	B	2	180.6
23	FiveIron	B	3	179.5
24	FiveIron	B	4	186.2
25	FiveIron	C	1	179.0
26	FiveIron	C	2	168.0
27	FiveIron	C	3	165.2
28	FiveIron	C	4	156.7
29	FiveIron	D	1	157.8
30	FiveIron	D	2	161.8
31	FiveIron	D	3	162.1
32	FiveIron	D	4	160.3

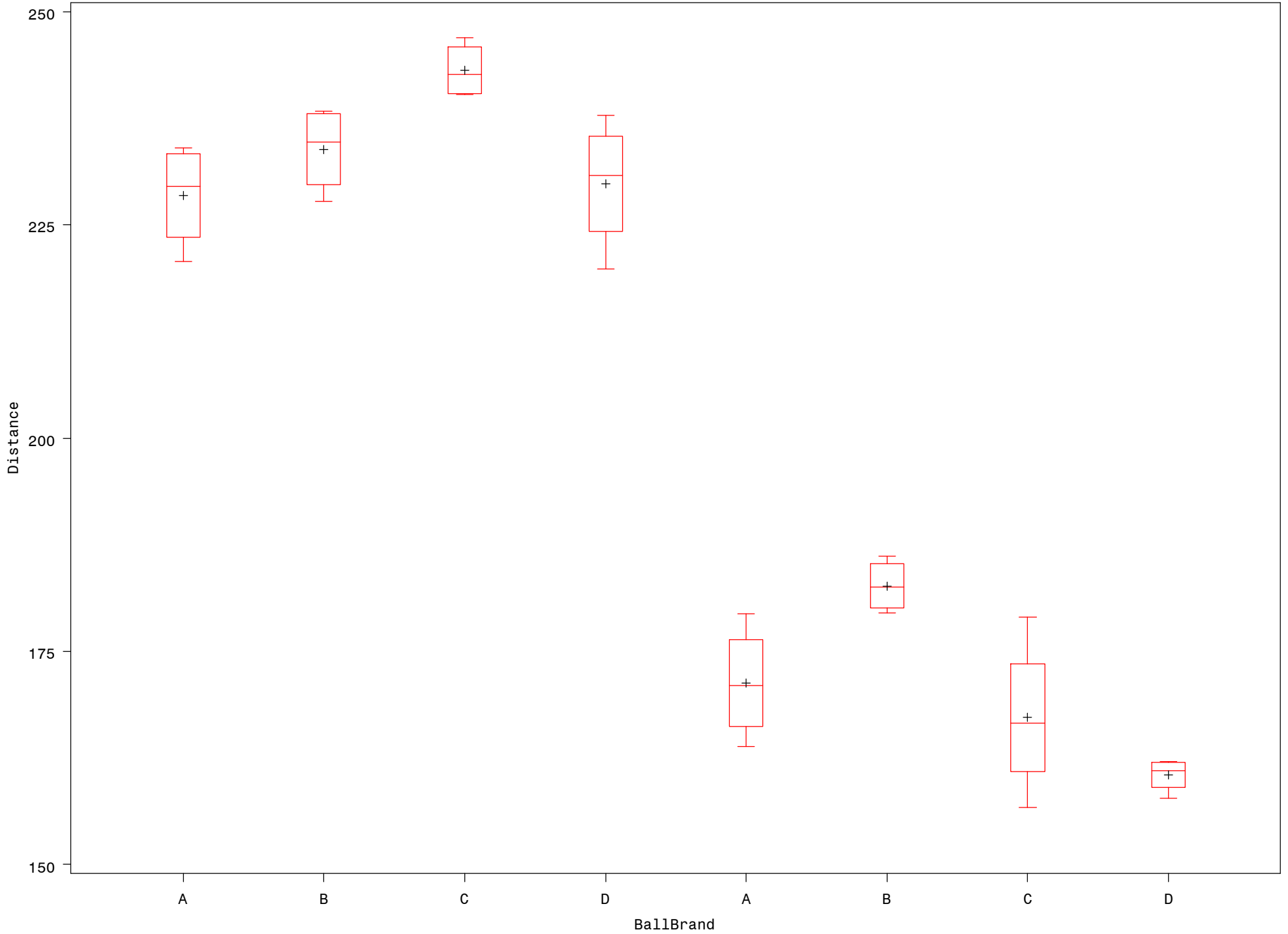
Factorial ANOVA (CRD with factorial treatment arrangement)
Analysis of Golf ball distance



Factorial ANOVA (CRD with factorial treatment arrangement)
Analysis of Golf ball distance



Factorial ANOVA (CRD with factorial treatment arrangement)
Analysis of Golf ball distance



Factorial ANOVA (CRD with factorial treatment arrangement)
 Analysis of Golf ball distance
 Testing for homogeneity of variance

The Mixed Procedure

Model Information

Data Set	WORK.GOLF
Dependent Variable	Distance
Covariance Structure	Variance Components
Group Effect	Club*BallBrand
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
Club	2	Driver FiveIron
BallBrand	4	A B C D

Dimensions

Covariance Parameters	8
Columns in X	15
Columns in Z	0
Subjects	32
Max Obs Per Subject	1

Number of Observations

Number of Observations Read	32
Number of Observations Used	32
Number of Observations Not Used	0

Iteration History

Iteration	Evaluations	-2 Res Log Like	Criterion
0	1	164.09044060	
1	1	154.70804719	0.00000000

Convergence criteria met.

Covariance Parameter Estimates

Cov Parm	Group	Estimate
Residual	Club*BallBrand Driver A	37.4292
Residual	Club*BallBrand Driver B	25.6900
Residual	Club*BallBrand Driver C	10.5333
Residual	Club*BallBrand Driver D	58.2733
Residual	Club*BallBrand FiveIron A	44.5200
Residual	Club*BallBrand FiveIron B	9.9292
Residual	Club*BallBrand FiveIron C	84.7092
Residual	Club*BallBrand FiveIron D	3.8600

FitStatistics

-2 Res Log Likelihood	154.7
AIC (smaller is better)	170.7
AICC (smaller is better)	180.3
BIC (smaller is better)	182.4

Null Model Likelihood Ratio Test

DF	Chi-Square	Pr > ChiSq
7	9.38	0.2264

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Club	1	15.3	934.73	<.0001
BallBrand	3	7.83	8.89	0.0066
Club*BallBrand	3	7.83	7.23	0.0120

Factorial ANOVA (CRD with factorial treatment arrangement)

Analysis of Golf ball distance

Analysis of Variance done with PROC MIXED

The Mixed Procedure

Model Information

Data Set	WORK.GOLF
Dependent Variable	Distance
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
Club	2	Driver FiveIron
BallBrand	4	A B C D

Dimensions

Covariance Parameters	1
Columns in X	15
Columns in Z	0
Subjects	1
Max Obs Per Subject	32

Number of Observations

Number of Observations Read	32
Number of Observations Used	32
Number of Observations Not Used	0

Covariance Parameter

Estimates

Cov Parm	Estimate
Residual	34.3680

FitStatistics

-2 Res Log Likelihood	164.1
AIC (smaller is better)	166.1
AICC (smaller is better)	166.3
BIC (smaller is better)	167.3

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	F Value	Pr > F
Club	1	24	934.73	<.0001
BallBrand	3	24	7.81	0.0008
Club*BallBrand	3	24	7.36	0.0012

Least Squares Means

Effect	Club	Ball Brand	Estimate	Standard Error	DF	t Value	Pr > t
Club	Driver		233.79	1.4656	24	159.52	<.0001
Club	FiveIron		170.43	1.4656	24	116.28	<.0001
BallBrand		A	199.86	2.0727	24	96.43	<.0001
BallBrand		B	208.26	2.0727	24	100.48	<.0001
BallBrand		C	205.16	2.0727	24	98.98	<.0001
BallBrand		D	195.15	2.0727	24	94.15	<.0001
Club*BallBrand	Driver	A	228.43	2.9312	24	77.93	<.0001
Club*BallBrand	Driver	B	233.85	2.9312	24	79.78	<.0001
Club*BallBrand	Driver	C	234.10	2.9312	24	82.93	<.0001
Club*BallBrand	Driver	D	229.80	2.9312	24	78.40	<.0001
Club*BallBrand	FiveIron	A	171.30	2.9312	24	58.44	<.0001
Club*BallBrand	FiveIron	B	182.68	2.9312	24	62.32	<.0001
Club*BallBrand	FiveIron	C	167.23	2.9312	24	57.05	<.0001
Club*BallBrand	FiveIron	D	160.50	2.9312	24	54.76	<.0001

Differences ofLeast Squares Means

Effect	Club	Ball Brand	_Club	Ball Brand	Estimate	Standard Error	DF	t Value	Pr > t
Club	Driver		FiveIron		63.3688	2.0727	24	30.57	<.0001
BallBrand		A		B	-8.4000	2.9312	24	-2.87	0.0085
BallBrand		A		C	-5.3000	2.9312	24	-1.81	0.0831
BallBrand		A		D	4.7125	2.9312	24	1.61	0.1210
BallBrand		B		C	3.1000	2.9312	24	1.06	0.3008
BallBrand		B		D	13.1125	2.9312	24	4.47	0.0002
BallBrand		C		D	10.0125	2.9312	24	3.42	0.0023
Club*BallBrand	Driver	A	Driver	B	-5.4250	4.1454	24	-1.31	0.2030
Club*BallBrand	Driver	A	Driver	C	-14.6750	4.1454	24	-3.54	0.0017
Club*BallBrand	Driver	A	Driver	D	-1.3750	4.1454	24	-0.33	0.7430
Club*BallBrand	Driver	A	FiveIron	A	57.1250	4.1454	24	13.78	<.0001
Club*BallBrand	Driver	A	FiveIron	B	45.7500	4.1454	24	11.04	<.0001
Club*BallBrand	Driver	A	FiveIron	C	61.2000	4.1454	24	14.76	<.0001
Club*BallBrand	Driver	A	FiveIron	D	67.9250	4.1454	24	16.39	<.0001
Club*BallBrand	Driver	B	Driver	C	-9.2500	4.1454	24	-2.23	0.0353
Club*BallBrand	Driver	B	Driver	D	4.0500	4.1454	24	0.98	0.3383
Club*BallBrand	Driver	B	FiveIron	A	62.5500	4.1454	24	15.09	<.0001
Club*BallBrand	Driver	B	FiveIron	B	51.1750	4.1454	24	12.35	<.0001
Club*BallBrand	Driver	B	FiveIron	C	66.6250	4.1454	24	16.07	<.0001
Club*BallBrand	Driver	B	FiveIron	D	73.3500	4.1454	24	17.69	<.0001
Club*BallBrand	Driver	C	Driver	D	13.3000	4.1454	24	3.21	0.0038
Club*BallBrand	Driver	C	FiveIron	A	71.8000	4.1454	24	17.32	<.0001
Club*BallBrand	Driver	C	FiveIron	B	60.4250	4.1454	24	14.58	<.0001
Club*BallBrand	Driver	C	FiveIron	C	75.8750	4.1454	24	18.30	<.0001
Club*BallBrand	Driver	C	FiveIron	D	82.6000	4.1454	24	19.93	<.0001
Club*BallBrand	Driver	D	FiveIron	A	58.5000	4.1454	24	14.11	<.0001
Club*BallBrand	Driver	D	FiveIron	B	47.1250	4.1454	24	11.37	<.0001
Club*BallBrand	Driver	D	FiveIron	C	62.5750	4.1454	24	15.10	<.0001
Club*BallBrand	Driver	D	FiveIron	D	69.3000	4.1454	24	16.72	<.0001
Club*BallBrand	FiveIron	A	FiveIron	B	-11.3750	4.1454	24	-2.74	0.0113
Club*BallBrand	FiveIron	A	FiveIron	C	4.0750	4.1454	24	0.98	0.3354
Club*BallBrand	FiveIron	A	FiveIron	D	10.8000	4.1454	24	2.61	0.0155
Club*BallBrand	FiveIron	B	FiveIron	C	15.4500	4.1454	24	3.73	0.0010
Club*BallBrand	FiveIron	B	FiveIron	D	22.1750	4.1454	24	5.35	<.0001
Club*BallBrand	FiveIron	C	FiveIron	D	6.7250	4.1454	24	1.62	0.1178

Differences ofLeast Squares Means

Effect	Club	Ball Brand	_Club	Ball Brand	Adjustment	Adj P
Club	Driver		FiveIron		Tukey	<.0001
BallBrand		A		B	Tukey	0.0397
BallBrand		A		C	Tukey	0.2942
BallBrand		A		D	Tukey	0.3934
BallBrand		B		C	Tukey	0.7179
BallBrand		B		D	Tukey	0.0009
BallBrand		C		D	Tukey	0.0114

Club*BallBrand	Driver	A	Driver	B	Tukey	0.8867
Club*BallBrand	Driver	A	Driver	C	Tukey	0.0303
Club*BallBrand	Driver	A	Driver	D	Tukey	1.0000
Club*BallBrand	Driver	A	FiveIron	A	Tukey	<.0001
Club*BallBrand	Driver	A	FiveIron	B	Tukey	<.0001
Club*BallBrand	Driver	A	FiveIron	C	Tukey	<.0001
Club*BallBrand	Driver	A	FiveIron	D	Tukey	<.0001
Club*BallBrand	Driver	B	Driver	C	Tukey	0.3691
Club*BallBrand	Driver	B	Driver	D	Tukey	0.9735
Club*BallBrand	Driver	B	FiveIron	A	Tukey	<.0001
Club*BallBrand	Driver	B	FiveIron	B	Tukey	<.0001
Club*BallBrand	Driver	B	FiveIron	C	Tukey	<.0001
Club*BallBrand	Driver	B	FiveIron	D	Tukey	<.0001
Club*BallBrand	Driver	C	Driver	D	Tukey	0.0624
Club*BallBrand	Driver	C	FiveIron	A	Tukey	<.0001
Club*BallBrand	Driver	C	FiveIron	B	Tukey	<.0001
Club*BallBrand	Driver	C	FiveIron	C	Tukey	<.0001
Club*BallBrand	Driver	C	FiveIron	D	Tukey	<.0001
Club*BallBrand	Driver	D	FiveIron	A	Tukey	<.0001
Club*BallBrand	Driver	D	FiveIron	B	Tukey	<.0001
Club*BallBrand	Driver	D	FiveIron	C	Tukey	<.0001
Club*BallBrand	Driver	D	FiveIron	D	Tukey	<.0001
Club*BallBrand	FiveIron	A	FiveIron	B	Tukey	0.1574
Club*BallBrand	FiveIron	A	FiveIron	C	Tukey	0.9726
Club*BallBrand	FiveIron	A	FiveIron	D	Tukey	0.2023
Club*BallBrand	FiveIron	B	FiveIron	C	Tukey	0.0198
Club*BallBrand	FiveIron	B	FiveIron	D	Tukey	0.0004
Club*BallBrand	FiveIron	C	FiveIron	D	Tukey	0.7331

Factorial ANOVA (CRD with factorial treatment arrangement)
 Analysis of Golf ball distance
 Analysis of Variance done with PROC MIXED
 Post hoc adjustment with macro by Arnold Saxton

Effect=Club ADJUSTMENT=Tukey(P<.01) bygroup=1

Ball					
Obs	Club	Brand	Estimate	StdErr	MSGROUP
1	Driver		233.79	1.4656	A
2	FiveIron		170.43	1.4656	B

Effect=BallBrand ADJUSTMENT=Tukey(P<.01) bygroup=2

Ball					
Obs	Club	Brand	Estimate	StdErr	MSGROUP
3		B	208.26	2.0727	A
4		C	205.16	2.0727	AB
5		A	199.86	2.0727	AB
6		D	195.15	2.0727	B

Effect=Club*BallBrand ADJUSTMENT=Tukey(P<.01) bygroup=3

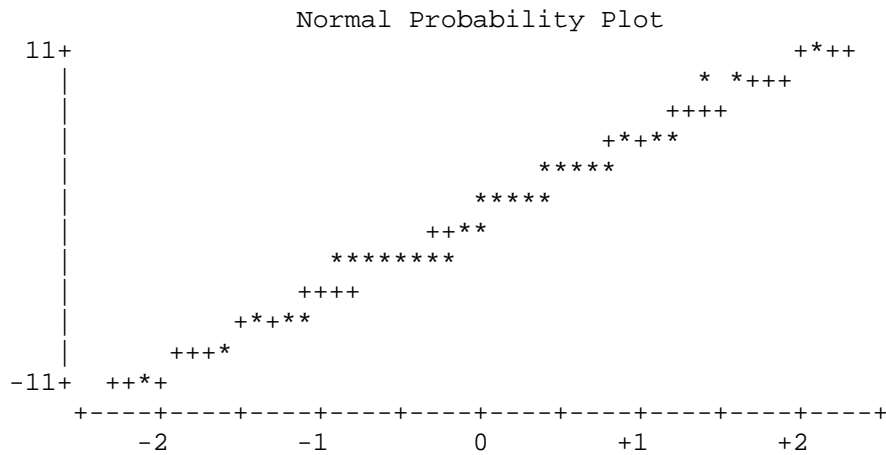
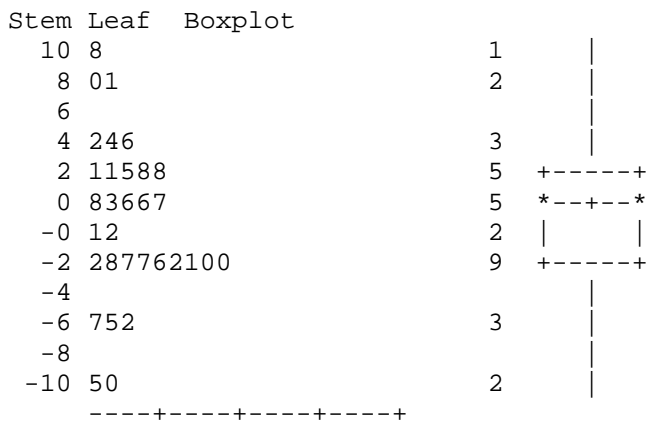
Ball					
Obs	Club	Brand	Estimate	StdErr	MSGROUP
7	Driver	C	243.10	2.9312	A
8	Driver	B	233.85	2.9312	A
9	Driver	D	229.80	2.9312	A
10	Driver	A	228.43	2.9312	A
11	FiveIron	B	182.68	2.9312	B
12	FiveIron	A	171.30	2.9312	BC
13	FiveIron	C	167.23	2.9312	BC
14	FiveIron	D	160.50	2.9312	C

Factorial ANOVA (CRD with factorial treatment arrangement)
 Analysis of Golf ball distance
 Analysis of Variance done with PROC MIXED
 Univariate analysis of RESIDUALS

The UNIVARIATE Procedure
 Variable: Resid

Tests for Normality

Test	--Statistic--	-----p Value-----
Shapiro-Wilk	W 0.978238	Pr < W 0.7470
Kolmogorov-Smirnov	D 0.112856	Pr > D >0.1500
Cramer-von Mises	W-Sq 0.051766	Pr > W-Sq >0.2500
Anderson-Darling	A-Sq 0.314863	Pr > A-Sq >0.2500



Factorial ANOVA (CRD with factorial treatment arrangement)
 Analysis of Golf ball distance
 Analysis of Variance done with PROC MIXED
 Univariate analysis of RESIDUALS

The UNIVARIATE Procedure
 Fitted Normal Distribution for Resid

Parameters for Normal Distribution

Parameter	Symbol	Estimate
Mean	Mu	0
Std Dev	Sigma	5.158246

Goodness-of-Fit Tests for Normal Distribution

Test	Statistic	p Value
Kolmogorov-Smirnov	D 0.11285590	Pr > D >0.150
Cramer-von Mises	W-Sq 0.05176630	Pr > W-Sq >0.250
Anderson-Darling	A-Sq 0.31486285	Pr > A-Sq >0.250

Quantiles for Normal Distribution

Percent	Quantile	
	Observed	Estimated
1.0	-10.52500	-11.9999
5.0	-10.00000	-8.4846
10.0	-7.50000	-6.6106
25.0	-2.70000	-3.4792
50.0	0.28750	0.0000
75.0	3.66250	3.4792
90.0	5.57500	6.6106
95.0	8.10000	8.4846
99.0	11.77500	11.9999

Plot of mean*BallBrand. Symbol is value of Club.

