STAT 430, ANOVA

ANOVA Examples with SAS
==========

ssh abc@glue.umd.edu, tap sas913, sas
https://www.statlab.umd.edu/sasdoc/sashtml/onldoc.htm

Ex1: Speed Reading, One-Way

Randomly assign 15 subjects to 3 speed reading methods (3 treatment groups) X,Y,Z. Five subjects per reading method.

Response: Number of words a subject reads per minute.

X	Y	Z
700	480	500
850	460	550
820	500	480
640	570	600
920	580	610

Assuming normal distributions with equal variance, we test:

H_0: mu_x=mu_y=mu_z, H_1: The means are not all equal

```
OPTIONS PS=35 LS=70;

DATA READING;
INPUT GROUP $  WORDS @@;
DATALINES;
X 700 X 850 X 820 X 640 X 920
Y 480 Y 460 Y 500 Y 570 Y 580
```

```
Z 500 Z 550 Z 480 Z 600 Z 610
;

PROC ANOVA DATA=READING;
TITLE "READING ANOVA";
CLASS  GROUP;
MODEL WORDS = GROUP;
MEANS GROUP;
RUN;
```

READING ANOVA

The ANOVA Procedure

Class Level Information

Class	Levels	Values
GROUP	3	X Y Z

Number of Observations Read	15
Number of Observations Used	15

READING ANOVA

Dependent Variable: WORDS

Source	DF	Sum of Squares	Mean Square	F Value
Model	2	215613.3333	107806.6667	16.78
Error	12	77080.0000	6423.3333	
Corrected Total	14	292693.3333		

Source	Pr > F	
Model	0.0003	REJECT H_0!!! Means not the same!!!
Error		
Corrected Total		

R-Square	Coeff Var	Root MSE	WORDS Mean
0.736653	12.98256	80.14570	617.3333

Level of GROUP	N	WORDS Mean	WORDS Std Dev
X	5	786.000000	113.929803
Y	5	518.000000	54.037024
Z	5	548.000000	58.051701

So, the means are not the same, which means that the reading methods are different. Therefore we perform Multiple Comparisons or Post Hoc analysis.

Can choose: DUNCAN, SNK,LSD,TUKEY,SCHEFFE. For example: We use SNK

```
MEANS GROUP/ SNK ALPHA=0.05;
```

```
  PROC ANOVA DATA=READING;
  TITLE "READING ANOVA";
  CLASS GROUP;
  MODEL WORDS = GROUP;
  MEANS GROUP/ SNK ALPHA=0.05;
  RUN;
```

The ANOVA Procedure

Student-Newman-Keuls Test for WORDS

NOTE: This test controls the Type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	6423.333

Number of Means	2	3
Critical Range	110.44134	135.22484

---> Means with the same letter are not significantly different.

SNK Grouping	Mean	N	GROUP	
A	786.00	5	X	<---- X method best.
B	548.00	5	Z	<---- Z,Y methods are
B				the same.
B	518.00	5	Y	

Do again with SCHEFFE:

```
PROC ANOVA DATA=READING;
  TITLE "READING ANOVA";
  CLASS GROUP;
  MODEL WORDS = GROUP;
  MEANS GROUP/ SCHEFFE ALPHA=0.05;
  RUN;
```

The ANOVA Procedure

Scheffe's Test for WORDS

NOTE: This test controls the Type I experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	12
Error Mean Square	6423.333
Critical Value of F	3.88529
Minimum Significant Difference	141.3

Means with the same letter are not significantly different.

Scheffe Grouping	Mean	N	GROUP
A	786.00	5	X
B	548.00	5	Z
B			
B	518.00	5	Y

Get the same results as those from SNK.

Now specific contrasts using PROC GLM.

```
PROC GLM DATA=READING;
  TITLE "Study Contrasts";
  CLASS GROUP;
  MODEL WORDS = GROUP;
  CONTRAST 'X VS. Y AND Z'  GROUP -1.3  0.65 0.65;
  CONTRAST 'X VS. Y'        GROUP -1    1    0;
  CONTRAST 'Y VS  Z'        GROUP  0    1   -1;
  RUN;
```

The GLM Procedure

```
Dependent Variable: WORDS

                    Source                 Pr > F

                    GROUP                  0.0003


Source                       DF    Type III SS    Mean Square   F Value

GROUP                         2    215613.3333    107806.6667     16.78

                    Source                 Pr > F

                    GROUP                  0.0003


Contrast                     DF    Contrast SS    Mean Square   F Value

X VS. Y AND Z                 1    213363.3333    213363.3333     33.22
X VS. Y                       1    179560.0000    179560.0000     27.95
Y VS  Z                       1      2250.0000      2250.0000      0.35

                    Contrast               Pr > F

                    X VS. Y AND Z          <.0001  Different!
                    X VS. Y                0.0002  Different!
                    Y VS  Z                0.5649  Same!
```

Ex1.1: Two-Way Extension of Speed Reading Example

GROUP			
X	Y	Z	
700	480	500	
850	460	550	
820	500	480	MALE
640	570	600	
920	580	610	

```
---------------         GENDER
900  590  610
880  540  660
899  560  525 FEMALE
780  570  610
899  555  645

Now we have 2 factors: GROUP (Levels X,Y,Z) and GENDER (Levels M,F)

We have 5 observations per cell. So, I=3,J=2,K=5

OPTIONS PS=35 LS=70;

DATA READING;
INPUT GROUP $  GENDER $ WORDS @@;
DATALINES;
X M 700 X M 850 X M 820 X M 640 X M 920
Y M 480 Y M 460 Y M 500 Y M 570 Y M 580
Z M 500 Z M 550 Z M 480 Z M 600 Z M 610
X F 900 X F 880 X F 899 X F 780 X F 899
Y F 590 Y F 540 Y F 560 Y F 570 Y F 555
Z F 520 Z F 660 Z F 525 Z F 610 Z F 645
;

PROC ANOVA DATA=READING;
TITLE "Two-Way Analysis of Reading Data";
CLASS  GROUP GENDER ;
MODEL WORDS = GROUP | GENDER;  <--- "|" means main effects and interactions.
MEANS GROUP | GENDER/ SNK;
RUN;


                    Two-Way Analysis of Reading Data


                         The ANOVA Procedure

                      Class Level Information

                   Class         Levels    Values
```

GROUP	3	X Y Z
GENDER	2	F M

Number of Observations Read	30
Number of Observations Used	30

Dependent Variable: WORDS

The ANOVA Procedure

Class Level Information

Class	Levels	Values
GROUP	3	X Y Z
GENDER	2	F M

Number of Observations Read	30
Number of Observations Used	30

Dependent Variable: WORDS

Source	DF	Sum of Squares	Mean Square	F Value
Model	5	531436.1667	106287.2333	23.92
Error	24	106659.2000	4444.1333	
Corrected Total	29	638095.3667		

Source	Pr > F

Model		<.0001
Error		
Corrected Total		

Note Model df: (I-1)+(J-1)+(I-1)*(J-1)=2+1+2=5
Note Error df: IJ(K-1)=3*2*4=24
Note Total df: IKJ-1=3*2*5-1=29

Note: F=23.92 ====> means model ok.

R-Square	Coeff Var	Root MSE	WORDS Mean
0.832848	10.31264	66.66433	646.4333

Source	DF	Anova SS	Mean Square	F Value
GROUP	I-1=2	503215.2667	251607.6333	56.62
GENDER	J-1=1	25404.3000	25404.3000	5.72
GROUP*GENDER	(I-1)*(J-1)=2	2816.6000	1408.3000	0.32

The ANOVA Procedure

Dependent Variable: WORDS

Source	Pr > F	
GROUP	<.0001	Reject alpha effects are zero.
GENDER	0.0250	Reject beta effects are zero.
GROUP*GENDER	0.7314	No interaction.

Student-Newman-Keuls Test for WORDS

NOTE: This test controls the Type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha	0.05
Error Degrees of Freedom	24
Error Mean Square	4444.133

Number of Means	2	3
Critical Range	61.53152	74.452114

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	GROUP	
A	828.80	10	X	NOTE: Across GENDER 5+5=10
B	570.00	10	Z	
B				
B	540.50	10	Y	

So we see method X is significantly better than Y,Z.

Student-Newman-Keuls Test for WORDS

NOTE: This test controls the Type I experimentwise error rate under the complete null hypothesis but not under partial null hypotheses.

Alpha	0.05
Error Degrees of Freedom	24
Error Mean Square	4444.133

Number of Means	2

Critical Range 50.240276

Means with the same letter are not significantly different.

SNK Grouping	Mean	N	GENDER	
A	675.53	15	F	NOTE: Across GROUP 5+5+5=15
B	617.33	15	M	

So, females have significantly higher reading speed than males.

Means and Standard deviations in each cell:

Level of GROUP	Level of GENDER	N	WORDS Mean	WORDS Std Dev
X	F	5	871.600000	51.887378
X	M	5	786.000000	113.929803
Y	F	5	563.000000	18.574176
Y	M	5	518.000000	54.037024
Z	F	5	592.000000	66.011363
Z	M	5	548.000000	58.051701

Ex2: Interpreting Significant Interactions

We have 2 groups of children: Normal and Hyperactive.
Each group is randomly divided, one half getting placebo,
the other half Ritalin.

DRUG	
PLACEBO	RITALIN
50	67
45	60

```
NORMAL        55          58
              52          65
-------------------------------  NOTE: DATA = MEASURE OF ACTIVITY

HYPERACTIVE   70          51
              72          57
              68          48
              75          55

I=2,J=2,K=4

DATA RITALIN;
DO GROUP = 'NORMAL', 'HYPER';
DO DRUG = 'PLACEBO', 'RITALIN';
DO SUBJECT = 1 TO 4;
INPUT ACTIVITY @;   <---- Defines the dependent variable ACTIVITY.
OUTPUT;                   @ means SAS will read the horizontal data line.
END;
END;
END;
DATALINES;
50 45 55 52 67 60 58 65 70 72 68 75 51 57 48 55
;

PROC PRINT DATA=RITALIN;
RUN;
```

Obs	GROUP	DRUG	SUBJECT	ACTIVITY
1	NORMAL	PLACEBO	1	50
2	NORMAL	PLACEBO	2	45
3	NORMAL	PLACEBO	3	55
4	NORMAL	PLACEBO	4	52
5	NORMAL	RITALIN	1	67
6	NORMAL	RITALIN	2	60
7	NORMAL	RITALIN	3	58
8	NORMAL	RITALIN	4	65
9	HYPER	PLACEBO	1	70
10	HYPER	PLACEBO	2	72
11	HYPER	PLACEBO	3	68

12	HYPER	PLACEBO	4	75
13	HYPER	RITALIN	1	51
14	HYPER	RITALIN	2	57
15	HYPER	RITALIN	3	48
16	HYPER	RITALIN	4	55

```
PROC ANOVA DATA=RITALIN;
TITLE "ACTIVITY STUDY";
CLASS GROUP DRUG;
MODEL ACTIVITY = GROUP | DRUG;
MEANS GROUP | DRUG;
RUN;
```

NOTE: No need for SNK multiple-comparison tests since there are only two levels for each factor.

Two-Way Analysis of Reading Data

Obs	GROUP	DRUG	SUBJECT	ACTIVITY
1	NORMAL	PLACEBO	1	50
2	NORMAL	PLACEBO	2	45
3	NORMAL	PLACEBO	3	55
4	NORMAL	PLACEBO	4	52
5	NORMAL	RITALIN	1	67
6	NORMAL	RITALIN	2	60
7	NORMAL	RITALIN	3	58
8	NORMAL	RITALIN	4	65
9	HYPER	PLACEBO	1	70
10	HYPER	PLACEBO	2	72
11	HYPER	PLACEBO	3	68
12	HYPER	PLACEBO	4	75
13	HYPER	RITALIN	1	51
14	HYPER	RITALIN	2	57
15	HYPER	RITALIN	3	48
16	HYPER	RITALIN	4	55

ACTIVITY STUDY

The ANOVA Procedure

Class Level Information

Class	Levels	Values
GROUP	2	HYPER NORMAL
DRUG	2	PLACEBO RITALIN

Number of Observations Read	16
Number of Observations Used	16

The ANOVA Procedure

Dependent Variable: ACTIVITY

Source	DF	Sum of Squares	Mean Square	F Value
Model	3	1093.500000	364.500000	24.10
Error	12	181.500000	15.125000	
Corrected Total	15	1275.000000		

Source	Pr > F
Model	<.0001
Error	
Corrected Total	

Note: (I-1)+(J-1)+(I-1)(J-1)=1+1+1=3

Note: IJ(k-1)=2*2*(4-1)=12
Note: IJK-1=2*2*4-1=15

R-Square	Coeff Var	Root MSE	ACTIVITY Mean
0.857647	6.563860	3.889087	59.25000

Source	DF	Anova SS	Mean Square	F Value
GROUP	(I-1)=1	121.0000000	121.0000000	8.00
DRUG	(J-1)=1	42.2500000	42.2500000	2.79
GROUP*DRUG	(I-1)(J-1)=1	930.2500000	930.2500000	61.50

Dependent Variable: ACTIVITY

Source	Pr > F	
GROUP	0.0152	Significant effect on activity.
DRUG	0.1205	No significant effect on activity???
GROUP*DRUG	<.0001	Significant GROUP*DRUG interactions.

Level of GROUP	N	ACTIVITY Mean	ACTIVITY Std Dev
HYPER	8	62.0000000	10.4197614
NORMAL	8	56.5000000	7.5023806

Level of DRUG	N	ACTIVITY Mean	ACTIVITY Std Dev
PLACEBO	8	60.8750000	11.5935635
RITALIN	8	57.6250000	6.4572772

Cell means: Important for understanding interactions.

```
----------
```

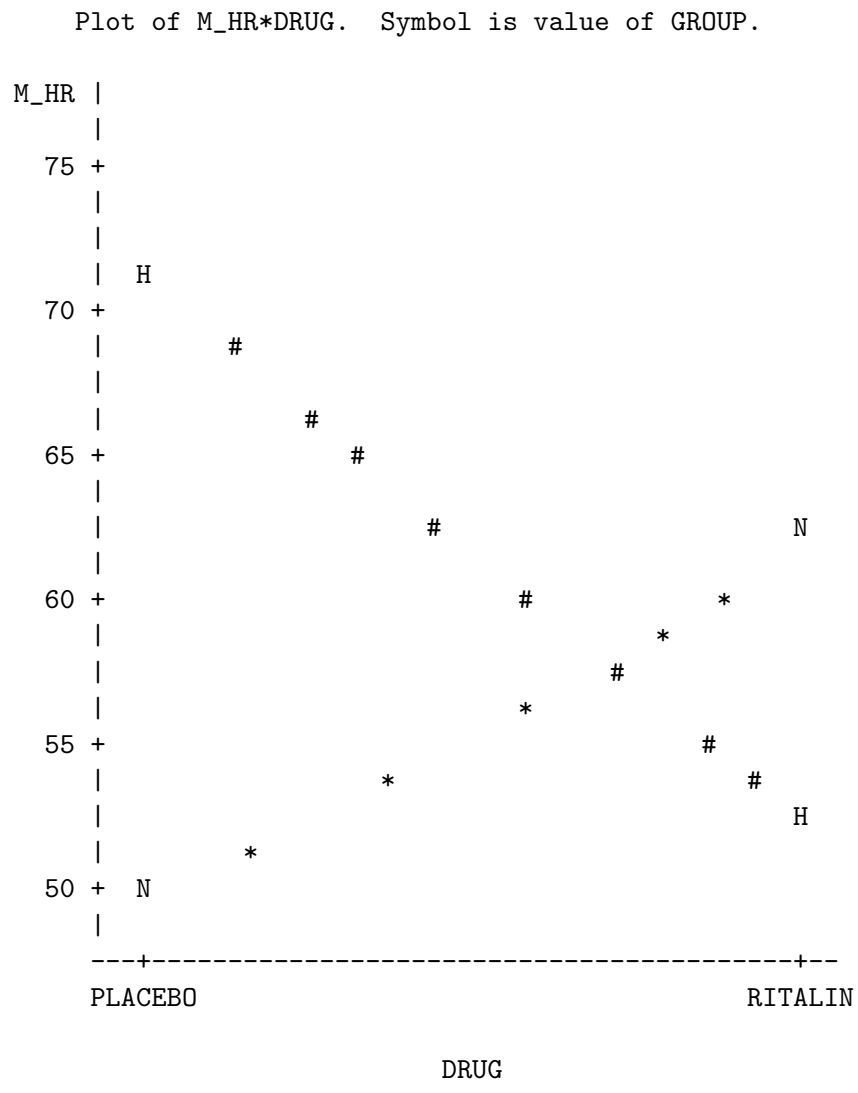
Level of GROUP	Level of DRUG	N	ACTIVITY Mean	ACTIVITY Std Dev
HYPER	PLACEBO	4	71.2500000	2.98607881
HYPER	RITALIN	4	52.7500000	4.03112887
NORMAL	PLACEBO	4	50.5000000	4.20317340
NORMAL	RITALIN	4	62.5000000	4.20317340

Note: The effect of DRUG on activity is not significant, but this could be misleading in the present case, since there is significant GROUP*DRUG interaction. We see that for NORMAL children the average activity increases with RITALIN (going from 50.5 to 62.5), whereas for HYPER children the average activity decreases with RITALIN (going from 71.25 to 52.75). More data are needed for more definitive analysis.

Can also see this graphically: Get two intersecting lines.

```
PROC MEANS DATA=RITALIN NWAY NOPRINT;
CLASS GROUP DRUG;
VAR ACTIVITY;
OUTPUT OUT=MEANS MEAN=M_HR;  <-- 4 Cell means of ACTIVITY.
RUN;

PROC PLOT DATA=MEANS;
PLOT M_HR*DRUG=GROUP; <--Using the values of GROUP "N"ormal, "H"yper
RUN;                      as plotting symbols.
```


Plot of M_HR*DRUG. Symbol is value of GROUP.
M_HR
75
70
65
60
55
50
PLACEBO
RITALIN
DRUG

```
Ex3: Machines, One-Way
----------------------

DATA MACHINES;
INPUT MACHINE $ OUTPUT @@;
DATALINE; <---SAS corrects this to DATALINES!!!
M1 56.7 M1 45.7 M1 48.3 M1 54.6 M1 37.7
M2 64.5 M2 53.4 M2 54.3 M2 57.5 M2 52.3
M3 56.7 M3 50.6 M3 49.5 M3 56.5 M3 44.7
;

PROC ANOVA DATA=MACHINES;
TITLE "ANALYSIS OF MACHINES DATA";
CLASS MACHINE;
MODEL OUTPUT = MACHINE;
MEANS MACHINE;
RUN;

Get the same results as with R:

                        The ANOVA Procedure

                     Class Level Information

                  Class         Levels    Values
                  MACHINE            3    M1 M2 M3

                     Number of observations    15

Dependent Variable: OUTPUT

                                      Sum of
Source           DF        Squares    Mean Square  F Value  Pr > F
-----------------------------------------------------------------------
Model             2    154.8000000     77.4000000  2.17     0.1575
Error            12    429.0000000     35.7500000
-----------------------------------------------------------------------
Corrected Total  14    583.8000000
```

```
         R-Square     Coeff Var      Root MSE    OUTPUT Mean

         0.265159      11.45427      5.979130       52.20000
       (Note Low R^2)


Level of           ------------OUTPUT-----------
MACHINE      N             Mean          Std Dev

M1           5       48.6000000       7.56505122
M2           5       56.4000000       4.92544414
M3           5       51.6000000       5.07543102
```

Ex2: Machines and Operators, Two-Way, 1 obs/cell

```
DATA MACHINES;
INPUT MACHINE $ OPERATOR $ OUTPUT @@;
DATALINES;
M1 O1 56.7 M1 O2 45.7 M1 O3 48.3 M1 O4 54.6 M1 O5 37.7
M2 O1 64.5 M2 O2 53.4 M2 O3 54.3 M2 O4 57.5 M2 O5 52.3
M3 O1 56.7 M3 O2 50.6 M3 O3 49.5 M3 O4 56.5 M3 O5 44.7
;

PROC ANOVA DATA=MACHINES;
TITLE "ANALYSIS OF MACHINES and OPERATORS DATA";
CLASS MACHINE OPERATOR;
MODEL OUTPUT = MACHINE OPERATOR;
RUN;
```

```
                        The ANOVA Procedure

                     Class Level Information

               Class         Levels    Values
```

```
MACHINE            3    M1 M2 M3
OPERATOR           5    O1 O2 O3 O4 O5

     Number of observations    15

         The ANOVA Procedure

Dependent Variable: OUTPUT

                                    Sum of
Source           DF        Squares    Mean Square   F Value   Pr > F
-------------------------------------------------------------------------
Model             6    536.5200000     89.4200000     15.13   0.0006
Error             8     47.2800000      5.9100000
-------------------------------------------------------------------
Corrected Total  14    583.8000000

Note: q=(3-1)+(5-1)=6, n-r= 15-(3+5-1)=8



         R-Square     Coeff Var      Root MSE    OUTPUT Mean
         0.919013      4.657182      2.431049       52.20000
       (Note high R^2)

Source      DF       Anova SS    Mean Square   F Value  Pr > F
-----------------------------------------------------------------
MACHINE      2    154.8000000     77.4000000     13.10  0.0030
OPERATOR     4    381.7200000     95.4300000     16.15  0.0007

Note: I-1=3-1=2, J-1=5-1=4


Ex3: Machines and Operators, Two-Way, 2 obs/cell
------------------------------------------------
Can now include interactions

DATA MACHINES;
```

```
INPUT MACHINE $ OPERATOR $ OUTPUT @@;
DATALINES;
M1 O1 56.7 M1 O2 45.7 M1 O3 48.3 M1 O4 54.6 M1 O5 37.7
M2 O1 64.5 M2 O2 53.4 M2 O3 54.3 M2 O4 57.5 M2 O5 52.3
M3 O1 56.7 M3 O2 50.6 M3 O3 49.5 M3 O4 56.5 M3 O5 44.7
M1 O1 56.0 M1 O2 45.0 M1 O3 48.0 M1 O4 54.0 M1 O5 37.0
M2 O1 64.0 M2 O2 53.0 M2 O3 54.0 M2 O4 57.0 M2 O5 52.0
M3 O1 56.0 M3 O2 50.0 M3 O3 49.0 M3 O4 56.0 M3 O5 44.0
;

PROC ANOVA DATA=MACHINES;
TITLE "ANALYSIS OF MACHINES and OPERATORS DATA";
CLASS MACHINE OPERATOR;
MODEL OUTPUT = MACHINE OPERATOR MACHINE*OPERATOR;
RUN;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
MACHINE	3	M1 M2 M3
OPERATOR	5	O1 O2 O3 O4 O5

Number of observations 30

Dependent Variable: OUTPUT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	1174.966667	83.926190	547.34	<.0001
Error	15	2.300000	0.153333		
Corrected Total	29	1177.266667			

R-Square	Coeff Var	Root MSE	OUTPUT Mean
0.998046	0.754001	0.391578	51.93333

(High)

Source	DF	Anova SS	Mean Square	F Value	Pr > F
MACHINE	2	318.0666667	159.0333333	1037.17	<.0001
OPERATOR	4	759.6600000	189.9150000	1238.58	<.0001
MACHINE*OPERATOR	8	97.2400000	12.1550000	79.27	<.0001

I=3, J=5, I-1=3-1=2, J-1=5-1=4, (I-1)(J-1)=8,
n-r=# obs - IJ=30-15=15

Same as in R.

Ex4. Factorial Experiment 2*2*2

```
DATA CATALYST;
INPUT Temp $ Conc $ Cat $ Yield @@;
DATALINES;
T1  C1   A    60
T2  C1   A    72
T1  C2   A    54
T2  C2   A    68
T1  C1   B    52
T2  C1   B    83
T1  C2   B    45
T2  C2   B    80
;


PROC ANOVA DATA=CATALYST;
TITLE "Analysis of Box-Hunter-Hunter 1978, p. 308";
CLASS Temp Conc Cat;
MODEL Yield = Temp  Conc  Cat;
RUN;
```

The ANOVA Procedure

Class Level Information

Class	Levels	Values
Temp	2	T1 T2
Conc	2	C1 C2
Cat	2	A B

Number of observations 8

Dependent Variable: Yield

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	1112.500000	370.833333	7.24	0.0430
Error	4	205.000000	51.250000		
Corrected Total	7	1317.500000			

q=3=(2-1)+(2-1)+(2-1), n=8, n-1=7, n-r=4

R-Square	Coeff Var	Root MSE	Yield Mean
0.844402	11.14227	7.158911	64.25000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Temp	1	1058.000000	1058.000000	20.64	0.0105
Conc	1	50.000000	50.000000	0.98	0.3792
Cat	1	4.500000	4.500000	0.09	0.7817

I-1=J-1=K-1=2-1=1

If use numerals, get the same results, since we only have different symbols for the character variables Temp, Conc, Cat:

```
DATA CATALYST;
```

```
INPUT Temp $ Conc $ Cat $ Yield @@;
DATALINES;
160   20   A    60
180   20   A    72
160   40   A    54
180   40   A    68
160   20   B    52
180   20   B    83
160   40   B    45
180   40   B    80
;


Ex5. Add more observations per cell: Get interaction
-----------------------------------------------------


DATA CATALYST;
INPUT Temp $ Conc $ Cat $ Yield @@;
DATALINES;
160   20   A    60
180   20   A    72
160   40   A    54
180   40   A    68
160   20   B    52
180   20   B    83
160   40   B    45
180   40   B    80
160   20   A    66
180   20   A    70
160   40   A    50
180   40   A    74
160   20   B    56
180   20   B    80
160   40   B    41
180   40   B    82
:


PROC ANOVA DATA=CATALYST;
```

```
TITLE "Analysis of Box-Hunter-Hunter 1978, p. 308";
CLASS Temp Conc Cat;
MODEL Yield = Temp  Conc  Cat Temp*Conc*Cat; <--Only 3-way interaction
RUN;
```

Analysis of Box-Hunter-Hunter 1978, p. 308

The ANOVA Procedure

Class Level Information

Class	Levels	Values
Temp	2	160 180
Conc	2	20 40
Cat	2	A B

Number of observations 16

Dependent Variable: Yield

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	2753.437500	393.348214	45.94	<.0001
Error	8	68.500000	8.562500		
Corrected Total	15	2821.937500			

R-Square	Coeff Var	Root MSE	Yield Mean
0.975726	4.532314	2.926175	64.56250
(High)			

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Temp	1	2139.062500	2139.062500	249.82	<.0001

```
Conc            1     126.562500     126.562500     14.78  0.0049
Cat             1       1.562500       1.562500      0.18  0.6805
Temp*Conc*Cat   4     486.250000     121.562500     14.20  0.0010
```

To include all possible interactions: Use "|".

```
PROC ANOVA DATA=CATALYST;
TITLE "Analysis of Box-Hunter-Hunter 1978, p. 308";
CLASS Temp Conc Cat;
MODEL Yield = Temp | Conc | Cat;
RUN;
```

```
Source          DF       Anova SS    Mean Square   F Value
-------------------------------------------------------------------------
Temp             1    2139.062500    2139.062500    249.82
Conc             1     126.562500     126.562500     14.78
Temp*Conc        1     115.562500     115.562500     13.50
Cat              1       1.562500       1.562500      0.18
Temp*Cat         1     370.562500     370.562500     43.28
Conc*Cat         1       0.062500       0.062500      0.01
Temp*Conc*Cat    1       0.062500       0.062500      0.01

                    Source                 Pr > F

                    Temp                   <.0001
                    Conc                   0.0049
                    Temp*Conc              0.0063
                    Cat                    0.6805
                    Temp*Cat               0.0002
                    Conc*Cat               0.9340
                    Temp*Conc*Cat          0.9340
```