Bonferroni method of multiple comparisons

If H_0 is rejected in an ANOVA, the Bonferroni post hoc method can be used:

For every pair of means, do a 2-sample t test, but divide α by the # of tests that you are doing.

2-way ANOVA

↑

2 factors, each with 2 or more levels

Hypothesis tests

(1) H_0: No difference between the various levels of Factor A.

H_1: difference

(2) H_0: No difference between the various levels of Factor B

H_1: difference

(3) H_0: No interaction between Factors A & B

H_1: interaction

On the handout

③

① We failed to detect a difference between the sizes

② There was a difference among the 3 designs

③ We failed to find an interaction

①	③	②
10	15	23

④

2-way ANOVA table

SS/df

Source	SS	df	MS	F
A		a-1		MSA/MSE
B		b-1		MSB/MSE
AB		(a-1)(b-1)		MSAB/MSE
Error		by subt.		
Total		n-1		

n-1 → total sample size

Chi-squared tests (χ^2)

O =

Gender	Low	Mid	High	
M	10	9	8	27
F	13	16	12	41
	23	25	20	68

Income

Observed results

Cross-tabulation or Contingency table

H_0: <row variable> and <column variable> are independent.

H_1: " " " " dependent.

E =

Gender	Low	Mid	High	
M	9.13	9.93	7.94	27
F	13.87	15.07	12.06	41
	23	25	20	68

Income

Expected results, under H_0

$\frac{27}{68} \cdot 23$ $\frac{27}{68} \cdot 25$

$df = (r-1)(c-1)$

$= 2$

HW#6 follows this page

16. Price to Earnings Ratios One measure of the value of a stock is its price to earnings ratio (or P/E ratio). It is the ratio of the price of a stock per share to the earnings per share and can be thought of as the price an investor is willing to pay for $1 of earnings in a company. A stock analyst wants to know whether the P/E ratios for three industry categories differ significantly. The following data represent simple random samples of companies from three categories: (1) financial, (2) food, and (3) leisure goods.

Financial	Food	Leisure Goods
8.83	19.75	14.10
12.75	17.87	10.12
13.48	15.18	15.57
14.42	22.84	13.48
10.06	15.60	11.27

Source: Yahoo!Finance

(a) Test the null hypothesis that the mean P/E ratio for each category is the same at the $\alpha = 0.05$ level of significance.

Note: The requirements for a one-way ANOVA are satisfied.

(b) If the null hypothesis is rejected in part (a), use Tukey's test to determine which pairwise means differ using a familywise error rate of $\alpha = 0.05$.

	defects	size	design
1	8	1	1
2	12	1	1
3	22	1	2
4	14	1	2
5	10	1	3
6	18	1	3
7	12	2	1
8	8	2	1
9	26	2	2
10	30	2	2
11	18	2	3
12	14	2	3

Univariate Analysis of Variance

Warnings

Post hoc tests are not performed for SIZE because there are fewer than three groups.

Between-Subjects Factors

		N
SIZE	1	6
	2	6
DESIGN	1	4
	2	4
	3	4

Tests of Between-Subjects Effects

Dependent Variable: DEFECTS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	448.000[a]	5	89.600	5.600	.029
Intercept	3072.000	1	3072.000	192.000	.000
SIZE	48.000	1	48.000	3.000	.134
DESIGN	344.000	2	172.000	10.750	.010
SIZE * DESIGN	56.000	2	28.000	1.750	.252
Error	96.000	6	16.000		
Total	3616.000	12			
Corrected Total	544.000	11			

a. R Squared = .824 (Adjusted R Squared = .676)

Post Hoc Tests

DESIGN

Multiple Comparisons

Dependent Variable: DEFECTS

	(I) DESIGN	(J) DESIGN	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	1	2	-13.00*	2.828	.009	-21.68	-4.32
		3	-5.00	2.828	.258	-13.68	3.68
	2	1	13.00*	2.828	.009	4.32	21.68
		3	8.00	2.828	.067	-.68	16.68
	3	1	5.00	2.828	.258	-3.68	13.68
		2	-8.00	2.828	.067	-16.68	.68
LSD	1	2	-13.00*	2.828	.004	-19.92	-6.08
		3	-5.00	2.828	.128	-11.92	1.92
	2	1	13.00*	2.828	.004	6.08	19.92
		3	8.00*	2.828	.030	1.08	14.92
	3	1	5.00	2.828	.128	-1.92	11.92
		2	-8.00*	2.828	.030	-14.92	-1.08

Based on observed means.

*. The mean difference is significant at the .05 level.

Homogeneous Subsets

DEFECTS

	DESIGN	N	Subset 1	Subset 2
Tukey HSD[a,b]	1	4	10.00	
	3	4	15.00	15.00
	2	4		23.00
	Sig.		.258	.067

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 16.000.

a. Uses Harmonic Mean Sample Size = 4.000.

b. Alpha = .05.