

ANOVA—Analysis of Variance

- t-test can only be use with 2 levels of independent variable
- common experiments will have more than 2 levels of independent variable so need to use ANOVA
- could use multiple t-tests but experiment error rate increases
- ANOVA tests for overall experimental effect
- ANOVA is conceptually the same as regression



F-Statistic or F-Ratio

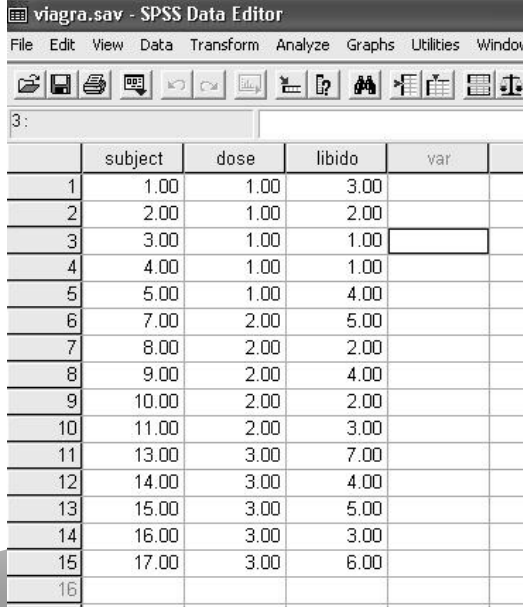
- ratio of the amount of systematic variance (due to experiment or effects of independent variable) to the amount of unsystematic variance
- ratio of the amount of between group variance divided by within group variance
- tests the hypothesis that:

$$X_1 = X_2 = X_3 \text{ is } \mathbf{not} \text{ true}$$

but does not indicate where the effect is



ANOVA Example--Viagra



viagra.sav - SPSS Data Editor

File Edit View Data Transform Analyze Graphs Utilities Window

3:

	subject	dose	libido	var
1	1.00	1.00	3.00	
2	2.00	1.00	2.00	
3	3.00	1.00	1.00	
4	4.00	1.00	1.00	
5	5.00	1.00	4.00	
6	7.00	2.00	5.00	
7	8.00	2.00	2.00	
8	9.00	2.00	4.00	
9	10.00	2.00	2.00	
10	11.00	2.00	3.00	
11	13.00	3.00	7.00	
12	14.00	3.00	4.00	
13	15.00	3.00	5.00	
14	16.00	3.00	3.00	
15	17.00	3.00	6.00	
16				

15 Subjects

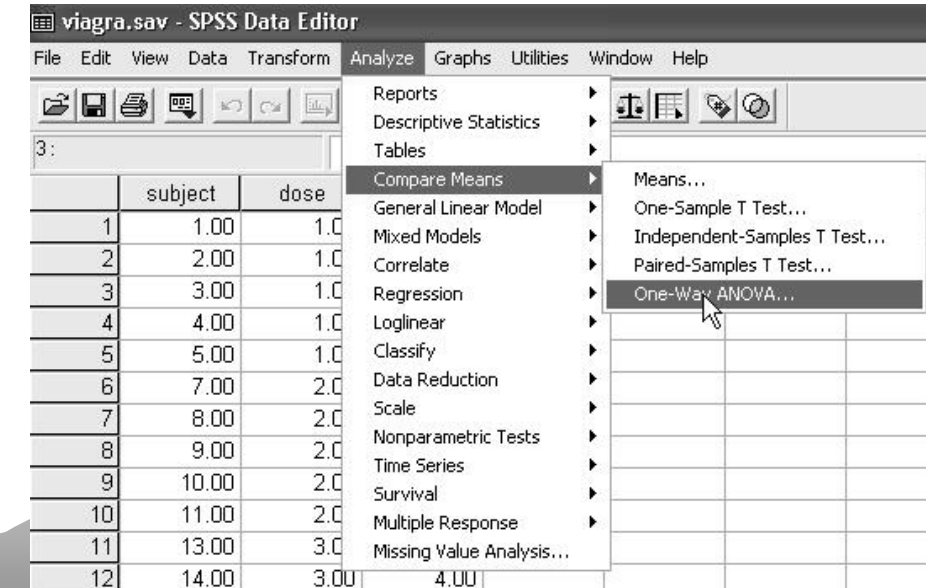
Dose

1=Placebo

2=Low dose

3=High dose

One-way ANOVA in SPSS



viagra.sav - SPSS Data Editor

File Edit View Data Transform Analyze Graphs Utilities Window Help

3:

	subject	dose
1	1.00	1.00
2	2.00	1.00
3	3.00	1.00
4	4.00	1.00
5	5.00	1.00
6	7.00	2.00
7	8.00	2.00
8	9.00	2.00
9	10.00	2.00
10	11.00	2.00
11	13.00	3.00
12	14.00	3.00

Reports

Descriptive Statistics

Tables

Compare Means

General Linear Model

Mixed Models

Correlate

Regression

Loglinear

Classify

Data Reduction

Scale

Nonparametric Tests

Time Series

Survival

Multiple Response

Missing Value Analysis...

Means...

One-Sample T Test...

Independent-Samples T Test...

Paired-Samples T Test...

One-Way ANOVA...

One-Way ANOVA Output

Between-Subjects Factors

	Value Label	N
Dose of Viagra	1.00	5
	2.00	5
	3.00	5

Significance of the model:

H_0 : Placebo = Low Dose = High Dose?

Tests of Between-Subjects Effects

Dependent Variable: Libido

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	20.133 ^a	2	10.067	5.119	.025
Intercept	180.267	1	180.267	91.661	.000
DOSE	20.133	2	10.067	5.119	.025
Error	23.600	12	1.967		
Total	224.000	15			
Corrected Total	43.733	14			

a. R Squared = .460 (Adjusted R Squared = .370)

Contrast or Post-Hoc ANOVA?

- With specific *a priori* predictions about the data, use contrasts
- Without specific *a priori* predictions, use post-hoc comparisons

Post Hoc comparisons are pairwise comparisons designed to compare all different combinations of treatment groups



Contrasts

- Partitioning variances to test *a priori* hypotheses

H1: Any level of viagra affects libido.

[Low Dose + High Dose] vs. Placebo

H2: High doses of viagra cause higher levels of libido.

High Dose vs. Low Dose




SPSS Contrast Output

Contrast 1: Any level of viagra vs. placebo

Contrast 2: Low dose vs. high dose

Contrast Tests

		Contrast	Value of Contrast	Std. Error	t	df	Sig. (2-tailed)
Libido	Assume equal variances	1	3.8000	1.53623	2.474	12	.029
		2	1.8000	.88694	2.029	12	.065
	Does not assume equal variances	1	3.8000	1.48324	2.562	8.740	.031
		2	1.8000	.91652	1.964	7.720	.086



Post Hoc Predictions in ANOVA

Guidelines for Selecting Post Hoc Comparisons

- LSD—least significant difference is equivalent to multiple t-tests—does not control type I error
- Tukey test is good choice for comparing large numbers of means
- REGWQ test is good for comparing all pairs of means, but not useful when group sizes are different
- Hochberg's GT2 is best when sample sizes are very different
- Games-Howell is useful when uncertain about whether population variances are equivalent.

Post Hoc Comparisons in SPSS

The screenshot shows the SPSS Data Editor interface with a data table and two dialog boxes. The data table has the following content:

	subject	dose	libido	var	var	var	var	var	var	var
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14	16.00	3.00	3.00							
15	17.00	3.00	6.00							
16										
17										
18										
19										
20										
21										
22										
23										

The One-Way ANOVA dialog box shows 'subject' in the Factor list and 'libido' in the Dependent List. The Post Hoc Multiple Comparisons dialog box shows the following options:

- Equal Variances Assumed:
 - LSD
 - Bonferroni
 - Sidak
 - Scheffe
 - R-E-G-W F
 - R-E-G-W Q
 - S-N-K
 - Tukey
 - Tukey's-b
 - Duncan
 - Hochberg's GT2
 - Gabriel
 - Waller-Duncan
 - Dunnett
- Equal Variances Not Assumed:
 - Tamhane's T2
 - Dunnett's T3
 - Games-Howell
 - Dunnett's C
- Significance level: .05

Multiple Comparisons							
Dependent Variable: Libido							
	(I) Dose of Viagra	(J) Dose of Viagra	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Placebo	Low Dose	-1.0000	.88694	.516	-3.3662	1.3662
		High Dose	-2.8000*	.88694	.021	-5.1662	-.4338
	Low Dose	Placebo	1.0000	.88694	.516	-1.3662	3.3662
		High Dose	-1.8000	.88694	.147	-4.1662	.5662
LSD	Placebo	Low Dose	2.8000*	.88694	.021	.4338	5.1662
		High Dose	1.8000	.88694	.147	-.5662	4.1662
	Low Dose	Placebo	-1.0000	.88694	.282	-2.9325	.9325
		High Dose	-2.8000*	.88694	.008	-4.7325	-.8675
Bonferroni	Placebo	Low Dose	1.0000	.88694	.282	-.9325	2.9325
		High Dose	-1.8000	.88694	.065	-3.7325	.1325
	Low Dose	Placebo	2.8000*	.88694	.008	.8675	4.7325
		High Dose	1.8000	.88694	.065	-.1325	3.7325
Gabriel	Placebo	Low Dose	-1.0000	.88694	.845	-3.4652	1.4652
		High Dose	-2.8000*	.88694	.025	-5.2652	-.3348
	Low Dose	Placebo	1.0000	.88694	.845	-1.4652	3.4652
		High Dose	-1.8000	.88694	.196	-4.2652	.6652
Hochberg	Placebo	Low Dose	2.8000*	.88694	.025	.3348	5.2652
		High Dose	1.8000	.88694	.196	-.6652	4.2652
	Low Dose	Placebo	-1.0000	.88694	.609	-3.4366	1.4366
		High Dose	-2.8000*	.88694	.024	-5.2366	-.3634
Games-Howell	Placebo	Low Dose	1.0000	.88694	.609	-1.4366	3.4366
		High Dose	-1.8000	.88694	.174	-4.2366	.6366
	Low Dose	Placebo	2.8000*	.88694	.024	.3634	5.2366
		High Dose	1.8000	.88694	.174	-.6366	4.2366
Games-Howell	Placebo	Low Dose	-1.0000	.82462	.479	-3.3563	1.3563
		High Dose	-2.8000*	.91652	.039	-5.4389	-.1611
	Low Dose	Placebo	1.0000	.82462	.479	-1.3563	3.3563
		High Dose	-1.8000	.91652	.185	-4.4389	.8389
Games-Howell	Placebo	Low Dose	2.8000*	.91652	.039	.1611	5.4389
		High Dose	1.8000	.91652	.185	-.8389	4.4389

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

← Good overall measure

← Most liberal measure

← Most conservative measure

← Use when sample sizes different

← Run in addition to other tests (doesn't assume pop. variances equivalent)

ANOVA—Second Example

Research question: How do different teaching methods affect students' knowledge?

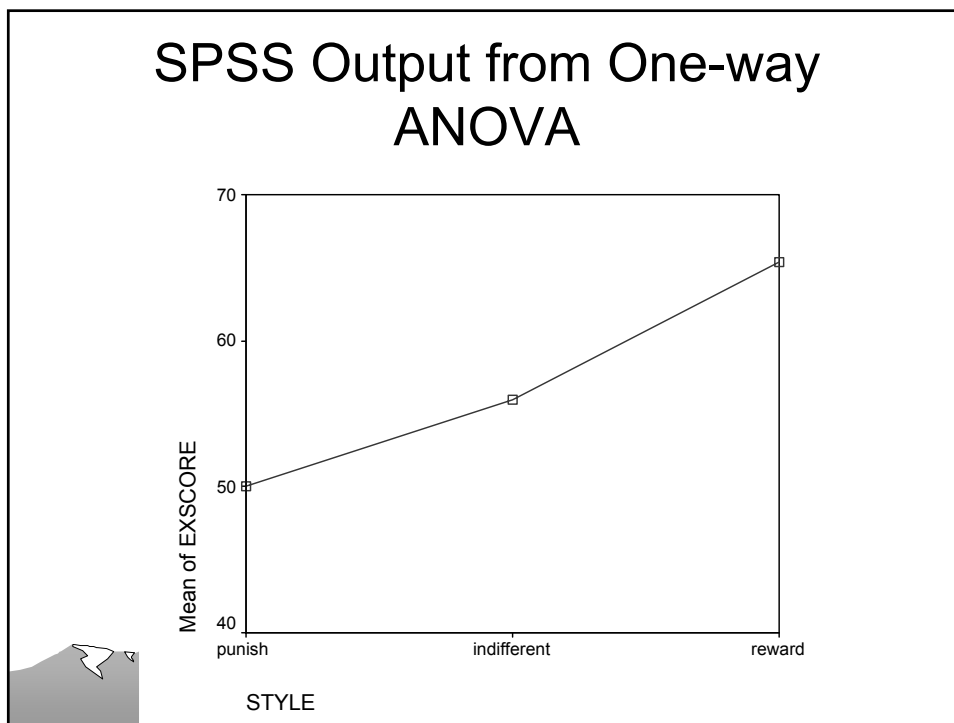
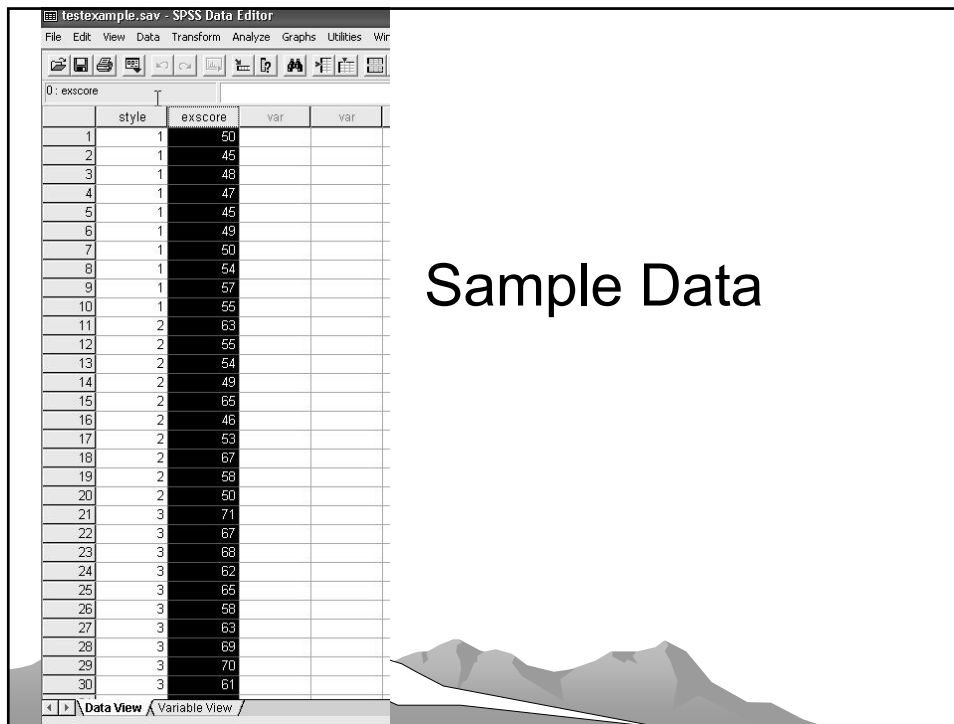
Experiment:

3 different statistics classes independent variable is teaching style and dependent variable is students' exam marks (percentage)

- 1) punish teaching style--students punished for getting questions wrong
- 2) reward teaching style—encourage students and give rewards to students who work hard
- 3) indifferent style—neither reward nor punish students

Test hypotheses that 1) teaching style affects exam marks, and 2) punishment style results in lower marks than indifference style 3) reward style results in higher marks than any style





SPSS Output--One-way ANOVA

ANOVA

EXSCORE

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1205.067	2	602.533	21.008	.000
Within Groups	774.400	27	28.681		
Total	1979.467	29			

test H_0

H_0 : Punish = Indifferent = Reward

Multiple Comparisons

Dependent Variable: EXSCORE

	(I) STYLE	(J) STYLE	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	punish	indifferent	-6.00*	2.395	.047	-11.94	-.06
		reward	-15.40*	2.395	.000	-21.34	-9.46
	indifferent	punish	6.00*	2.395	.047	.06	11.94
		reward	-9.40*	2.395	.002	-15.34	-3.46
	reward	punish	15.40*	2.395	.000	9.46	21.34
		indifferent	9.40*	2.395	.002	3.46	15.34
LSD	punish	indifferent	-6.00*	2.395	.019	-10.91	-1.09
		reward	-15.40*	2.395	.000	-20.31	-10.49
	indifferent	punish	6.00*	2.395	.019	1.09	10.91
		reward	-9.40*	2.395	.001	-14.31	-4.49
	reward	punish	15.40*	2.395	.000	10.49	20.31
		indifferent	9.40*	2.395	.001	4.49	14.31
Games-Howell	punish	indifferent	-6.00	2.599	.086	-12.78	.78
		reward	-15.40*	1.887	.000	-20.22	-10.58
	indifferent	punish	6.00	2.599	.086	-.78	12.78
		reward	-9.40*	2.626	.007	-16.23	-2.57
	reward	punish	15.40*	1.887	.000	10.58	20.22
		indifferent	9.40*	2.626	.007	2.57	16.23

Reject H_0

Ok...then where is the source of variance?

Punish \neq Reward

Indifferent \neq Reward

Indifferent \neq Punish

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

Factorial Designs

- Analyze the potential effects of 2 or more factors (independent variables) on a dependent variable
- Need to use GLM procedure in SPSS
- Looking for “main effects” and “interactions”

Example

- A 2 x 5 factorial model (gender by profession) to determine if these variables affect one's land ethic
- main effects (gender and profession)
- interaction—does gender and profession combine in such a way as to influence land ethic



The screenshot shows the SPSS Data Editor window for the file "U.S. Forest Service (1996) Survey.sav". The "Univariate" dialog box is open, showing the following settings:

- Dependent Variable: q14
- Fixed Factor(s): q11a, q5
- Random Factor(s): (empty)
- Covariate(s): (empty)
- WLS Weight: (empty)

The dialog box includes buttons for "Model...", "Contrasts...", "Plots...", "Post Hoc...", "Save...", and "Options...". The background shows a list of variables in the SPSS Data Editor, including keyf, matchup, study, newnum, ncode, recnum, code, return_c, group, grp90_96, grp3var1, grp3var2, q1, q2, q3, q4, and others.

Factor Output in SPSS

Between-Subjects Factors

	Value Label	N
Sex	1 Male	436
	2 Female	142
Profession Identify With	1 Forestry	295
	2 Range	44
	3 Wildlife/Fisheries Biology	132
	4 Recreation	68
	5 Engineering	39

Tests of Between-Subjects Effects

Dependent Variable: Land Ethic

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	159.762 ^a	9	17.751	23.252	.000
Intercept	623.184	1	623.184	816.305	.000
Q11A	2.161	1	2.161	2.831	.093
Q5	96.771	4	24.193	31.690	.000
Q11A * Q5	2.021	4	.505	.662	.619
Error	433.623	568	.763		
Total	3680.100	578			
Corrected Total	593.385	577			

a. R Squared = .269 (Adjusted R Squared = .258)

Multiple Comparisons

Dependent Variable: Land Ethic

(I) Profession Identify With	(J) Profession Identify With	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval		
					Lower Bound	Upper Bound	
Tukey HSD	Forestry	Range	.1007	.14120	.954	-.2858	.4871
		Wildlife/Fisheries Biology	1.1340*	.09150	.000	.8836	1.3844
		Recreation	.9327*	.11754	.000	.6111	1.2544
	Engineering	.0634	.14887	.993	-.3440	.4708	
	Range	Forestry	-.1007	.14120	.954	-.4871	.2858
		Wildlife/Fisheries Biology	1.0333*	.15210	.000	.6171	1.4496
		Recreation	.8321*	.16905	.000	.3695	1.2947
	Engineering	-.0373	.19216	1.000	-.5632	.4886	
	Wildlife/Fisheries Biology	Forestry	-1.1340*	.09150	.000	-1.3844	-.8836
		Range	-1.0333*	.15210	.000	-1.4496	-.6171
		Recreation	-.2012	.13042	.535	-.5582	.1557
	Engineering	-1.0706*	.15924	.000	-1.5064	-.6349	
Recreation	Forestry	-.9327*	.11754	.000	-1.2544	-.6111	
	Range	-.8321*	.16905	.000	-1.2947	-.3695	
	Wildlife/Fisheries Biology	-.0634	.14887	.993	-.4708	.4886	