Intermediate IBM SPSS

Advanced Statistical Techniques for Difference Questions

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- Please note that the workshop is aimed to be a brief introduction to the topic and this PowerPoint is primarily designed to support the flow of the workshop. It cannot be seen as either an exclusive or exhaustive resource on the statistical concepts which are introduced in this course. You are encouraged to refer to peer-reviewed books or papers that are listed throughout the presentation.
- It is acknowledged that a number of slides have been adapted from presentations produced by the previous statistical consultant (Kylie Lange) and a colleague with whom I worked with in the past (Dr Kelvin Gregory).

Statistical Consulting Website

http://www.flinders.edu.au/library/research/eresearch/statistics-consulting/

or go to Flinders University Website →A-Z Index →S →Statistical Consultant

Introductory Level
- **Introduction to IBM SPSS**
- **Introduction to Statistical Analysis**

IBM SPSS - Intermediate Level
- **Understanding Your Data (Descriptive Statistics, Graphs and Custom Tables)**
  - **Correlation and Multiple Regression**
    - **Logistic Regression and Survival Analysis**
  - **Basic Statistical Techniques for Difference Questions**
    - **Advanced Statistical Techniques for Difference Questions**
      - **Longitudinal Data Analysis - Repeated Measures ANOVA**
  - **Categorical Data Analysis**

IBM SPSS - Advanced Level
- **Structural Equation Modelling using Amos**
- **Linear Mixed Models**
  - **Longitudinal Data Analysis - Mixed and Latent Variable Growth Curve Models**
- **Scale Development**
- **Complex Sample Survey Design / ABS and FaHCSIA Confidentialised Datasets**

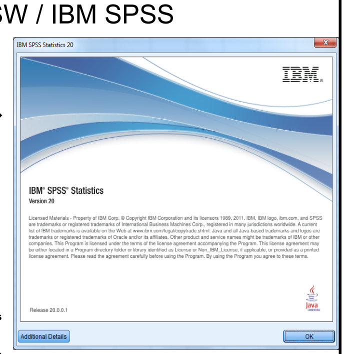
??? SPSS / PASW / IBM SPSS ???

- In late 2009 SPSS Inc. was taken over by IBM Company and the software changed its official name twice over the period of one year. From SPSS it was relabelled to PASW (Predictive Analytics Software) and later to IBM SPSS. Consequently, there may be books, online resources, etc. that use either of those different names but in fact refer to the same software.
- **SPSS**
  – Statistical Package for the Social Sciences
- **PASW**
  – Predictive Analytics Software
- **IBM SPSS Statistics**

SPSS / PASW / IBM SPSS

(1) How to check?

START SOFTWARE → HELP → ABOUT



(2) How to cite?

(Examples with APA Style)

- **SPSS Inc. Released 2007. SPSS for Windows, Version 16.0. Chicago, SPSS Inc.**
- **SPSS Inc. Released 2008. SPSS Statistics for Windows, Version 17.0. Chicago: SPSS Inc.**
- **SPSS Inc. Released 2009. PASW Statistics for Windows, Version 18.0. Chicago: SPSS Inc.**
- **IBM Corp. Released 2010. IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY: IBM Corp.**
- **IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.**
- **IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.**

IBM SPSS on Flinders University

- Flinders University has licence for number of IBM SPSS products (versions 19, 20, 21) covering following modules:
  – IBM SPSS Statistics Base
  – IBM SPSS Regression
  – IBM SPSS Advanced Statistics
  – IBM SPSS Complex Samples
  – IBM SPSS Categories
  – IBM SPSS Exact Tests
  – IBM SPSS Missing Values
  – IBM SPSS Forecasting
  – IBM SPSS Custom Tables
  – IBM SPSS Conjoint
  – IBM SPSS Statistics Programmability Extension

  and AMOS
- For details explaining various modes of obtaining access to the software go to

http://www.flinders.edu.au/library/research/eresearch/statistics-consulting/spss-licenses-and-technical-support/licenses-for-university-and-home.cfm

Levels of Measurement and Measurement Scales

		EXAMPLES:
Ratio Data	Differences between measurements, true zero exists	Height, Age, Weekly Food Spending
Interval Data	Differences between measurements but no true zero	Temperature in Celsius, Standardized exam score
Ordinal Data	Ordered Categories (rankings, order, or scaling)	Service quality rating, Student letter grades
Nominal Data	Categories (no ordering or direction)	Marital status, Type of car owned, Gender/Sex

MEASUREMENT

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Selection of statistical methods

Example 1
Figure 4.11 from Dancey, C. P., & Reidy, J. (2004). Statistics without maths for psychology : using SPSS for Windows (3rd ed.). New York: Prentice Hall.

Example 2
Table from Pallant, J. (2007). SPSS Survival Manual : A step by step guide to data analysis using SPSS for Windows (SPSS Version 15) (3rd ed.). Maidenhead, Berkshire. U.K. ; New York, NY: Open University Press.

Example 3
Flowchart from http://gjyp.nl/marta/Flowchart%20(English).pdf

Similar ones in other resources …

3

Selection of an Appropriate Inferential Statistics for Basic, Two Variable Difference Questions or Hypotheses – PART 2

	Level of Measurement of Dependent Variable	Compare	One Factor or Independent Variable with 3 or More Categories or Levels /Groups /Samples: Independent Samples or Groups (Between)	Repeated Measures or Related Samples (Within)
Parametric Statistics	Dependent Variable Approximates Normal (Scale) Data and Assumptions Not Markedly Violated	Means	ONE-WAY ANOVA	GLM REPEATED MEASURES ANOVA
Nonparametric Statistics	Dependent Variable Clearly Ordinal Data or the Assumptions Are Markedly Violated	Mean Ranks	KRUSKAL-WALLIS H TEST	FRIEDMAN TEST
	Dependent Variable is Nominal or (dichotomous) Data	Counts	CHI-SQUARE SIGNIFICANCE TEST	COCHRAN Q TEST

Adapted from (Leech, Barrett, & Morgan, 2008, p. 74)

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Selection of an Appropriate Inferential Statistics for Basic, Two Variable Difference Questions or Hypotheses – PART 2

	Level of Measurement of Dependent Variable	Compare	One Factor or Independent Variable with 3 or More Categories or Levels /Groups /Samples: Independent Samples or Groups (Between)	Repeated Measures or Related Samples (Within)
Parametric Statistics	Dependent Variable Approximates Normal (Scale) Data and Assumptions Not Markedly Violated	Means	Analyze → Compare Means → One-Way ANOVA	Analyze → General Linear Model → Repeated Measures
Nonparametric Statistics	Dependent Variable Clearly Ordinal Data or the Assumptions Are Markedly Violated	Mean Ranks	Analyze → Nonparametric Tests → k Independent Samples	Analyze → Nonparametric Tests → k Related Samples
	Dependent Variable is Nominal or (dichotomous) Data	Counts	Analyze → Descriptive Statistics → Crosstabs	Analyze → Nonparametric Tests → k Related Samples

Adapted from (Leech, Barrett, & Morgan, 2008, p. 74)

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Table 5.5. *Interpretation of the Strength of a Relationship (Effect Sizes)*

General Interpretation of the Strength of a Relationship	The d Family[a]: d	The r Family[b]: r and ϕ	R	η (eta)	Risk Potency: RD (%)
Much larger than typical	$\geq$ |1.00|[c, d]	$\geq$ |.70|	|.70|+	|.45|+	$\geq$52
Large or larger than typical	|.80|	|.50|	|.51|	|.37|	43
Medium or typical	|.50|	|.30|	|.36|	|.24|	28
Small or smaller than typical	|.20|	|.10|	|.14|	|.10|	11

[a] d values can vary from 0.0 to + or −infinity, but d greater than one is relatively uncommon.
[b] r family values can vary from 0.0 to + or −1.0, but except for reliability (i.e., same concept measured twice), r is rarely above .70. In fact, some of these statistics (e.g., phi) have a restricted range in certain cases; that is, the maximum phi may be less then 1.0.
[c] We interpret the numbers in this table as a range of values. For example, a d greater than .90 (or less than −.90) would be described as "much larger than typical," a d between say .70 and .90 would be called "larger than typical," and d between say .60 and .70 would be "typical to larger than typical." We interpret the other three columns similarly.
[d] Note that | | indicates absolute value of the coefficient. The absolute magnitude of the coefficient, rather than its sign, is the information that is relevant to effect size. R and eta usually are calculated by taking the square root of a squared value, so that the sign usually is positive.

Reproduced from (Leech, Barrett, & Morgan, 2008, p. 81)

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One-Way Analysis of Variance
Kruskal-Wallis H test

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ANOVA Terminology

- Factor
  - The independent variable
    - The treatment condition
  - A categorical variable
  - Sometimes called the "cause"
- Levels
  - The categories of the factor
  - The treatment levels
- Replicate
  - The subjects
- Balanced
  - The same number of replicates (subjects) in each treatment level
- Unbalanced
  - Different number of replicates (subjects) in each treatment condition

ANOVA Terminology – Balanced Design

Treatment		
One	Two	Three
X_{11}	X_{12}	X_{13}
X_{21}	X_{22}	X_{23}
X_{31}	X_{32}	X_{33}
•	•	•
•	•	•
X_{n1}	X_{n2}	X_{n3}
$\bar{X}_1$ s_1^2	$\bar{X}_2$ s_2^2	$\bar{X}_3$ s_3^2

Factor

Treatment levels

Replicates and their scores on a dependent variable

Note the type of statistics we have here

Hypotheses of One-Way ANOVA

- Null hypothesis
  - All population means are equal
    - i.e., no treatment effect (no variation in means among groups)

$$H_o : \mu_1 = \mu_2 = \ldots = \mu_J$$

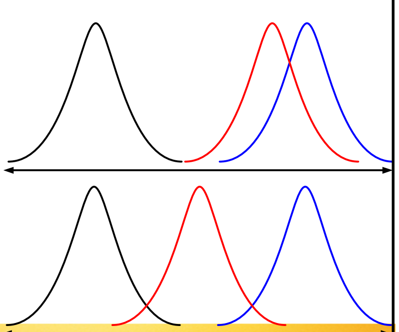
- Note that this hypothesis is saying that the subjects are really drawn from the same population
  - And there is no treatment effect

Hypotheses of One-Way ANOVA

- Alternative hypothesis
  - At least one population mean is different
    - i.e., there is a treatment effect
    - Does not mean that all population means are different (some pairs may be the same)
    - It just means that at least one mean is statistically different from the other means
- So, this hypothesis is saying that at least one mean is drawn from a different population

Hypotheses of One-Way ANOVA

- At least one mean is different from the other means



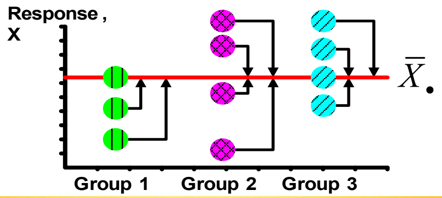
Partitioning the Variation

- Variation is a measure of spread
  - Of distance from a mean
- ANOVA is concerned with variation
  - And in particular partitioning the observed variation
- Total variation can be split into two parts

  $SS_T = SS_B + SS_W$
  - Where
    - SS_T = the total sums of squares (the total variation from the overall or grand mean)
    - SS_B = the sum of squares among or between groups (the variation from each group's mean from the overall mean)
    - SS_W = the sum of the variation within each group

Total Sum of Squares

$$SS_T = (X_{11} - \bar{X}_\bullet)^2 + (X_{12} - \bar{X}_\bullet)^2 + \ldots + (X_{n_i n_j} - \bar{X}_\bullet)^2$$



Total Sum of Squares

$$SS_T = SS_B + SS_W$$

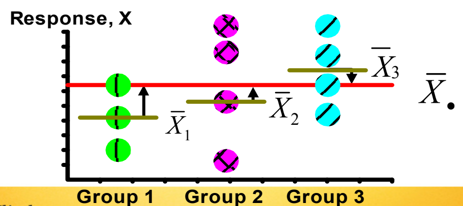
$$SS_T = \sum_{j=1}^{J} \sum_{i=1}^{n_j} (X_{ij} - \bar{X}_\bullet)^2$$

Where:

- SS_T = Total sum of squares
- J = number of groups (levels or treatments)
- n_j = number of observations in group j
- X_{ij} = i^{th} observation from group j
- $\bar{X}_\bullet$ = grand mean (mean of all data values)

Among-Group Variation

$$SS_B = n_1(\bar{x}_1 - \bar{x}_\bullet)^2 + n_2(\bar{x}_2 - \bar{x}_\bullet)^2 + \ldots + n_J(\bar{x}_J - \bar{x}_\bullet)^2$$



Among-Group Variation

$$SS_T = SS_B + SS_W$$

$$SS_B = \sum_{j=1}^{J} n_j(\bar{X}_j - \bar{X}_\bullet)^2$$

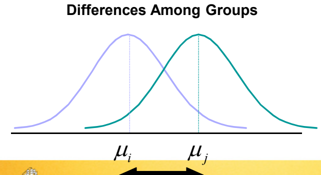
Where:

- SS_B = Sum of squares among groups
- J = number of groups
- n_j = sample size from group j
- $\bar{X}_j$ = sample mean from group j
- $\bar{X}_\bullet$ = grand mean (mean of all data values)

Among-Group Variation

$$SS_B = \sum_{j=1}^{J} n_j(\bar{X}_j - \bar{X}_\bullet)^2$$

Variation Due to
Differences Among Groups

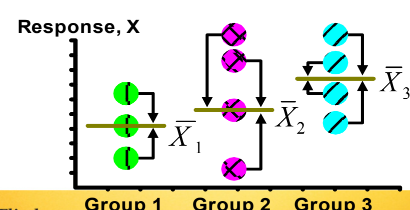


$$MS_B = \frac{SS_B}{J-1}$$

Mean Square Among = SS_B/degrees of freedom

Within-Group Variation

$$SS_W = (x_{11} - \bar{X}_1)^2 + \ldots(X_{12} - \bar{X}_2)^2 + \ldots(X_{n_i n_j} - \bar{X}_J)^2$$



Within-Group Variation

$SS_T = SS_B + SS_W$

$$SS_W = \sum_{j=1}^{J}\sum_{i=1}^{n_j}(X_{ij} - \bar{X}_j)^2$$

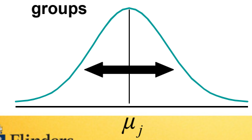
Where:

- SS_W = Sum of squares within groups
- J = number of groups
- n_j = sample size from group j
- $\bar{X}_j$ = sample mean from group j
- X_{ij} = i^{th} observation in group j

Within-Group Variation

$$SS_W = \sum_{j=1}^{J}\sum_{i=1}^{n_j}(X_{ij} - \bar{X}j)^2$$

Summing the variation within each group and then adding over all groups



$$MS_W = \frac{SS_W}{N-J}$$

Mean Square Within = SS_W/degrees of freedom

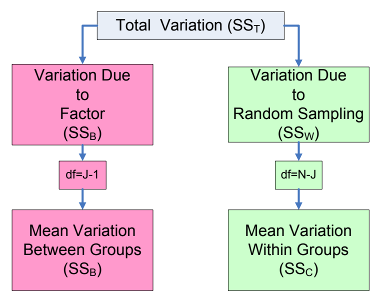
Obtaining the Mean Squares

$$MS_B = \frac{SS_B}{J-1}$$

$$MS_W = \frac{SS_W}{N-J}$$

$$MS_T = \frac{SS_T}{N-1}$$

Partition of Total Variation



Partition of Total Variation

- Three "sum of squares" or "squared deviations" serve as the "backbone" of ANOVA
  - Total sum of squares: overall, how far are the observations from the overall (grand) mean
  - Sum of squares between
    - For a balanced design: how far is the group mean from the overall mean
  - Sum of squares within
    - For each group: how far are the observations within that group from that group's mean

$$SS_{total} = \sum_j^J\sum_i^n\left(X_{ij} - \bar{X}_\bullet\right)^2$$

$$SS_B = \sum_j^J n_j\left(\bar{X}_j - \bar{X}_\bullet\right)^2$$

$$SS_W = \sum_j^J\sum_i^n\left(X_{ij} - \bar{X}_j\right)^2$$

One-Way ANOVA Table

Source of Variation	SS	df	MS (Variance)	F ratio
Among Groups	SS_B	J - 1	$MS_B = \frac{SS_B}{J-1}$	$F = \frac{MS_B}{MS_W}$
Within Groups	SS_W	N - J	$MS_W = \frac{SS_W}{N-J}$	
Total	$SS_T = SS_B + SS_W$	N - 1		

J = number of groups
N = sum of the sample sizes from all groups
df = degrees of freedom

One-Way ANOVA - F Test Statistic

H_0: $\mu_1 = \mu_2 = \ldots = \mu_c$

H_1: At least two population means are different

- **Test statistic**

$$F = \frac{MS_B}{MS_W}$$

MS_B is mean squares among groups

MS_W is mean squares within groups

- **Degrees of freedom**
  - $df_1 = J - 1$ (J = number of groups)
  - $df_2 = N\text{-}J$ (N = sum of sample sizes from all populations)

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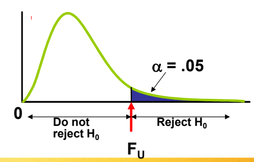
Interpreting One-Way ANOVA F Statistic

- **The F statistic is the ratio of the among estimate of variance and the within estimate of variance**
  - The ratio must always be positive
  - $df_1 = J - 1$ will typically be small
  - $df_2 = N\text{-}J$ will typically be large

Decision Rule:

- **Reject H_0 if $F > F_U$, otherwise do not reject H_0**



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Assumptions

- **Interval data**
- **Independent samples**
- **Multivariate normality**
- **Homogeneity of variances**
- **Absence of outliers**

MORE IN

Garson, G. D. (2012). *Univariate GLM, ANOVA, & ANCOVA*. Asheboro, NC: Statistical Associates Publishers.

http://www.statisticalassociates.com/glm_univariate.htm

OR SIMILAR RESOURCES

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- If assumptions are not met:
  - More of a problem if have small sample sizes and/or different sample sizes
  - Constant variance typically more important than normality
  - May influence the p-value in either direction

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Assumptions

- Chiarotti, F. (2004). Detecting assumption violations in mixed-model analysis of variance. *Annali dell'Istituto Superiore di Sanita, 40*(2), 165-171.
- Lix, L. M., Keselman, J. C., & Keselman, H. J. (1996). Consequences of assumption violations revisited: A quantitative review of alternatives to the one-way analysis of variance F test. *Review of Educational Research, 66*(4), 579-619.
- McGuinness, K. A. (2002). Of rowing boats, ocean liners and tests of the ANOVA homogeneity of variance assumption. *Austral Ecology, 27*(6), 681-688.
- Schmider, E., Ziegler, M., Danay, E., Beyer, L., & Bühner, M. (2010). Is It Really Robust? Reinvestigating the Robustness of ANOVA Against Violations of the Normal Distribution Assumption [10.1027/1614-2241/a000016]. *Methodology: European Journal of Research Methods for the Behavioral and Social Sciences, 6*(4), 147-151.
- Yang, H., & Huck, S. W. (2010). The Importance of Attending to Underlying Statistical Assumptions. *Newborn and Infant Nursing Reviews, 10*(1), 44-49.

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Effect Size

- Sometimes called magnitude of effect
  - A measure of the degree to which variability among observations can be attributed to treatments
- Measures of effect size in ANOVA are measures of the degree of association between and effect (e.g., a main effect, an interaction, a linear contrast) and the dependent variable.
- They can be thought of as the correlation between an effect and the dependent variable.
- If the value of the measure of association is squared it can be interpreted as the proportion of variance in the dependent variable that is attributable to each effect.

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Commonly Used Measures of Effect Size

- Four of the commonly used measures of effect size in AVOVA are
  - Eta squared
  - partial Eta squared
  - omega squared
  - Intraclass correlation
- Eta squared and partial Eta squared are estimates of the degree of association for the sample
- Omega squared and the intraclass correlation are estimates of the degree of association in the population
- SPSS for Windows displays the partial Eta squared when you check the display effect size option

$\eta^2 \quad \eta_p^2 \quad \omega \quad \rho_I$

Eta Squared

η^2

- Eta squared is the proportion of the total variance that is attributed to an effect
- It is calculated as the ratio of the effect variance (SSeffect) to the total variance (SStotal)

$$\eta^2 = \frac{ss_B}{ss_T}$$

Eta Squared

η^2

- In our example it would be (4716/5836)=0.8080

$$\eta^2 = \frac{ss_B}{ss_T} = \frac{4716}{5836} = 0.8080$$

- This means that schools (the treatment) account for over 80% of the variation in student achievement

ANOVA

Distance

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4716.400	2	2358.200	25.275	.000
Within Groups	1119.600	12	93.300		
Total	5836.000	14			

Eta Squared

- Very easy to calculate
- But it is a biased statistic
  - Tends to overestimate the true value in the population
- Better to use the omega-squared

Omega Squared

- The formula for the omega squared statistic is

$$\omega^2 = \frac{(k-1)(F-1)}{(k-1)(F-1)+kn}$$

where k=numbers of group,
n=number of participants

Partial Eta Squared

η_p^2

- The partial Eta squared is the proportion of the the effect + error variance that is attributable to the effect
- The formula differs from the Eta squared formula in that the denominator includes the SSeffect plus the SSerror rather than the SStotal

Exercise 1
Is there a difference in average students' mathematics achievement among four groups established by fathers occupational status?

! Assumptions

- Exercise_1_a.sav & Exercise_1_b.sav & Exercise_1_c.sav

Simplified data from PISA 2003 Study – Australia & Indonesia
(The **P**rogramme for **I**nternational **S**tudents **A**ssessment)

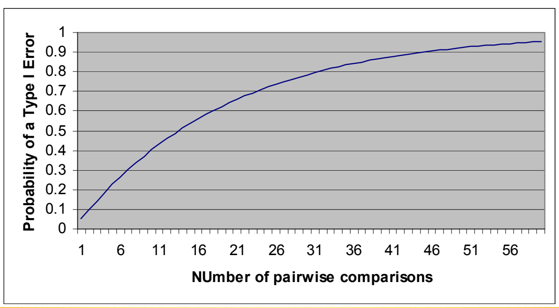
http://www.pisa.oecd.org

Comparing Means from More Than Two Populations

- If there are J groups, then the number of pair-wise comparisons is J(J-1)/2
  - So, if the number of groups was 5, then there would be ten pairwise comparisons
    - The probability of a Type I error is a single pairwise comparison is α
    - And the probability of one or more type I errors within the set is greater than α
    - If C is the number of comparisons, then the actual error rate is

$$p = 1 - (1 - \alpha)^C$$

Probability of Type I Error (α=0.05)



Post Hoc Tests

- When a significant F has been obtained and the factor (or treatment) has more than two levels, post hoc tests can be used to determine which particular groups differ significantly from one another
- Multiple comparisons procedures are methods for identifying differences among the group means once the hypothesis of overall equality has been rejected

Differences Between Post Hoc Tests

- Post hoc tests differ is in the degree to which they control experimentwise error or familywise error
  - Familywise error refers to refers to the probability that a family of tests will produce any Type I errors
    - For our example in which we looked at whether school (00008, 00009, 00018) was associated with mathematics achievement, the family of tests would refer to those that test the differences among the schools

Differences Between Post Hoc Tests

- The greater the degree to which a post hoc test controls for familywise error, the more conservative it is said to be
- All other things being equal, the more conservative a post hoc test is, the less power it has
- Making decisions about which type of post hoc test to use often involves a trade-off between Type I error and power

- Bender, R., & Lange, S. (2001). Adjusting for multiple testing - When and how? *Journal of Clinical Epidemiology, 54*(4), 343-349.
- Page 374 from Field, A. P. (2009). *Discovering statistics using SPSS : (and sex, drugs and rock 'n' roll)* (3rd ed.). Los Angeles: SAGE Publications.

Exercise 2
Is there a difference in average time students allocate on mathematics among groups established by students' self expected occupational status?

! Assumptions

- Exercise_2.sav

Simplified data from PISA 2003 Study – Australia & Indonesia
(The **P**rogramme for **I**nternational **S**tudents **A**ssessment)

http://www.pisa.oecd.org

Analysis of covariance

Analysis of covariance

- an extension of ANOVA in which main effects and interactions are assessed on DV scores after the DV has been adjusted for by the DV's relationship with one or more Covariates (CVs)

Applications

- Major applications
  - Increase test sensitivity (main effects and interactions) by using the CV(s) to account for more of the error variance therefore making the error term smaller
  - Adjust DV scores to what they would be if everyone scored the same on the CV(s)
    - This second application is used often in non-experimental situations where subjects cannot be randomly assigned

Analysis of Covariance

- Combination of both categorical (factors) and continuous (covariates) predictors of a continuous dependent variable
- Covariates
  - Confounders: nuisance variables that are (linearly) related to the dependent variable
  - First remove the effect of the confounder(s) and then test the effect of the factors on the dependent variable

Analysis of Covariance

- Default ANCOVA model:
  - All interactions between factors (as in ANOVA)
  - Main effects of covariates
  - No interactions between factors and covariates
  - No interactions between covariates

Assumptions

- Typical ANOVA assumptions still hold

In addition there are few more:

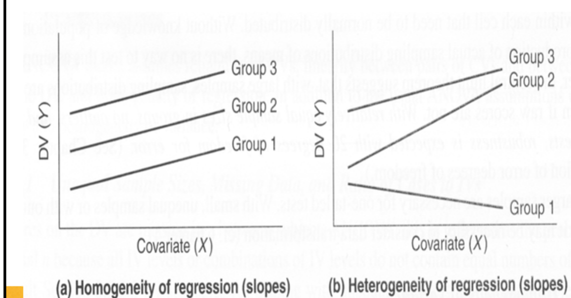
(a) Linearity is assumed that each CV has a linear relationship with the DV and other CVs

Assumptions

(b) Homogeneity of Regression

- the slope of the line predicting the DV from the CV should be the same for each level of the IV.
- In other words the regression coefficient (B) relating a CV to the DV should be the same for each group.

(b) Homogeneity of Regression



Assumptions

(c) Reliability of Covariates

- it is assumed that each CV is measured without error (this is unrealistic).

MORE ABOUT ASSUMPTIONS IN

Garson, G. D. (2012). *Univariate GLM, ANOVA, & ANCOVA*. Asheboro, NC: Statistical Associates Publishers.

http://www.statisticalassociates.com/glm_univariate.htm

OR SIMILAR RESOURCES

Exercise 3

Is there a difference in average students' mathematics achievement among groups established by fathers occupational status while controlling for disciplinary climate in the classroom?

! Assumptions

- Exercise_3.sav

Simplified data from PISA 2003 Study – Australia & Indonesia

(The **P**rogramme for **I**nternational **S**tudents **A**ssessment)

http://www.pisa.oecd.org

Two-way ANOVA

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The Design: An Example

- Suppose we had
  - Assignment to three schools as one factor
  - And gender (sex) as another factor
- We now have a much more complex ANOVA design
  - Effect of school
  - Effect of gender
  - Effect of any interaction between school and gender
    - An interaction example would be when girls prefer one school over another because of some feature of that school

The Design: An Example

	Treatment: Schools		
Treatment: Gender	One	Two	Three
Female	X_{111}	X_{121}	X_{131}
	X_{211}	X_{221}	X_{231}
	X_{311}	X_{321}	X_{331}
	•	•	•
	•	•	•
	X_{n11}	X_{n21}	X_{n31}
Male	X_{112}	X_{122}	X_{132}
	X_{212}	X_{222}	X_{232}
	X_{312}	X_{322}	X_{332}
	•	•	•
	•	•	•
	X_{n12}	X_{n22}	X_{n32}

Factorial Design:Two-Way ANOVA

- Examines the effect of
  - Two factors of interest on the dependent variable
    - e.g., Percent carbonation and line speed on soft drink bottling process
  - Interaction between the different levels of these two factors
    - e.g., Does the effect of one particular carbonation level depend on which level the line speed is set?

Two-Way ANOVA

Assumptions

- Similar to One-way ANOVA

MORE IN
Garson, G. D. (2012). *Univariate GLM, ANOVA, & ANCOVA*. Asheboro, NC: Statistical Associates Publishers.
http://www.statisticalassociates.com/glm_univariate.htm
OR SIMILAR RESOURCES

Two-Way ANOVA Sources of Variation

Two Factors of interest: A and B

r = number of levels of factor A

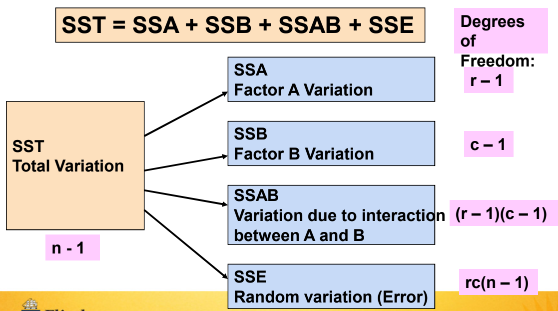
c = number of levels of factor B

n' = number of replications for each cell

n = total number of observations in all cells (n = rcn')

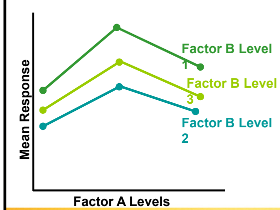
X_{ijk} = value of the k^{th} observation of level i of factor A and level j of factor B

Two-Way ANOVA Sources of Variation

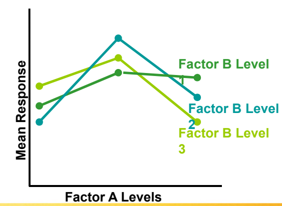


Examples: Interaction vs. No Interaction

- No interaction:



- Interaction is present:



Interaction

- If interaction is present then main effects can no longer be interpreted
- Decomposing significant interactions
- Profile plots
  - Parallel lines => no interaction
- Simple main effects
  - Pair-wise comparisons of the levels of A, within each level of B
  - Specify reduced set of comparisons of interest if possible

Main effects

- Significant main effect => not all levels of the factor have the same response
- If more than 2 levels, post-hoc tests are needed to determine which levels are different to which others
  - Adjustments for multiple comparisons
  - All pairwise tests (Bonferroni, Tukey etc)
  - Comparison to control (Dunnett)

Higher-way ANOVA

- *n*-way => *n* factors
- Full factorial model => all main effects, plus all 2-way, 3-way, …, *n*-way interaction terms
- If higher-order terms are non-significant may want to remove from model to give greater power to estimates of the lower-order terms

Exercise 4
Is there a difference in average students' reading achievement among males and females who are from two different types of family structure?

! Assumptions

- Exercise_4.sav

Simplified data from PISA 2003 Study – Australia & Indonesia
(The **P**rogramme for **I**nternational **S**tudents **A**ssessment)
http://www.pisa.oecd.org

SPSS – BOOKS (**Hard copies**)

- Chapters 7,8, 10 in Allen, Peter James, & Bennett, Kellie. (2012). SPSS statistics : a practical guide : version 20. South Melbourne, Vic.: Cengage Learning Australia.
- Chapters 19, 25 in Argyrous, George. (2011). Statistics for research : with a guide to SPSS (3rd ed.). Los Angeles: Sage.
- !!! Chapters 5 & 6 in Landau, Sabine, & Everitt, Brian. (2004). A handbook of statistical analyses using SPSS. Boca Raton: Chapman & Hall/CRC.
- !!! Chapters 7,8 in Kinnear, Paul R., & Gray, Colin D. (2009). PASW statistics 17 made simple (replaces SPSS statistics 17). London ; New York: Psychology Press.
- !!! Chapters 10,11,12 in Field, Andy P. (2009). Discovering statistics using SPSS : (and sex, drugs and rock 'n' roll) (3rd ed.). Los Angeles: SAGE Publications.
- Chapters 9 & 19, 22 in Norušis, Marija J. (2008). *SPSS 16.0* [or later versions] *Statistical Procedures Companion*. Upper Saddle River, NJ: Prentice Hall.

SPSS – BOOKS (**Online copies**)

Hard copies and online versions

- !!! Chapters 18 & 19 in Pallant, Julie. (2010). SPSS survival manual a step by step guide to data analysis using SPSS (4th ed.). Maidenhead: Open University Press/McGraw-Hill.
- Chapter 10 in Morgan, George A. (2011). IBM SPSS for introductory statistics : use and interpretation (4th ed.). New York: Routledge.
- !!! Chapters 8 in Leech, Nancy L., Barrett, Karen Caplovitz, Morgan, George A., & Leech, Nancy L. (2011). *IBM SPSS for intermediate statistics : use and interpretation* (4th ed.). New York: Routledge.

Online versions

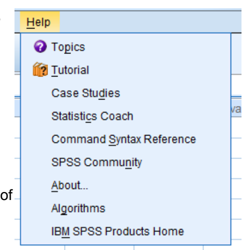
- Chapter 9 in Bryman, Alan, & Cramer, Duncan. (2011). Quantitative data analysis with IBM SPSS 17, 18 & 19 : a guide for social scientists. Hove ; New York: Routledge.
- Chapters 10,11,13 & 14 in Larson-Hall, Jenifer. (2010). A guide to doing statistics in second language research using SPSS

BOOKS – More Theoretical Level

- Tabachnick, B. G., & Fidell, L. S. (2007 or later). *Using multivariate statistics* (5th ed.). Boston: Pearson/Allyn & Bacon
- Quinn, G. P., & Keough, M. J. (2002). *Experimental design and data analysis for biologists*. Cambridge: Cambridge University Press
- Whitlock, M., & Schluter, D. (2009). *The analysis of biological data*. Greenwood Village, Colo.: Roberts
- !!! Levine, Gustav, Page, Melanie C., Braver, Sanford L., & MacKinnon, David Peter. (2003). *Levine's guide to SPSS for analysis of variance* (2nd ed.). Mahwah, N.J.: L. Erlbaum

SPSS – Help and Resources

- SPSS has a range of help options available
  - Topics
    - Used to find specific information
  - Tutorial
    - Find illustrated, step-by-step instructions for the basic features
  - Case studies
    - Hands-on examples of various types of statistical procedures
  - Statistics coach
    - To help you find the procedure you want to use



And manuals available online - http://www-01.ibm.com/support/docview.wss?uid=swg27021213

SPSS – **Online tutorials and resources**

(!!! Please keep in mind that usually online resources are not academically peer reviewed. Despite many of them being of high quality as well as being very useful from educational point of view, they shouldn't be treated as a completely reliable and academically sound references)

- **Statnotes: Topics in Multivariate Analysis, by G. David Garson**
  http://www.statisticalassociates.com/
- **UCLA Institute for Digital Research and Education - SPSS Starter Kit**
  http://www.ats.ucla.edu/stat/spss/sk/default.htm
- **Getting Started with SPSS for Windows by John Samuel, Indiana University**
  http://www.indiana.edu/~statmath/stat/spss/win/index.html
- **Companion Website for the 3rd edition of Discovering Statistics Using SPSS by Andy Field**
  http://www.uk.sagepub.com/field3e/SPSSFlashmovieslect.htm
- **SPSS for Windows and Amos tutorials by Information Technology Services, University of Texas**
  http://ssc.utexas.edu/software/software-tutorials#SPSS
- **Journey in Survey Research by John Hall**
  http://surveyresearch.weebly.com/index.html

SPSS – Help and Resources

- **Online SPSS FORUMS**

(!!! Please keep in mind that usually online resources are not academically peer reviewed. Despite many of them being of high quality as well as being very useful from educational point of view, they shouldn't be treated as a completely reliable and academically sound references.

!!! Suggestions / Guidance found on forums should be especially treated very doubtfully, yet they may point to more reliable academic resources and be somewhat of help.

Archives of SPSSX-L@LISTSERV.UGA.EDU – List Serve that is endorsed by IBM SPSS
http://www.listserv.uga.edu/archives/spssx-l.html

Other forums

http://groups.google.com/group/comp.soft-sys.stat.spss/topics?gvc=2
http://www.spssforum.com/

THANK YOU

Please provide us with your feedback by completing the short survey.

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Pawel Skuza 2013