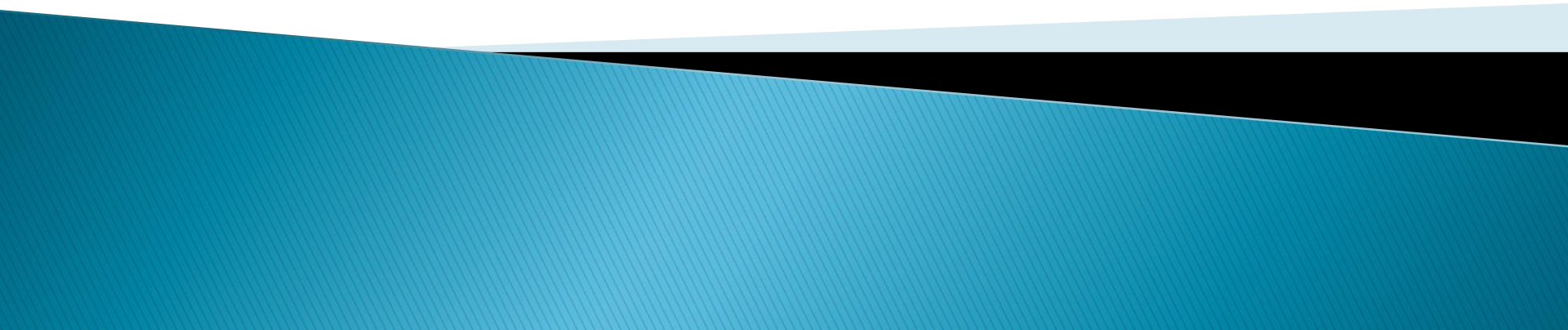


Research Design and Analysis

Multi-level Analysis

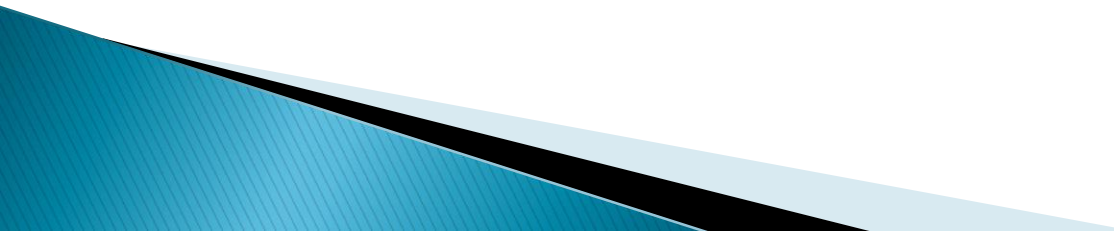
Dr. Paul Hutchings
Miss Katie Sullivan



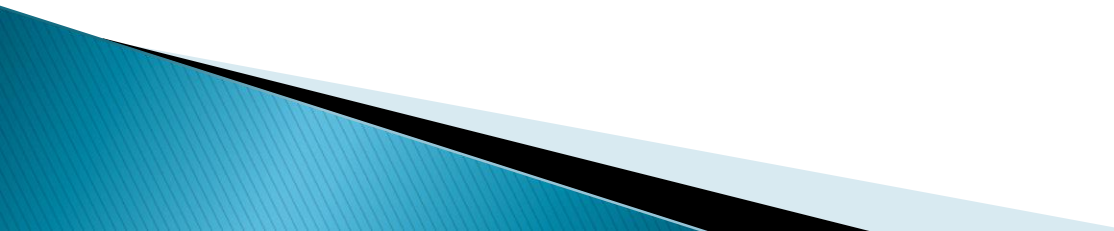
ESSENTIAL READING

- ▶ Coolican, H. (2014). *Research methods and statistics in psychology*. London: Taylor & Francis. **Chapters 20, 21, & 22.**

Lecture Outlines: Next three lectures

- ▶ Brief recap on simple designs involving two groups or two conditions.
 - ▶ Brief recap on basic ANOVA design (Multi-level analysis/one-way ANOVA).
 - ▶ Introduction to Multi-factorial designs.
 - ▶ Understanding calculations for each type of analysis
 - When appropriate/not appropriate
- 

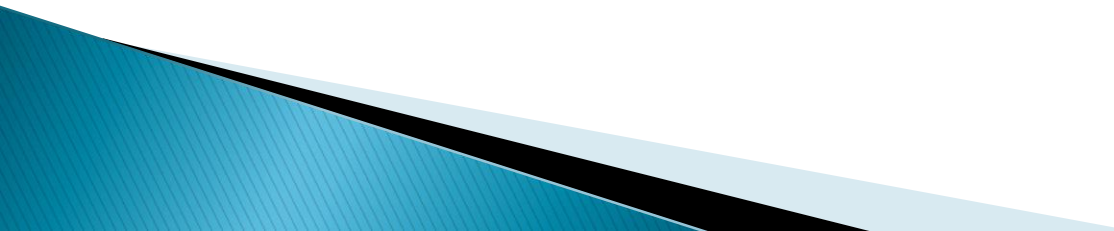
Basic Terms

- ▶ **Factors:** These are the Independent Variables (IVs)
 - ▶ **Levels of factors:** Similar to conditions
 - ▶ **Between-subject factor:** Factors whose levels vary between Ps (each P only experiences 1 level of a factor).
 - ▶ **Within-subject factors:** Factors whose various levels vary within a P (each P will experience 2 or more levels of a factor).
- 

Factors in experiments/studies

- ▶ Many research design examples you have come across so far have involved:
 - **Single** variable studies E.g.:
 - Does IV 'extraversion' effect Facebook use?
 - Does IV 'task difficulty' effect number of errors?
- ▶ These effects are judged/analysed in isolation

Factors in experiments/studies

- ▶ The specific design of any piece of research will depend on the hypothesis:
 - Is there an association/relationship?
 - Are there differences between groups?
 - Are there differences within groups across different conditions?
 - ▶ All still simple design – two variables of interest only (one IV and the DV).
- 

Factors in experiments/studies

HOWEVER:

- ▶ There may be other variables that influence these processes? Or the strength of a relationship?



Factors in experiments/studies

- ▶ Often we want to ask a more complex question.
- ▶ Sometimes we want to examine more than two groups.
- ▶ We may want to examine which of a number of variables **has the greatest influence** over a given outcome?
- ▶ How does a variable/factor **effect the DV** in light of another variable/factor?
- ▶ What is the **interaction** of two (or more) variables/factors **in their effect on DV**?



Analysis of Variance (ANOVA)

- ▶ So, if an experiment has more than 2 groups, more than 2 conditions, or involves more than 1 IV then the Analysis of Variance (ANOVA) statistical procedure is used to analyse the data.

- ▶ Why?



ANOVA Recap

1. ANOVA can handle data from experiments involving more than two conditions:
 - E.g., A researcher wants to examine participants ability to solve crossword puzzles under three different time pressures: 5 minutes, 10 minutes, & 15 minutes.

ANOVA Recap

- If there were only 2 groups e.g., 5 minutes vs. 15 minutes, we would conduct a t-test.
- So, why not just conduct 3 t-tests when there are 3 conditions?
 - 5 min vs. 10 min
 - 5 min vs. 15 min
 - 10 min vs. 15 min

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \quad \begin{array}{l} \mapsto \\ \mapsto \\ \mapsto \end{array} \quad \begin{array}{l} \text{difference between means} \\ \text{variance} \\ \text{sample size} \end{array}$$

where $\bar{x}_1$ = mean of sample 1

$\bar{x}_2$ = mean of sample 2

n_1 = number of subjects in sample 1

n_2 = number of subjects in sample 2

$$s_1^2 = \text{variance of sample 1} = \frac{\sum(x_1 - \bar{x}_1)^2}{n_1}$$

$$s_2^2 = \text{variance of sample 2} = \frac{\sum(x_2 - \bar{x}_2)^2}{n_2}$$

ANOVA Recap

- ▶ Too many multiple comparisons = increased likelihood of Type 1 error
- ▶ Type 1 error more possible by chance
 - Accept a difference as significant ($p < .05$) in error
- ▶ ANOVA corrects for this problem:
 - More stringent test of significance than t-test
 - Reduction in significance level

One-way ANOVA

- ▶ This is the One-way ANOVA, which you covered during the first year.
- ▶ Only one IV with more than two conditions.
- ▶ Can also be called Multi-level analysis

$$F = \frac{\text{estimate of } \sigma^2 \text{ from means}}{\text{estimate of } \sigma^2 \text{ from individuals}}$$

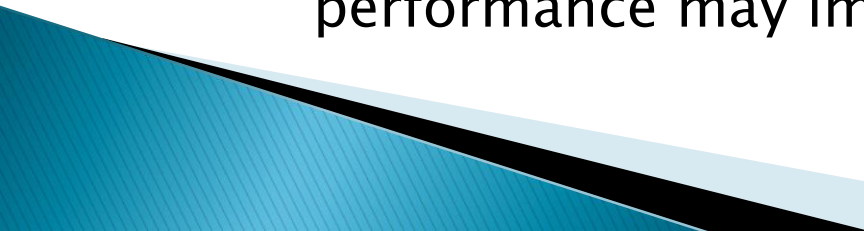
$$F = \frac{\text{Variance between Treatments}}{\text{Variance within Treatments}}$$

$$F = \frac{\text{Variance of Treatments}}{\text{Variance of Error}}$$

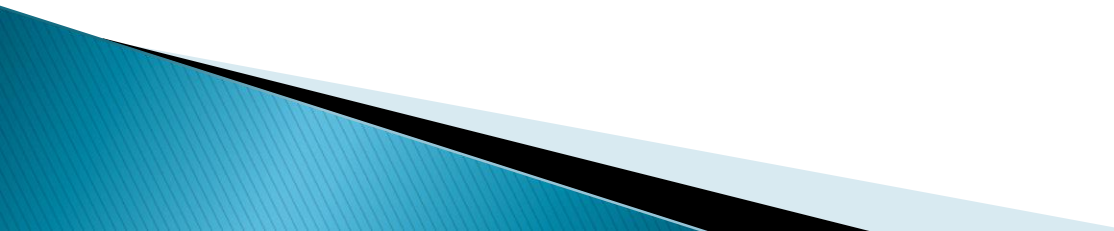
ANOVA – Multifactorial design

- 2. ANOVA allows us to investigate the effect of more than one Independent variable (IV)
 - E.g., examine the effect of participant sex and age on remembering a list of words.
 - Here there are 2 IVs: (1) Sex and (2) Age
 - One DV: Memory for the list of words
- ▶ ANOVA can handle any number of IVs
(but more than about 4 are rarely used)

ANOVA – Interactions

- ▶ Allows us to investigate how multiple IVs combine (or interact) to affect the DV.
 - E.g., consider the previous example: The effects of sex and age on memory score.
 - Males may remember more than females; older Ps may remember more than younger Ps.
 - OR we may see an interaction:
 - Male performance may decline with age while female performance may improve with age.
- 

ANOVA Recap

- ▶ ANOVA is a parametric test so the following conditions must be met in order to use it:
 1. The DV comprises of interval or ratio data.
 2. Data is from a population that's normally distributed.
 3. There is homogeneity of variance (population variances are all equal).
 4. For independent group designs, independent random samples must have been taken from each population.
- 

ANOVA Recap

- ▶ Human performance varies both between individuals and within the same individual.
 - ▶ If the variance between conditions is larger than variance within conditions then we can say that the IV is having a larger effect on scores than individual differences are.
 - ▶ So ANOVA needs to calculate both types of variances.
- 

ANOVA Recap

- ▶ ANOVA compares the **between-group variation** to the random variation (**within group variation**) within each group.
- ▶ If there are differences between groups, the **between group variance** will be **larger** than the **within group variance**
- ▶ Calculated as the ***F ratio***

The F-ratio

- ▶ The F-ratio looks at whether variances are due to our manipulation of the IV or from other nuisance factors (also known as the error variance).

$$F = \frac{\text{estimate of } \sigma^2 \text{ from means}}{\text{estimate of } \sigma^2 \text{ from individuals}}$$

$$F = \frac{\text{Variance between Treatments}}{\text{Variance within Treatments}}$$

$$F = \frac{\text{Variance of Treatments}}{\text{Variance of Error}}$$

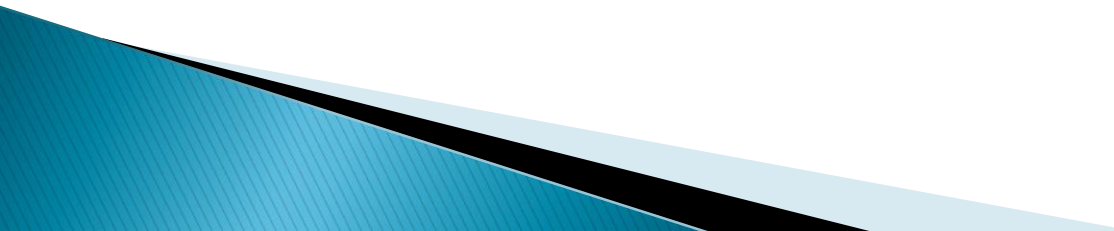
Next three weeks...

- ▶ Multi-factorial ANOVA design
 - More than one IV.

Let's look at an example in detail...

- ▶ Effect of two types of particular teaching strategy (A & B) on learning (DV = reading test scores)
 - IV: Teaching strategy A and B (2 conditions)
 - Between participants design ($\frac{1}{2}$ of the pupils in strategy A and $\frac{1}{2}$ in strategy B)
 - Find that scores higher for strategy B

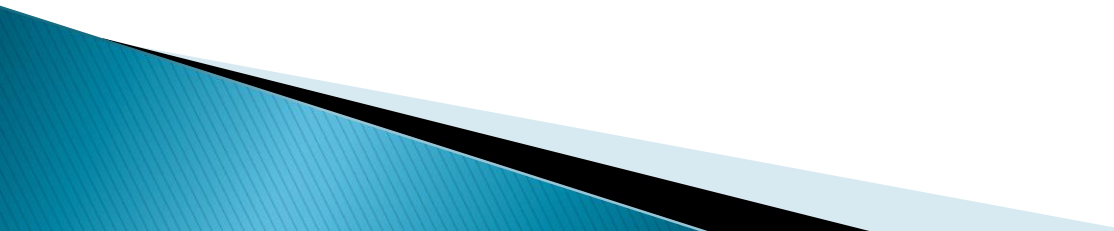
Teaching example

- ▶ What other factors need to be considered?
Could things other than just teaching strategy influence reading test scores?
 - ▶ What about the level of ability of the children in each group to begin with?
 - ▶ How can we deal with this as a possible influencing factor?
- 

Exploring Multiple Factors

- Need to study more than one Independent Variable
 - Investigate possible 'interaction' between IVs
 - Still looking at the effect on one DV (reading score)
 - IV: Teaching strategy used (A or B)
 - IV: Original ability (High or Low)
 - DV: Reading score after teaching
- ▶ This is a 'multifactorial' design

Describing ANOVAs

- ▶ You need to specify 3 things:
 1. How many **factors** are involved
 2. How many **levels** there are of each factor
 3. Whether each factor is a **within-** or **between-** subject factor
- 

Teaching strategy study:

- ▶ Because we have two IVs:
 - Have to combine the conditions of each
 - Both IVs have 2 conditions:
 - Teaching Strategy: A or B
 - Original Ability: High or Low
 - This gives us a 2 x 2 design
 - To test all combinations need 4 conditions

Multifactorial designs

- ▶ Teaching strategy study:
- ▶ 2 x 2 table of conditions (4 conditions)

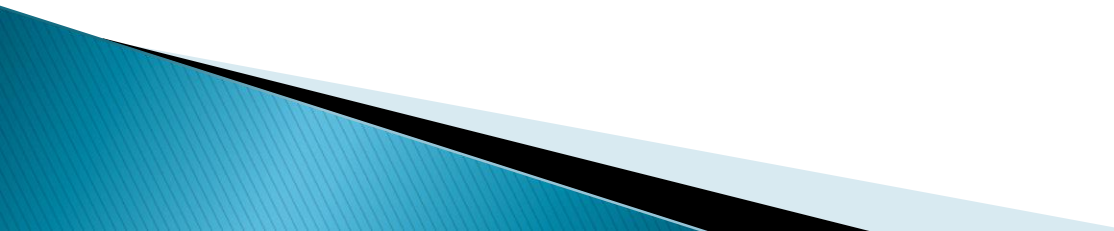
	Strategy A	Strategy B
Low ability	Condition 1	Condition 2
High ability	Condition 3	Condition 4

Multifactorial designs

- ▶ Sample mean scores for the study:

	Strategy A	Strategy B	Means
Low ability	2	7	4.5
High ability	8	8	8
Means	5	7.5	

Main effects and interactions

- ▶ We can assess the effect of each factor on their own and the interaction between them.
 - ▶ Main effect: is used to describe the independent effect of a factor (IV).
 - ▶ E.g., in the teaching strategy example, 2 main effects will be reported:
 - Teaching Strategy
 - Original Ability
- 

Multifactorial designs

- ▶ ‘Main effects’ are effects of one IV alone (e.g. Original Ability)
- ▶ Where is effect of ‘ability’ IV shown in the scores?

	Strategy A	Strategy B	Means
Low ability	2	7	4.5
High ability	8	8	8
Means	5	7.5	

Multifactorial designs

- ▶ Where is effect of 'teaching strategy' IV shown in the scores?

	Strategy A	Strategy B	Means
Low ability	2	7	4.5
High ability	8	8	8
Means	5	7.5	

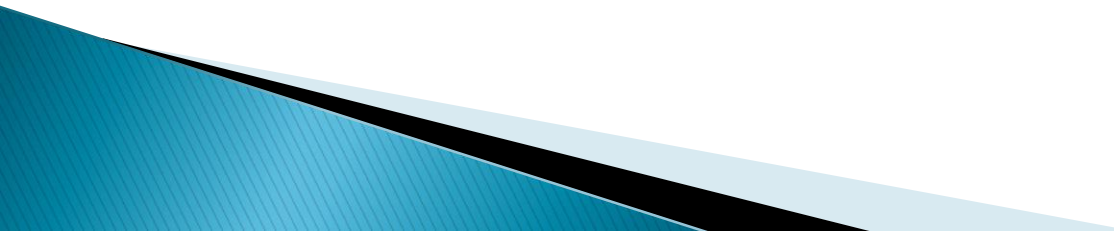
Main effects

- ▶ The study can show us the ‘main effects’
 - Effects of each IV in isolation on DV score
 - Is there a significant difference between conditions
- ▶ However, the point was to examine how the **TWO** IVs may influence the DV **together**
- ▶ Analyse any possible ‘interaction’ between IVs
 - Combination of IVs in effecting the DV
 - Differences dependent on conditions of both IVs

Main effects and Interactions

- ▶ The **main effects** compare the means for one **level/condition** of a factor with the mean of the other **level(s)/condition(s)** of that factor.
 - In the same way as in experiment with only 1 IV.
 - Only this time you would have more than 1 main effect.
- ▶ **Interactions**: assess the combined effect of the **factors** (all the IVs)

Interactions

- ▶ An interaction that assesses how 2 factors combine to effect performance (DV) is called a two-way interaction.
 - ▶ When 3 factors are involved it is a three-way interaction.
 - ▶ And so on....
- 

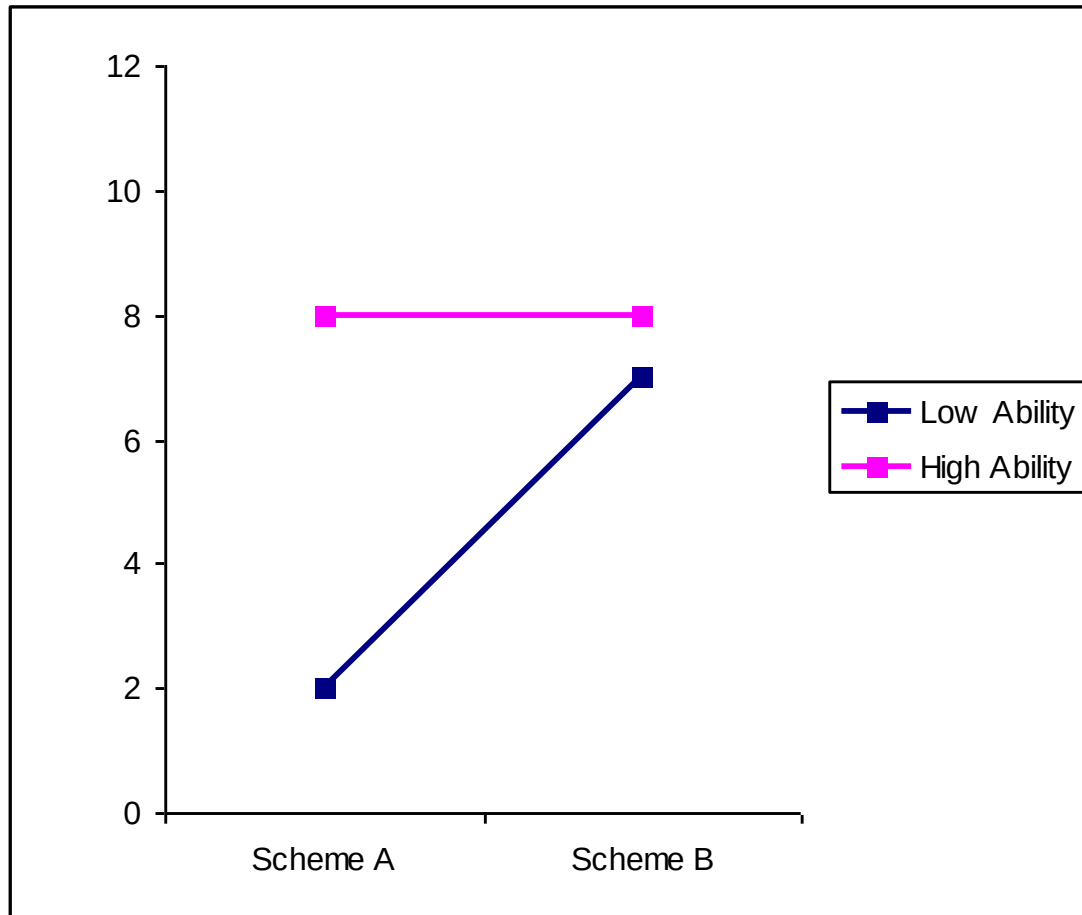
Multifactorial designs

- ▶ How do the two IVs interact?
- ▶ Effect of **strategy** only for **low ability** group?

	Strategy A	Strategy B	Means
Low ability	2	7	4.5
High ability	8	8	8
Means	5	7.5	

Using graphs to show interactions

Reading
score



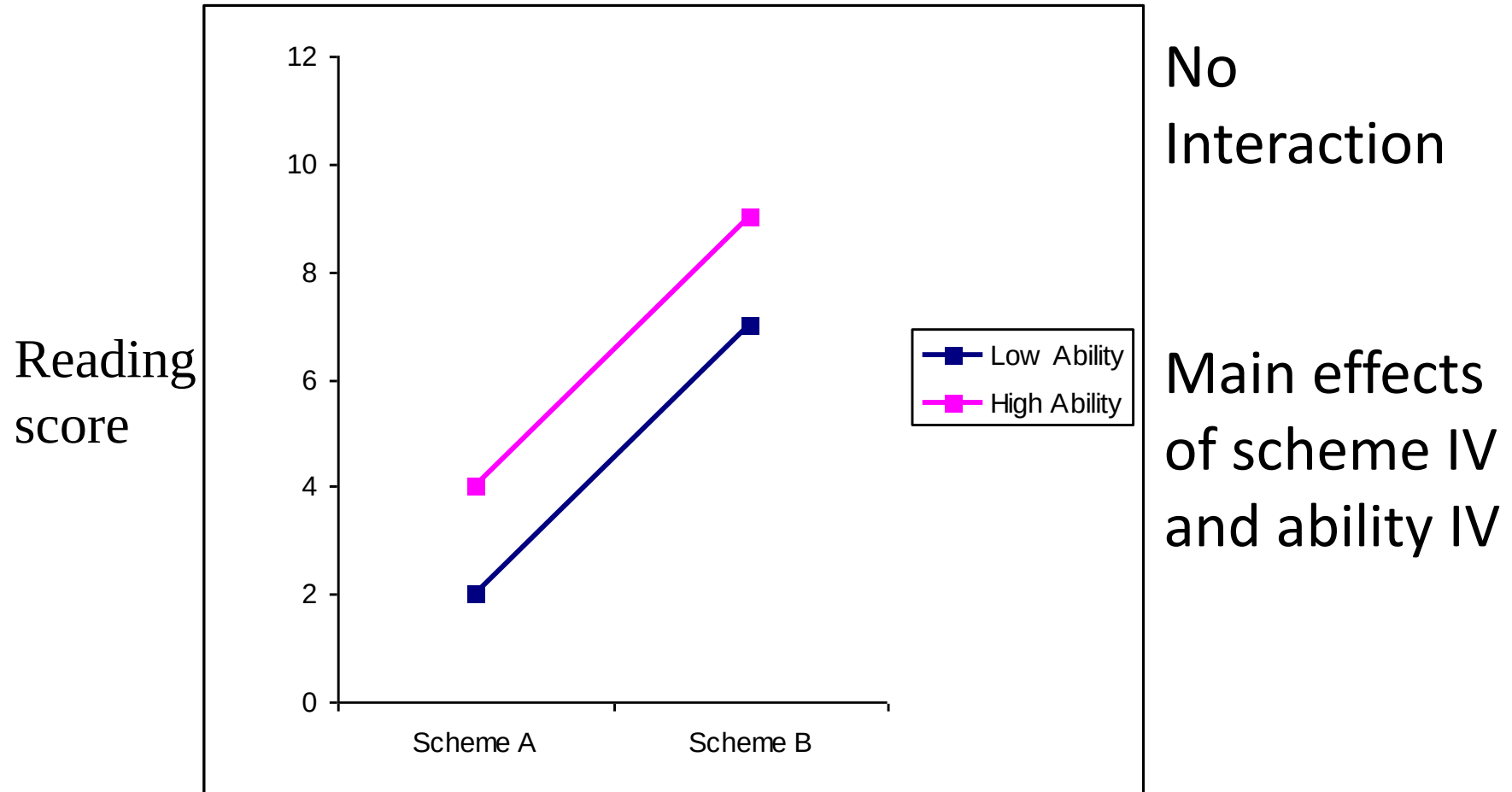
Why interaction?

Effect of strategy IV (higher scores for B) but effect shown only for one ability (IV) group

Using graphs to show interactions

- ▶ Key to interpreting is relative slope of lines
- ▶ Same/Similar slope = likely no interaction
- ▶ Markedly different slope indicates may be interaction between the IVs

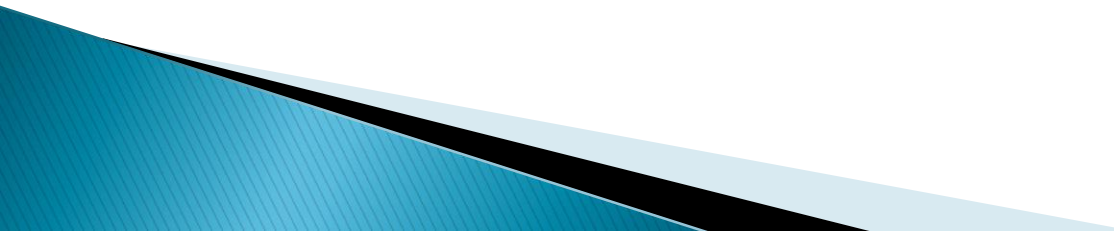
Using graphs to show interactions



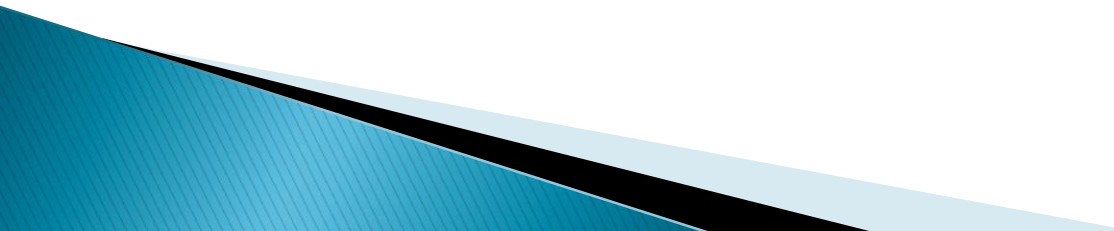
Multifactorial designs

- ▶ Was the teaching strategy IV within or between subjects?
 - Between: 1 group of pupils were taught under teaching strategy A, while a different set of pupils were taught under teaching strategy B.
- ▶ What about the original ability IV?
 - Also between: some pupils had high ability while different pupils had low ability

Possible ANOVA designs

- ▶ **One-way within:** Has 1 factor (IV) with multiple levels (conditions) – Each participant takes part in all conditions.
 - ▶ **One-way between:** Has 1 factor (IV) with multiple levels (conditions) – Different participants take part in each of the different conditions.
- 

Possible ANOVA designs

- ▶ **Two-way within:** Has 2 factors (IVs) with multiple levels (conditions) – Each participant takes part in each possible combination of the 2 factors.
 - ▶ **Two-way between:** Has 2 factors (IV) with multiple levels (conditions) – Different participants take part in each of the different combination of factors and conditions.
- 

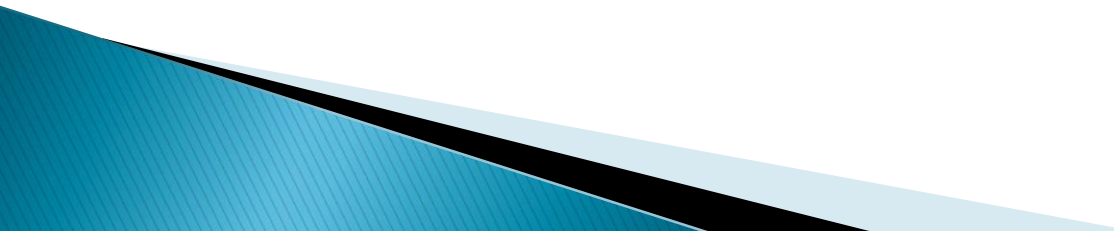
Mixed Design

- ▶ Can also use a **mixed design**
 - A between (unrelated) independent variable
 - A within (related) independent variable
 - Included together in one analysis
- A very common structure for studies
- **This is what you will be using for your assignment**

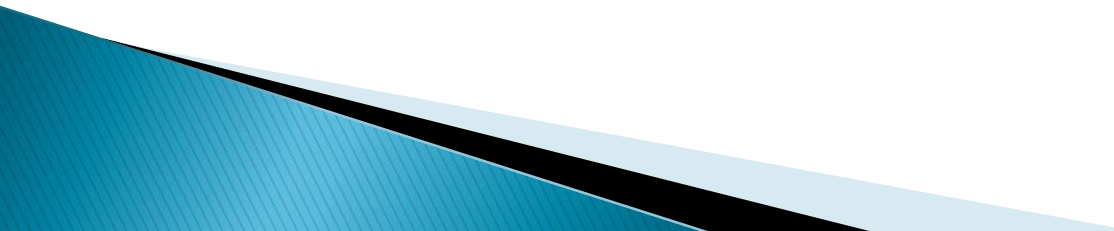
Reporting multifactorial ANOVA statistics

- ▶ ANOVA will analyse:
 - Main effects (effects of one IV in isolation)
 - Interactions (combined effects of more than one IV)
 - Main statistics for each analysis:
 - F-value, degrees of freedom, p-value (sig. value)
 - F-value equating to the t-value in the t-test
 - Sig. Value used in exactly same way as t-test ($p < 0.05$ is significant)
 - All showing whether (or not) there are **significant differences** (and to what degree) between the means in each grouping of data

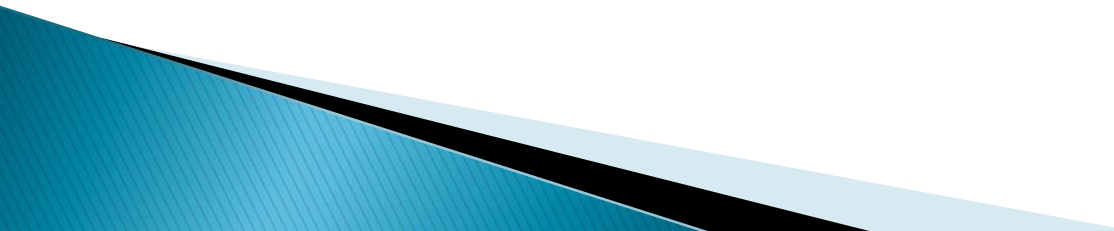
Interpretation of ANOVA Output

- ▶ Report descriptives
 - ▶ Check Levene's test of equality of error variances
 - Needs to be **greater** than .05
 - ▶ Report main effects
 - ▶ Report interaction effects
 - ▶ Report effect size
 - ▶ Report post-hoc tests (if needed)
- 

Interpretation of ANOVA Output

- ▶ Use your SPSS stats book
 - This is the only way you will understand it for yourself!
 - ▶ Tells you exactly what to interpret and how to report it
 - ▶ Just make sure you have selected the correct ANOVA based on your experimental design
- 

Note 1:

- ▶ With ANOVA outputs, although the main values you will need for your write-up are the F, df, & sig values you need to check other tables from the output (depending on the type of ANOVA) in order to ensure there have been no violations and to ensure you read the values you need from the correct rows.
- 

Note 2:

- ▶ Remember that with ANOVA you need 2 values for the degrees of freedom (df):
 - the value from the row of your IV and the value from the top 'error' row of output.

Good Practice in SPSS

- ▶ If you don't need decimal places then in Variable view best change this to 0.
- ▶ Always ask for Descriptive statistics.
- ▶ In the 'Options' dialogue box, usually a good idea to ask for:
 - 'Estimates of effect size' which tells you the proportion of total variance accounted for by the factor (ANOVA).
 - 'Homogeneity tests' – you can proceed and assume homogeneity if Levene's test is **not** significant.

Final reminder.....

**READ YOUR
RESEARCH
METHODS BOOKS**

