Overview of Lecture

- Testing the Null Hypothesis
- Statistical Power
- On What Does Power Depend?
- Measures of Effect Size
- Calculating Effect Size
- Reporting Effect Size
- What to Avoid

Making a decision

- With F-ratios that exceed F-critical we reject the null hypothesis.
  - independent variable(s) influence(s) the dependent variable.
  - Statistically significant effect.
- When a finding does not exceed alpha level ($p < 0.05$) we fail to reject the null hypothesis:
  - Ho=all means are equal implies no evidence of an effect of the treatment
  - No evidence of a statistical difference.

Failing to reject the null hypothesis

- However, "no statistical difference" does not prove the null hypothesis.
  - We simply do not have evidence to reject it.
  - A failure to find a significant effect does not necessarily mean the means are equal.
- So it is difficult to have confidence in the null hypothesis:
  - Perhaps an effect exists, but our data is too noisy to demonstrate it.

Statistical Power

- Sometimes we will incorrectly fail to reject the null hypothesis – a type II error.
- There really is an effect but we did not find it
- Statistical power is the probability of detecting a real effect
- More formally, power is given by:

  $1-\beta$

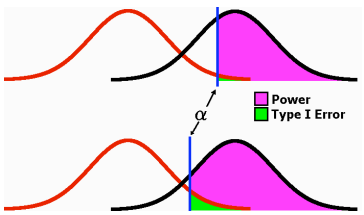
  where β is the probability of making a type II error
- In other words, it is the probability of not making a type II error

What does power depend on?

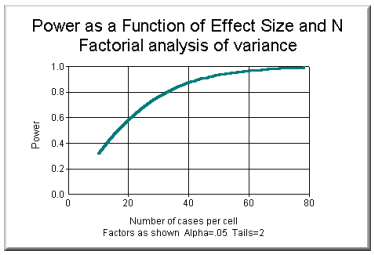
- Power is your ability to find a difference when a real difference exists. The power of a study is determined by three factors:
  - Alpha level.
  - Sample size.
  - Effect size:
    - Association between DV and IV
    - Separation of Means relative to error variance.

Power and alpha

- By making alpha less strict, we can increase power. (e.g. $p < 0.05$ instead of 0.01)
- However, we increase the chance of a Type I error.



Power and sample size



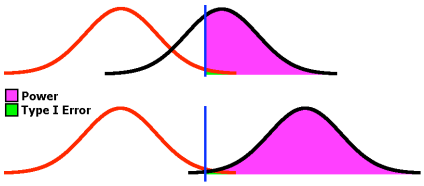
Low N's have very little power.
Power saturates with many subjects.

Power and Sample Size

- One of the most useful aspects of power analysis is the estimation of the sample size required for a particular study
  - Too small an effect size and an effect may be missed
  - Too large an effect size too expensive a study
- Different formulae/tables for calculating sample size are required according to experimental design

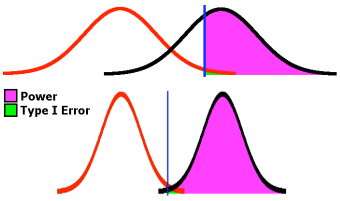
Power and effect size

- As the separation between two means increases the power also increases



Power and effect size

- As the variability about a mean decreases power also increases



Measures of effect size for ANOVA

- Measures of association
  - Eta-squared (η^2)
  - R-squared (R^2)
  - Omega-squared (ω^2)
- Measures of difference
  - d
  - f

Measures of association - Eta-Squared

- Eta squared is the proportion of the total variance that is attributed to an effect.

$$\eta^2 = \frac{SS_{treatment}}{SS_{total}}$$

- Partial eta-squared is the proportion of the effect + error variance that is attributable to the effect

$$\eta_p^2 = \frac{SS_{treatment}}{SS_{treatment} + SS_{error}}$$

- Both kinds are measures of association for the sample

Measures of association - R-Squared

- In general R^2 is the proportion of variance explained by the model
  - Each anova can be thought of as a regression-like model in which each IV and interaction between Ivs can be thought of as a predictor variable
- In general R^2 is given by

$$R^2 = \frac{SS_{model}}{SS_{total}}$$

Measures of association - Omega-squared

- Omega-squared is an estimate of the dependent variable population variability accounted for by the independent variable.
- For a one-way between groups design:

$$\omega^2 = \frac{(p-1)(F-1)}{(p-1)(F-1)+np}$$

- Where, *p*=number of levels of the treatment variable and *n*= the number of participants per treatment level

Measures of difference - d

- When there are only two groups *d* is the standardised difference between the two groups

$$\hat{d} = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{MS_{error}}}$$

Measures of difference - *f*

- Cohen's (1988) *f* for the one-way between groups analysis of variance can be calculated as follows

$$\hat{f} = \sqrt{\frac{\omega^2}{1-\omega^2}}$$

- It is an averaged standardised difference between the 3 or more levels of the IV (even though the above formula doesn't look like that)
- Small effect - *f*=0.10; Medium effect - *f*=0.25; Large effect - *f*=0.40

Using Power Analysis to Calculate Sample Size

- A simple power analysis program available on the web called GPower is available for download from the following address:
  - http://www.psycho.uni-duesseldorf.de/aap/projects/gpower/
- This program can be used to calculate the sample size required for different effect sizes and specific levels of statistical power for a variety of different tests and designs.
- There are excellent help files available on the website

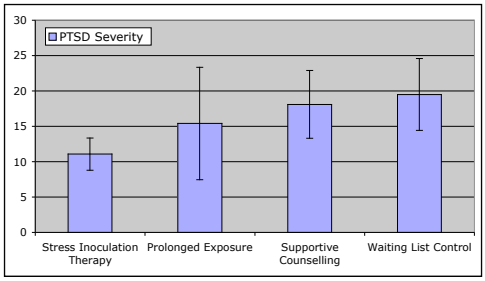
Estimating Effect Size

- There are two ways to decide what effect size is being aimed for:
  - On the basis of previous research
    - Meta-Analysis: Reviewing the previous literature and calculating the previously observed effect size (in the same and/or similar situations)
  - On the basis of theoretical importance
    - Deciding whether a small, medium or large effect is required.
- The former strategy is preferable but the latter strategy may be the only available strategy.

Calculating *f* on the basis of previous research

- This example is based on a study by Foa, Rothbaum, Riggs, and Murdock (1991, *Journal of Counseling and Clinical Psychology).*
- The subjects were 48 trauma victims who were randomly assigned to one of four groups. The four groups were
  - 1) Stress Inoculation Therapy (SIT) in which subjects were taught a variety of coping skills;
  - 2) Prolonged Exposure (PE) in which subjects went over the traumatic event in their mind repeatedly for seven sessions;
  - 3) Supportive Counseling (SC) which was a standard therapy control group
  - 4) a Waiting List (WL) control.
- The dependent variable was PTSD Severity

A graph of the means



Anova on example data

ANOVA
PTSD Severity

	SS	df	Mean Square	F	Sig.
Between Groups	507.84	3	169.28	3.269	0.030
Within Groups	2278.74	44	51.7895		
Total	2786.58	47			

- Give the above analysis

$$\eta^2 = \frac{(p-1)(F-1)}{(p-1)(F-1)+np} = \frac{(4-1)(3.269-1)}{(4-1)(3.269-1)+(12)(4)} = 0.124$$

- So

$$\hat{f} = \sqrt{\frac{\eta^2}{1-\eta^2}} = \sqrt{\frac{0.124}{1-0.124}} = 0.378$$

Number of participants required to replicate results

- Give GPower the following values
  - Alpha=0.05
  - Beta=0.80
  - f=0.378
- Then the total number of participants required is 84 (i.e. 21 participants per group)

- Give GPower the following values
  - Alpha=0.05
  - Beta=0.80
  - f=0.378
- Then the total number of participants required is 128 (i.e. 32 participants per group)

Estimating Sample Size For Small, Medium and Large Effects

- **Small Effect**
- Give GPower the following values
  - Alpha=0.05
  - Beta=0.80
  - f=0.100
- Then the total number of participants required is 1096 (i.e. 274 participants per group)

- **Medium Effect**
- Give GPower the following values
  - Alpha=0.05
  - Beta=0.80
  - f=0.250
- Then the total number of participants required is 180 (i.e. 45 participants per group)

- **Large Effect**
- Give GPower the following values
  - Alpha=0.05
  - Beta=0.80
  - f=0.400
- Then the total number of participants required is 76 (i.e. 19 participants per group)

What should we report?

- Practically any effect size measure is better than none particularly when there is a non-significant result
  - However, SPSS provides some measures of effect size (though not *f*)
- Meta-analysis (e.g. the estimation of effect sizes over several trials) requires effect size measures
- Calculating sample sizes for future studies requires effect size information

Things to be avoided….if possible

- "Canned" effect sizes
  - The degree of measurement accuracy is ignored by using fixed estimates of effect size
  - The same sample sizes are used for measures capable of millisecond and second accuracy if a particular size effect is desired
- Retrospective justification
  - Saying that a non-significant result means there is no effect because the power was high
  - Saying that there is a non-significant result because the statistical power was low