Empirical Research Methods in Information Science

IS 4800 / CS 6350

Lecture 18

Within-Subjects Designs

Quiz #8

https://tinyurl.com/IS4800WITHIN

Types of Studies Discussed

- Descriptive
- Correlational
- Demonstration
- Experimental
  - One-factor, two-level, between-subjects
  - One-factor, two-level, within-subjects
    - aka “repeated measures” or “crossover”
  - Matched pairs

Types of Experimental Designs

- *Between-Subjects Design*
  - Different groups of subjects are randomly assigned to the levels of your independent variable
  - Data are averaged for analysis
  - Use t-test for independent means

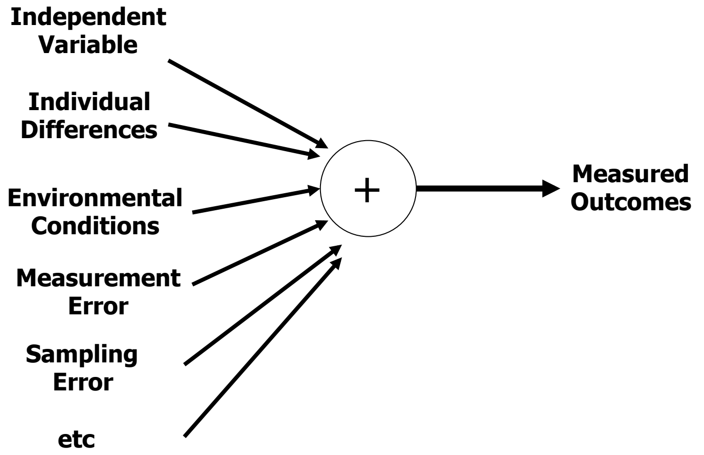
  - We have discussed “single factor, two-level, between subjects” designs.

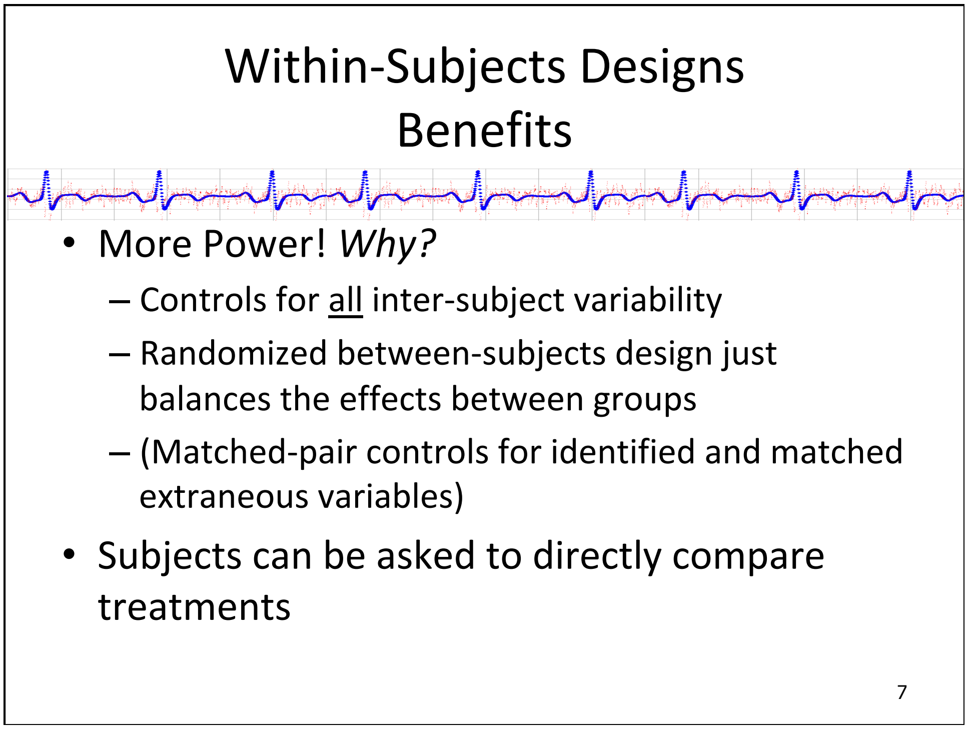
Types of Experimental Designs

- *Within-Subjects Design*
  - A single group of subjects is exposed to all levels of the independent variable
  - Data are averaged for analysis
  - aka “repeated measures design”, “crossover design”
  - Use t-test for dependent means aka “paired samples t-test”

  - We will discuss “single factor, two-level, within subjects” designs.

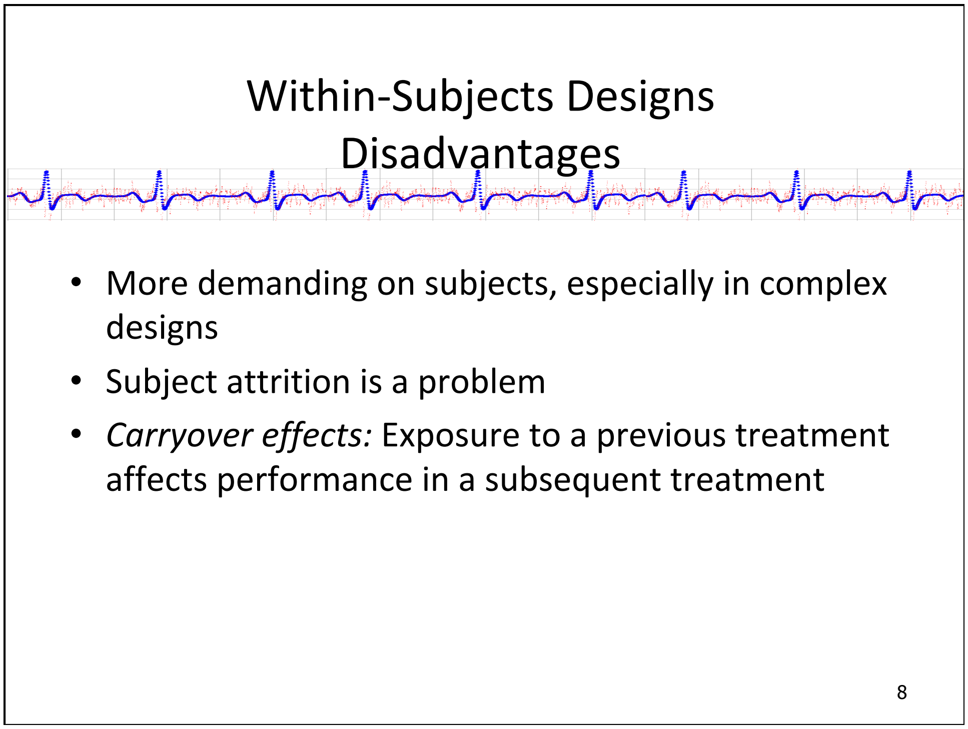
Error Variance





Within-Subjects Designs
Benefits

- More Power! *Why?*
  - Controls for all inter-subject variability
  - Randomized between-subjects design just balances the effects between groups
  - (Matched-pair controls for identified and matched extraneous variables)
- Subjects can be asked to directly compare treatments

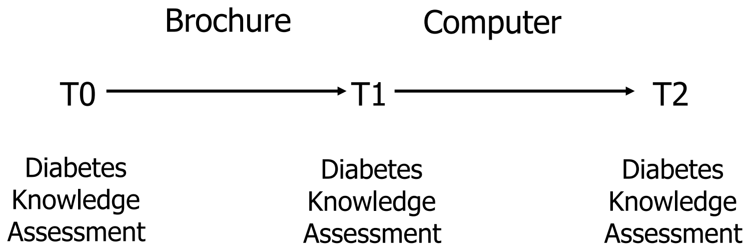


Within-Subjects Designs
Disadvantages

- More demanding on subjects, especially in complex designs
- Subject attrition is a problem
- *Carryover effects:* Exposure to a previous treatment affects performance in a subsequent treatment

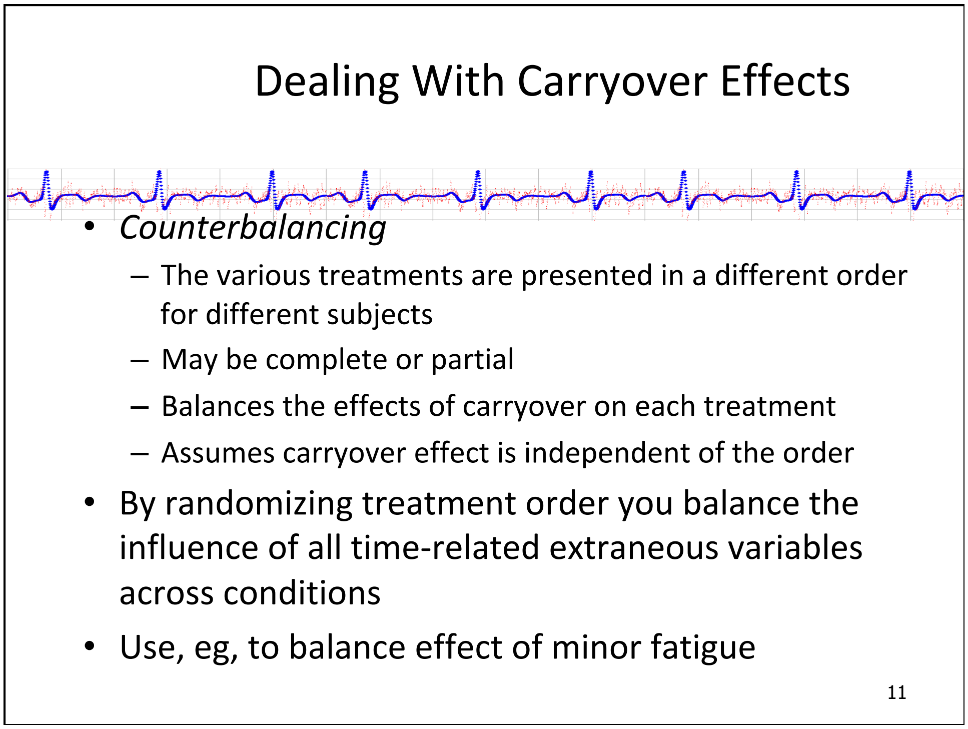
Carryover Example

- Embodied Conversational Agents to Promote Health Literacy for Older Adults


Brochure
Computer
T0
T1
T2
Diabetes Knowledge Assessment
Diabetes Knowledge Assessment
Diabetes Knowledge Assessment

Sources of Carryover

- *Learning*
  - Learning a task in the first treatment may affect performance in the second
- *Fatigue*
  - Fatigue from earlier treatments may affect performance in later treatments
- *Habituation*
  - Repeated exposure to a stimulus may lead to unresponsiveness to that stimulus
- *Sensitization*
  - Exposure to a stimulus may make a subject respond more strongly to another
- *Contrast*
  - Subjects may compare treatments, which may affect behavior
- *Adaptation*
  - If a subject undergoes adaptation (e.g., dark adaptation), then earlier results may differ from later ones



Dealing With Carryover Effects

- *Counterbalancing*
  - The various treatments are presented in a different order for different subjects
  - May be complete or partial
  - Balances the effects of carryover on each treatment
  - Assumes carryover effect is independent of the order
- By randomizing treatment order you balance the influence of all time-related extraneous variables across conditions
- Use, eg, to balance effect of minor fatigue

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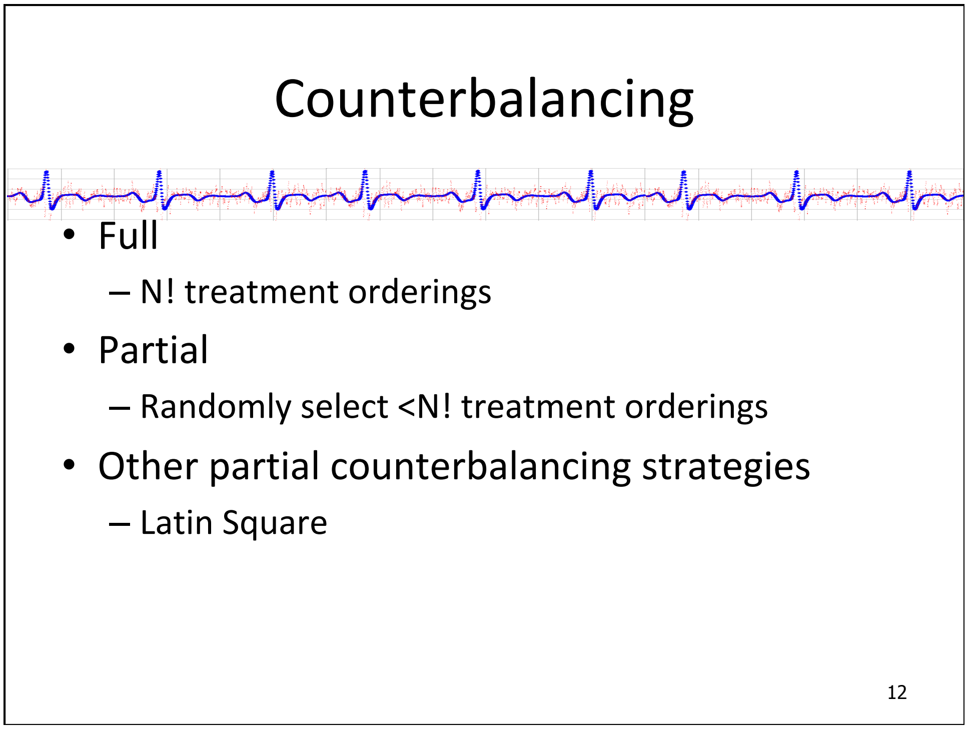

Counterbalancing

- Full
  - N! treatment orderings
- Partial
  - Randomly select <N! treatment orderings
- Other partial counterbalancing strategies
  - Latin Square

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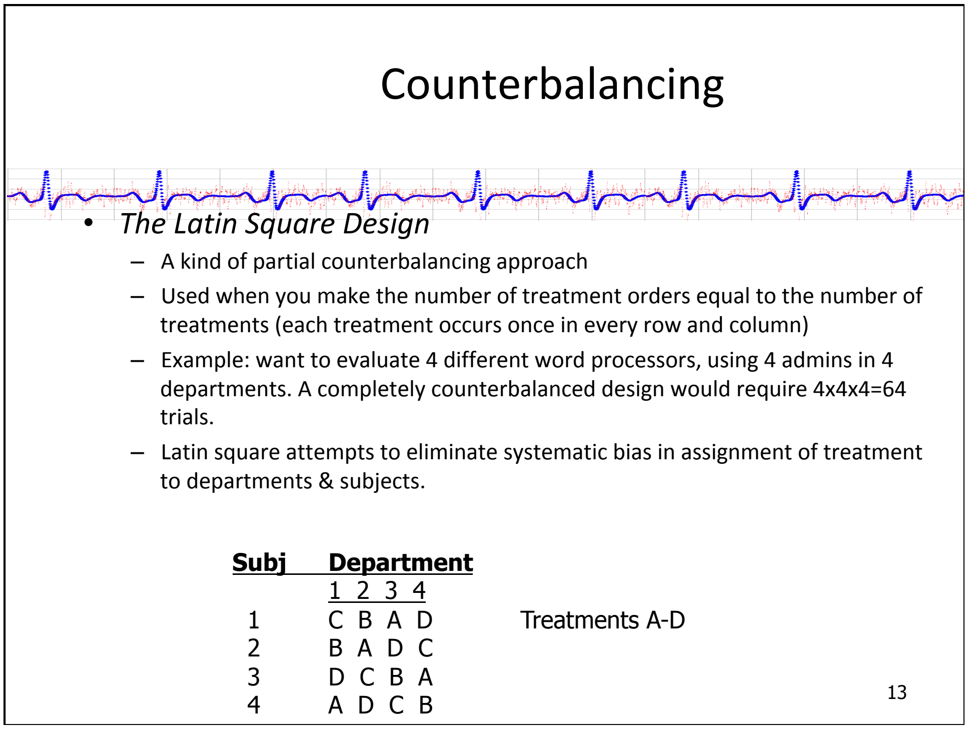
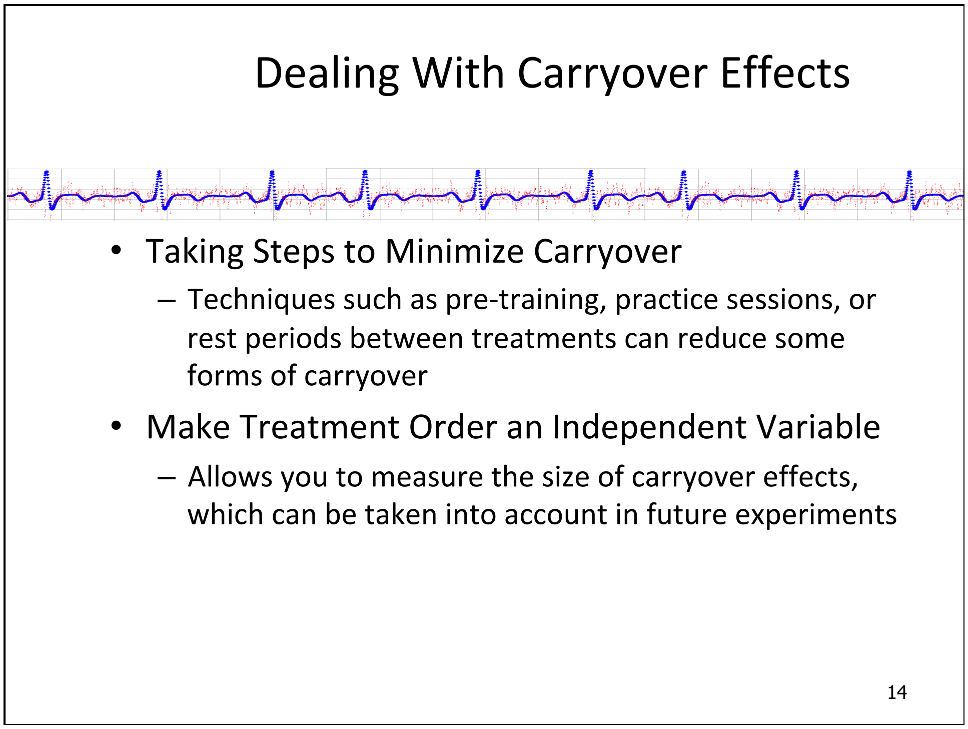


Counterbalancing

- *The Latin Square Design*
  - A kind of partial counterbalancing approach
  - Used when you make the number of treatment orders equal to the number of treatments (each treatment occurs once in every row and column)
  - Example: want to evaluate 4 different word processors, using 4 admins in 4 departments. A completely counterbalanced design would require 4x4x4=64 trials.
  - Latin square attempts to eliminate systematic bias in assignment of treatment to departments & subjects.

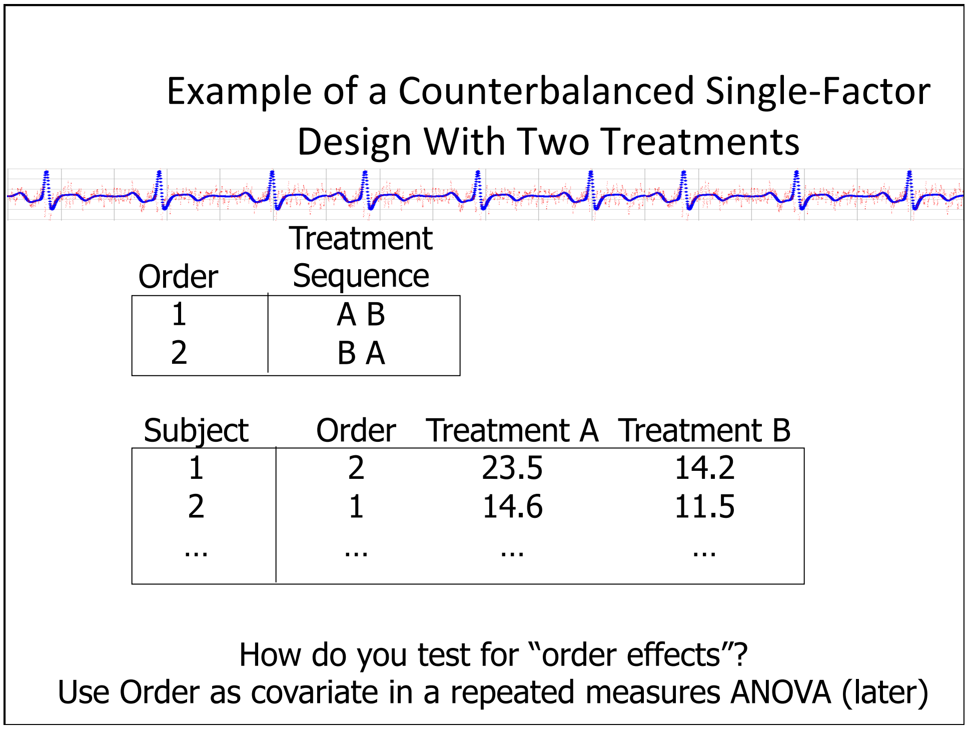
Subj	**Department**			
	1	2	3	4
1	C	B	A	D
2	B	A	D	C
3	D	C	B	A
4	A	D	C	B

Treatments A-D



Dealing With Carryover Effects

- Taking Steps to Minimize Carryover
  - Techniques such as pre-training, practice sessions, or rest periods between treatments can reduce some forms of carryover
- Make Treatment Order an Independent Variable
  - Allows you to measure the size of carryover effects, which can be taken into account in future experiments

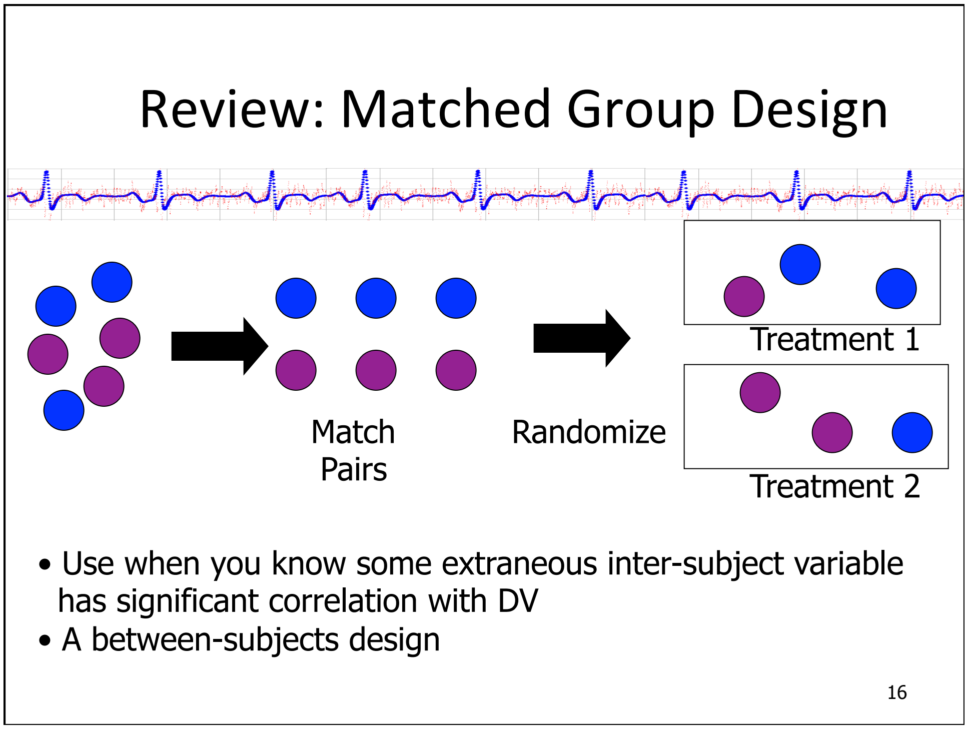


Example of a Counterbalanced Single-Factor Design With Two Treatments

Order	Treatment Sequence
1	A B
2	B A

Subject	Order	Treatment A	Treatment B
1	2	23.5	14.2
2	1	14.6	11.5
…	…	…	…

How do you test for "order effects"?
Use Order as covariate in a repeated measures ANOVA (later)



Review: Matched Group Design

- Use when you know some extraneous inter-subject variable has significant correlation with DV
- A between-subjects design

Design Criteria

- Between-subjects
  - Default
  - No carryover issues, but may require many subjects
- Within-subjects
  - More power, fewer subjects
  - Sensitive to carryover effects, requires more subject time
  - Allows direct comparison of treatments by subjects
- Matched-pairs
  - Suspect extraneous inter-subject variable highly correlated with DV
  - and, anticipate large carryover effect or other constraint (else within-S)
- Other issues (e.g., recruiting) may be determining factor

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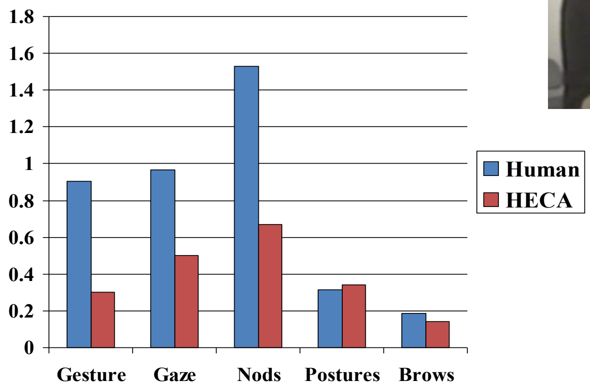
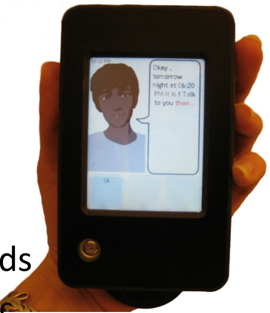
Example Study: Handheld ECAs



Modality Study

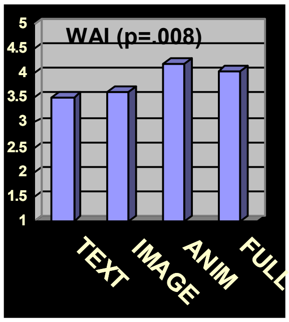
- Compared 4 modalities:
  - Text only
  - Text + Static agent image
  - Animated agent
  - Animated agent + nonverbal sounds
    - Backchannels, Discourse markers, etc.
- DVs: WAI, Credibility, Comfort

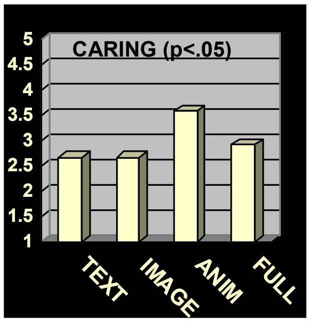


Modality Study

- 4 treatments
- How to design?
- 4 characters
- 4 topics
- Counterbalance treatment order AND randomize pairing of character/topic/treatment

Modality Study



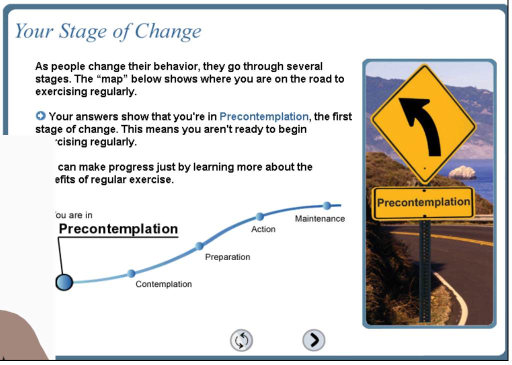


- Animated agent also scored higher (approaching significance) on *credibility of health information* and *comfort using in the workplace.*

RAISE: Web-based Intervention with and without Agent

- Compare: 1) existing web-based intervention to 2) intervention + agent to 3) control (N=1,200).
- 1 year intervention + 1 year followup

- 0.142 vs. 0.048 contacts / week.

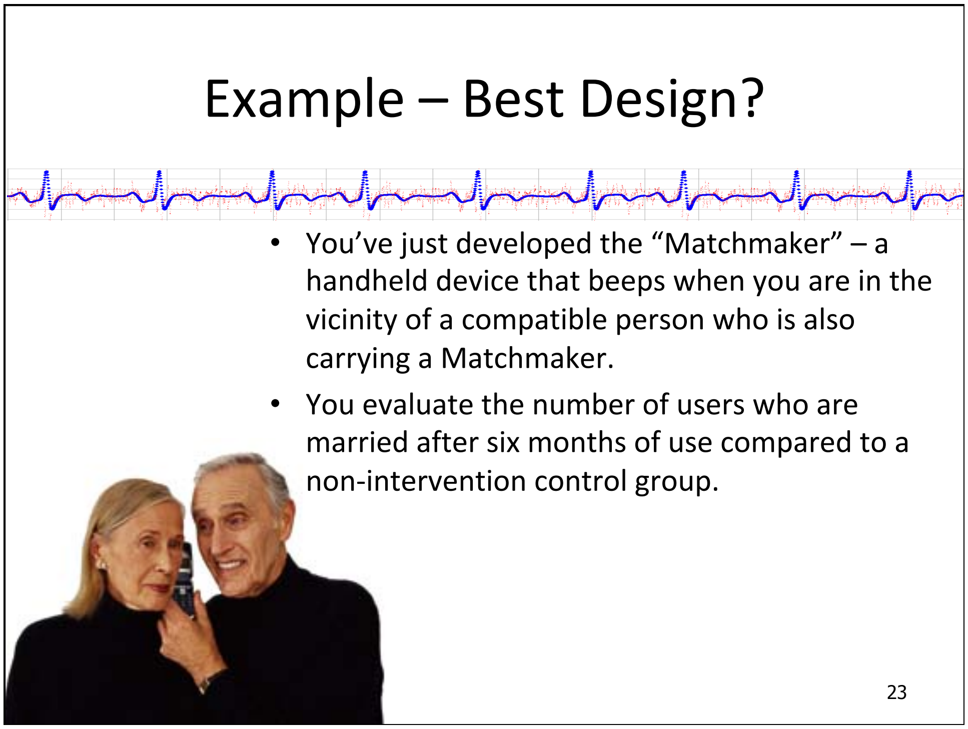


Your Stage of Change

As people change their behavior, they go through several stages. The "map" below shows where you are on the road to exercising regularly.

Your answers show that you're in Precontemplation, the first stage of change. This means you aren't ready to begin ·rcising regularly.

can make progress just by learning more about the efits of regular exercise.



Example – Best Design?

- You’ve just developed the “Matchmaker” – a handheld device that beeps when you are in the vicinity of a compatible person who is also carrying a Matchmaker.
- You evaluate the number of users who are married after six months of use compared to a non-intervention control group.

Example – Best Design?

- You’ve just developed “Reado Speedo” tha reads print books using OCR and speaks them to you at twice your normal reading rate. You want to evaluate your product against the old fashioned way on reading rate, comprehension and satisfaction.

Example – Best Design?

- You've developed a new web-based help system for your email client. You want to compare your system to the old printed manual.

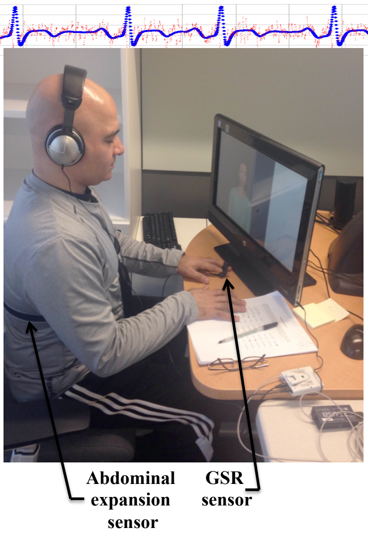
Example – Best Design?

- You are evaluating a new customer support ticketing system and want to handle some customer calls with the new system to compare it to the old one.

Example – Best Design?

- Want to evaluate skype instead of face-to-face for sales calls among your international B2B salesforce
- 10x productivity difference among salespeople
- A salesperson makes 1-2 sales calls per month

Example: Best design?



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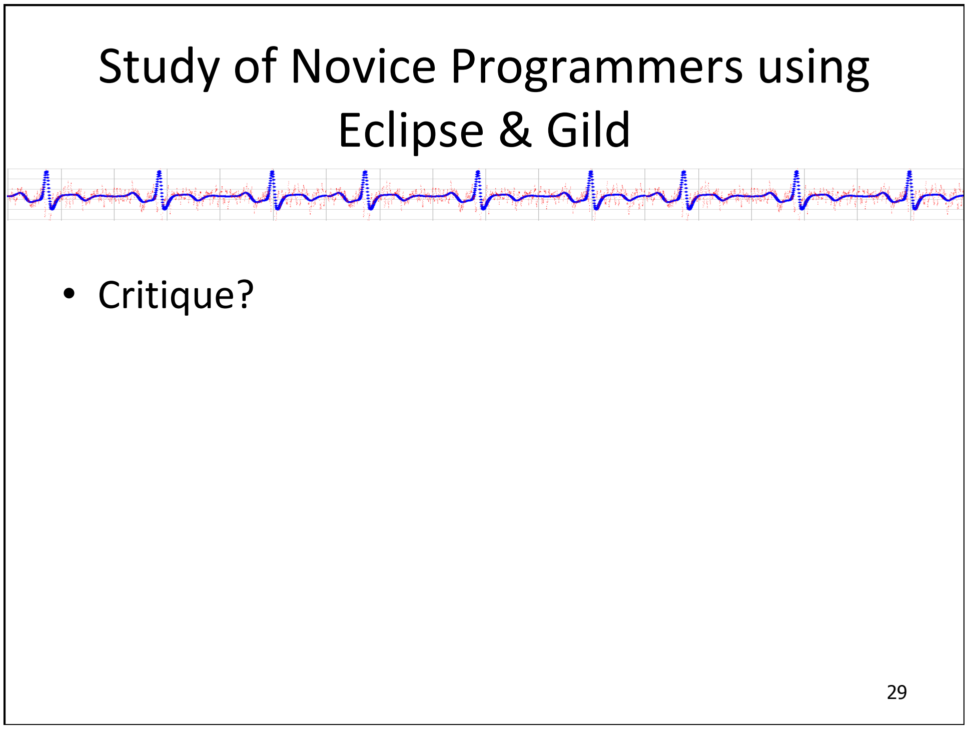
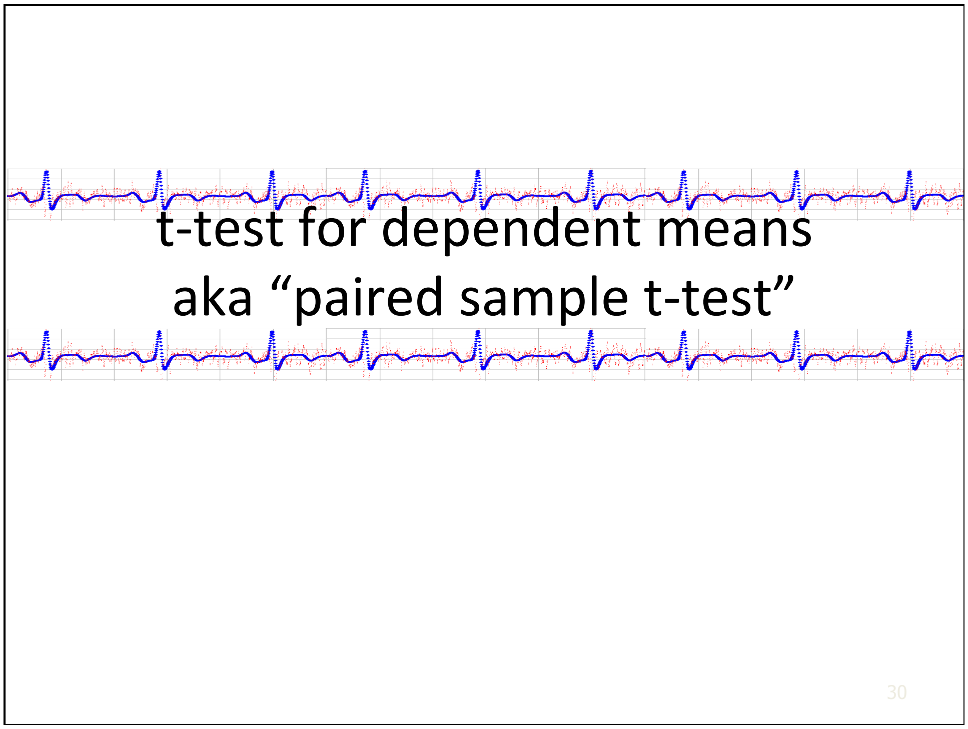
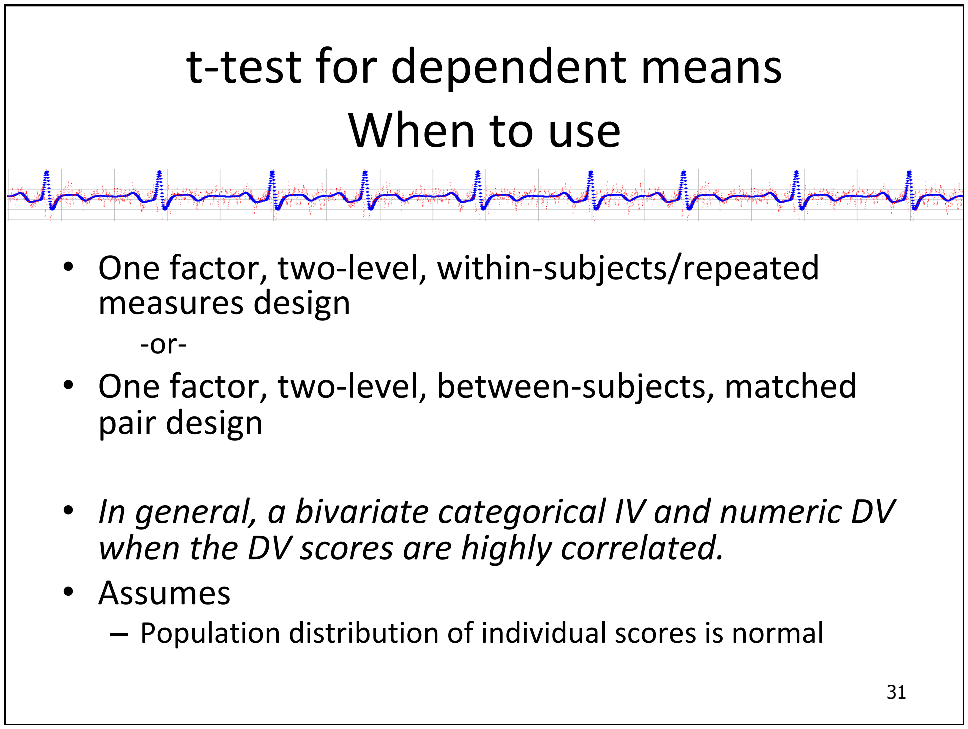


Study of Novice Programmers using Eclipse & Gild

- Critique?



t-test for dependent means aka “paired sample t-test”



t-test for dependent means
When to use

- One factor, two-level, within-subjects/repeated measures design

  -or-

- One factor, two-level, between-subjects, matched pair design

- *In general, a bivariate categorical IV and numeric DV when the DV scores are highly correlated.*
- Assumes
  - Population distribution of individual scores is normal

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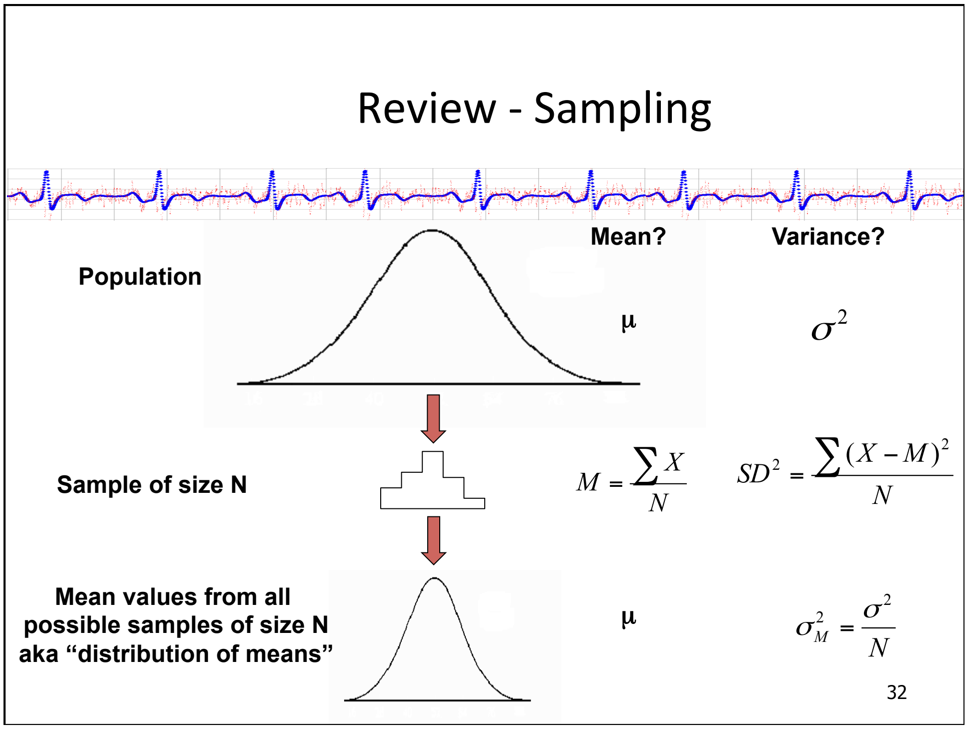

Review - Sampling

	Mean?	Variance?
Population	μ	σ^2
Sample of size N	$M = \frac{\sum X}{N}$	$SD^2 = \frac{\sum (X-M)^2}{N}$
Mean values from all possible samples of size N aka "distribution of means"	μ	$\sigma_M^2 = \frac{\sigma^2}{N}$

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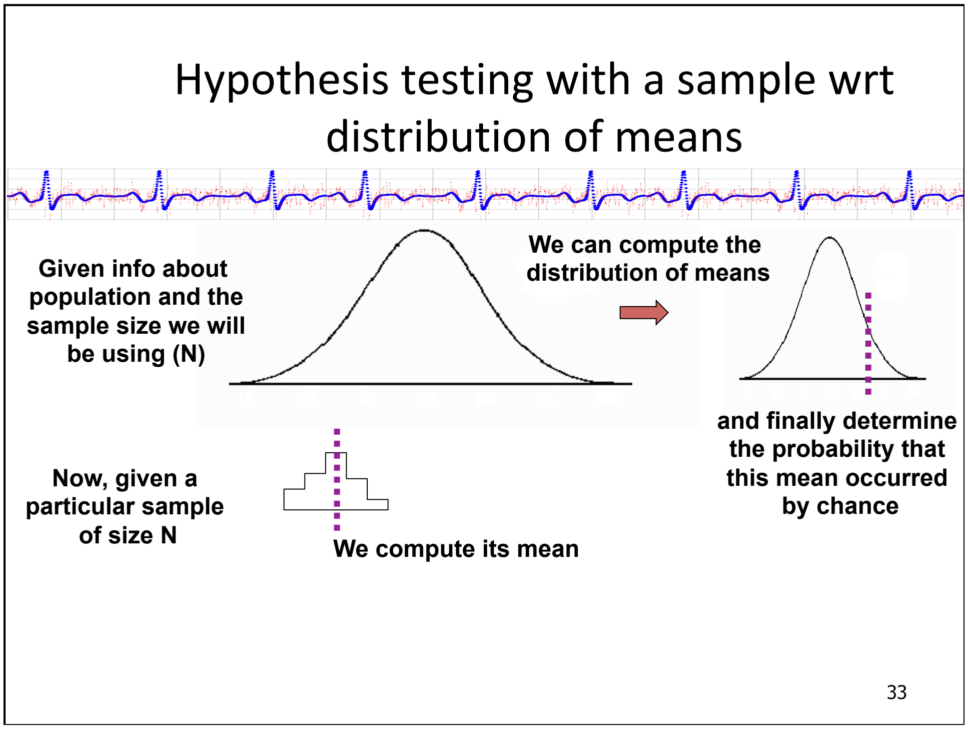


Hypothesis testing with a sample wrt distribution of means

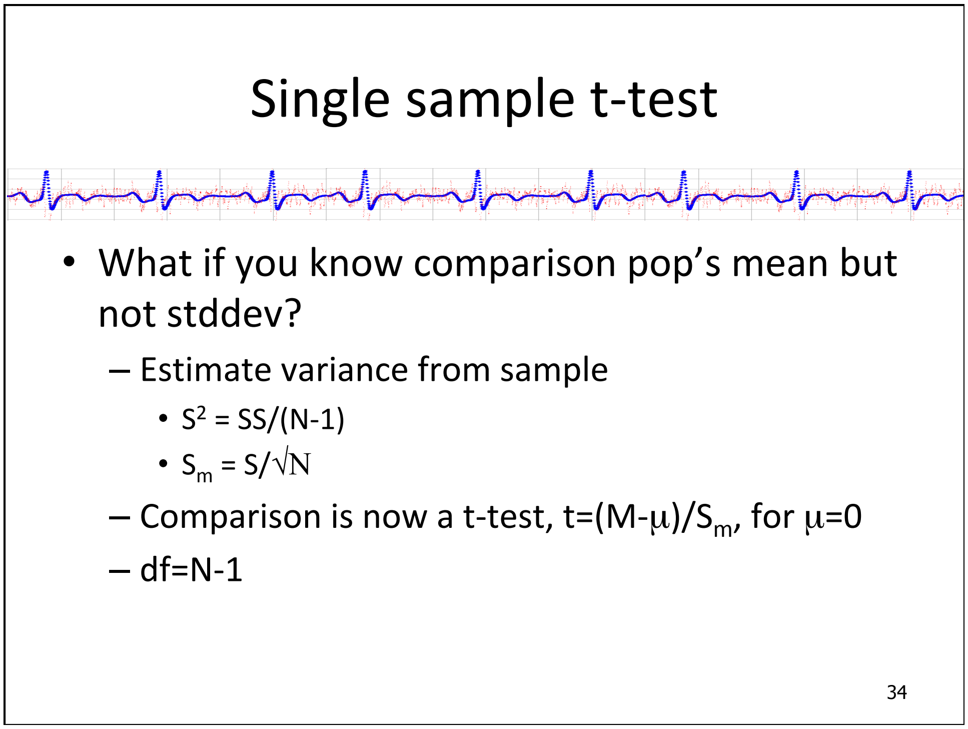
Given info about population and the sample size we will be using (N)

We can compute the distribution of means

and finally determine the probability that this mean occurred by chance

Now, given a particular sample of size N

We compute its mean



Single sample t-test

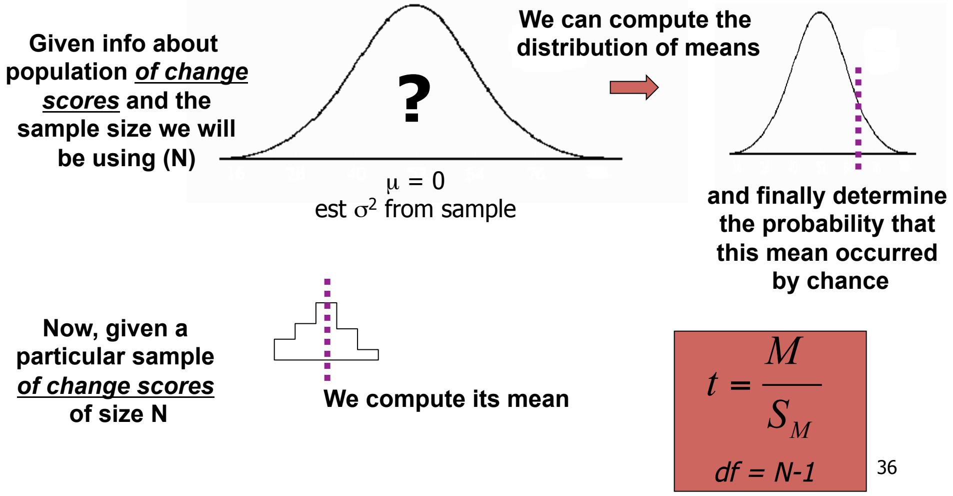
- What if you know comparison pop's mean but not stddev?
  - Estimate variance from sample
    - $S^2 = SS/(N-1)$
    - $S_m = S/\sqrt{N}$
  - Comparison is now a t-test, $t=(M-\mu)/S_m$, for $\mu=0$
  - df=N-1

Wanted: a statistic for differences between paired measures

- In a repeated-measures or matched-pair design, you directly compare one subject with him/herself or another specific subject (not groups to groups).
- So, start with a sample of change (difference) scores:

Sample 1 = Mary's wpm using Wizziword –
Mary's wpm using Word

Hypothesis testing with paired samples



Given info about population ***of change scores*** and the sample size we will be using (N)

$\mu = 0$
est σ^2 from sample

We can compute the distribution of means

and finally determine the probability that this mean occurred by chance

Now, given a particular sample ***of change scores*** of size N

We compute its mean

$$t = \frac{M}{S_M}$$

df = N-1

“t-test for dependent means” aka “paired sample t-test”

- Map two measures for each subject into one difference score for each
  - e.g. change due to intervention =

    after measure – before measure
- Null hypothesis (usually) no change
  - Thus mean of comparison dist is zero

Effect Size & Power

- d = M / S
  - M = mean of difference scores
  - S = std dev of population of individual’s difference scores
  - 0.2 = small; 0.5 = medium; 0.8 = large

N required for 80% power, two-tailed, α=.05:

	Effect Size	
Small (d=0.2)	**Medium (d=0.5)**	**Large (d=0.8)**
196	**33**	**14**

For Comparison

Power calcs for t-test for indep means

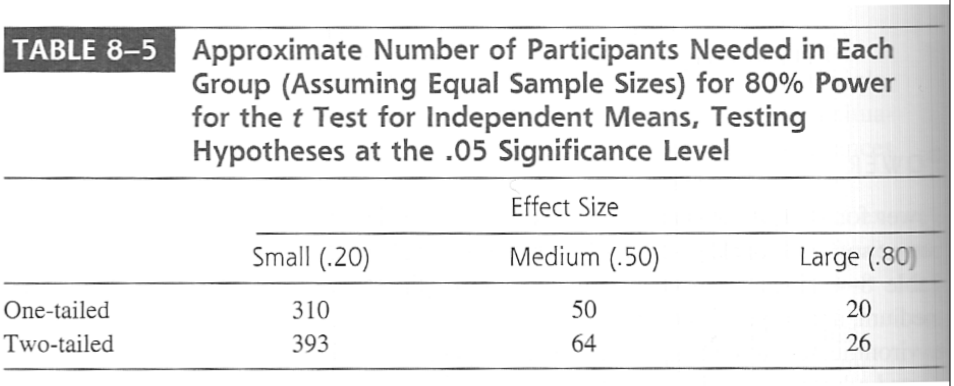
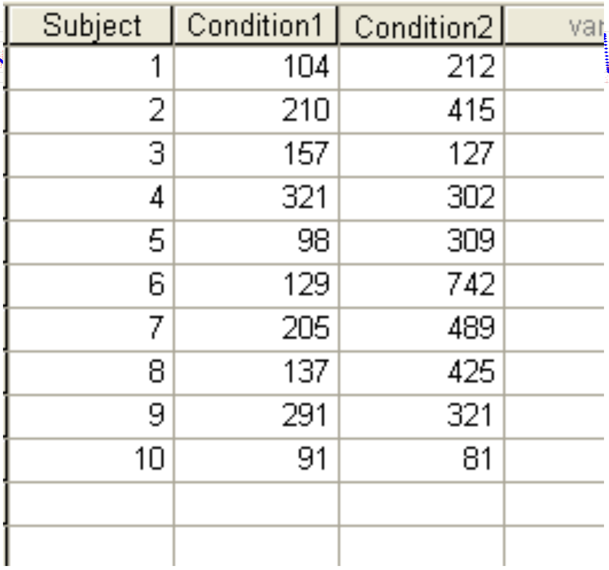


TABLE 8–5 Approximate Number of Participants Needed in Each Group (Assuming Equal Sample Sizes) for 80% Power for the *t* Test for Independent Means, Testing Hypotheses at the .05 Significance Level

	Effect Size		
	Small (.20)	Medium (.50)	Large (.80)
One-tailed	310	50	20
Two-tailed	393	64	26

R



Subject	Condition1	Condition2	var
1	104	212	
2	210	415	
3	157	127	
4	321	302	
5	98	309	
6	129	742	
7	205	489	
8	137	425	
9	291	321	
10	91	81	

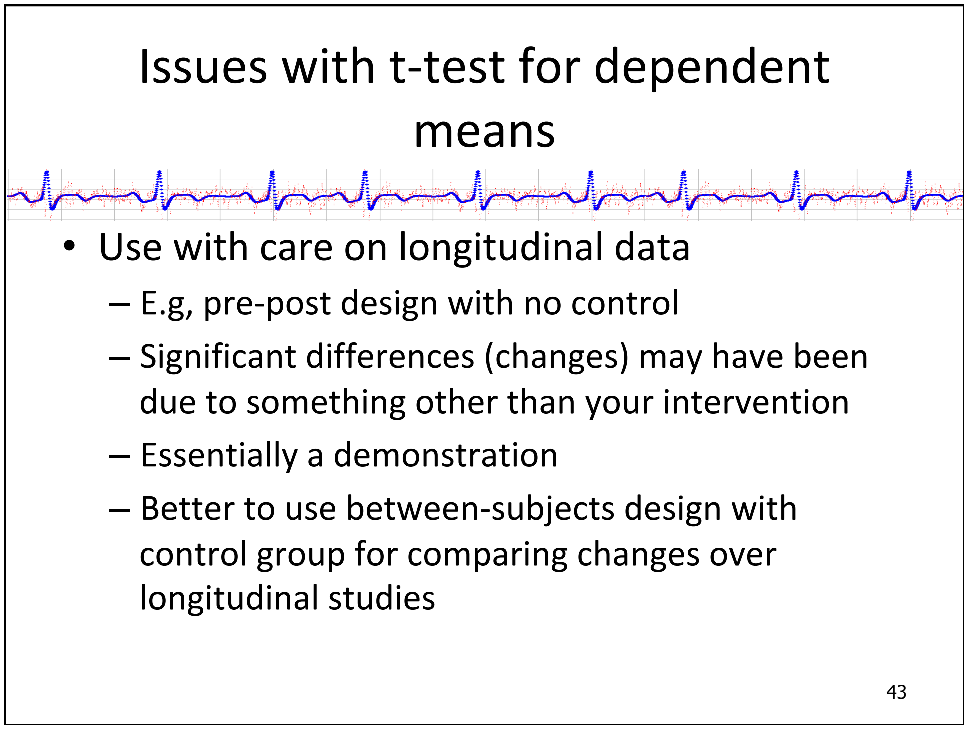
R

```
#two-sided by default
> t.test(d$Condition1, d$Condition2, paired=TRUE)


Paired t-test


data: d$Condition1 and d$Condition2
t = 4.1849, df = 16, p-value = 0.0003501
alternative hypothesis: true difference in means is greater than 0
…
```

paired t(16)=4.18, p<.05

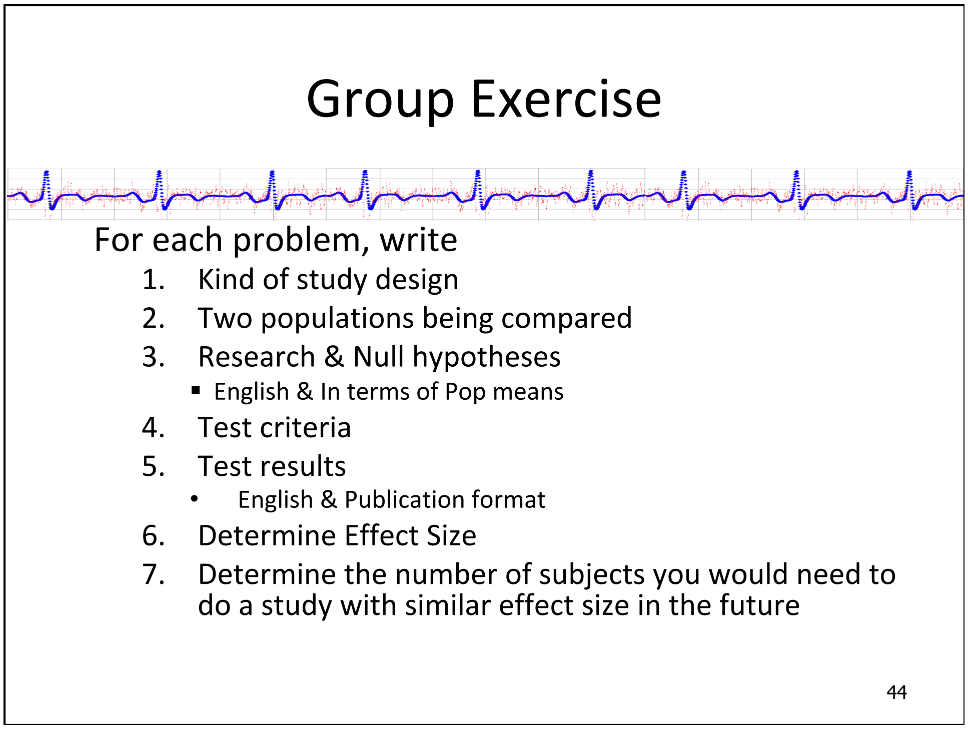
Effect Size

```
> diffs <- abs(d$Condition1 - d$Condition2)

#Effect size
> mean(diffs)/sd(diffs)
```



Issues with t-test for dependent means

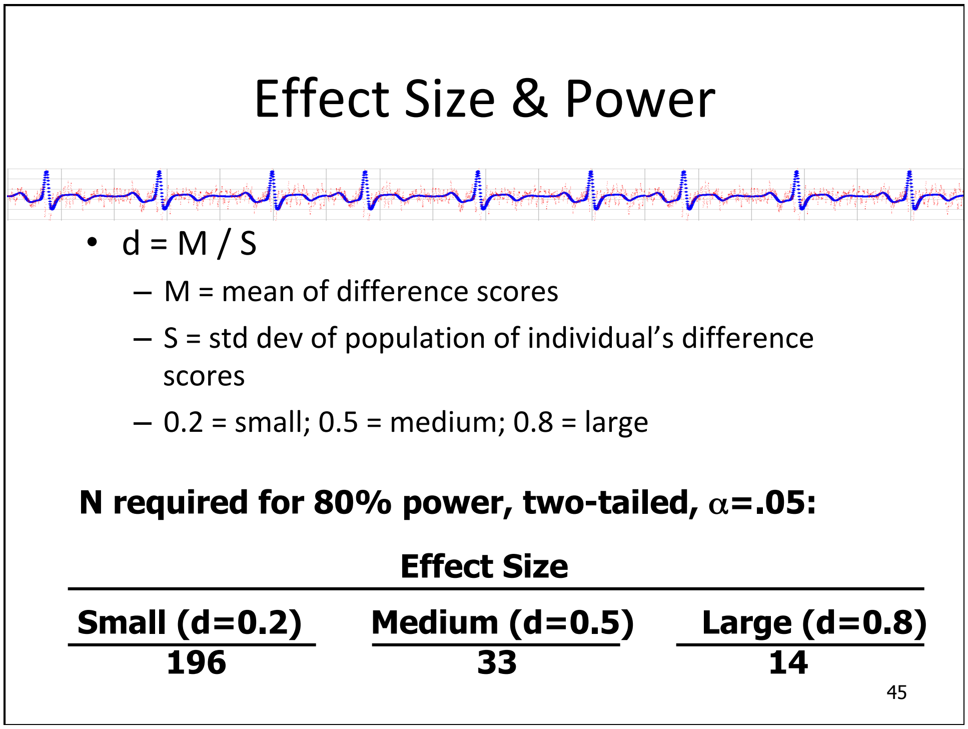
- Use with care on longitudinal data
  - E.g, pre-post design with no control
  - Significant differences (changes) may have been due to something other than your intervention
  - Essentially a demonstration
  - Better to use between-subjects design with control group for comparing changes over longitudinal studies



Group Exercise

For each problem, write

1. Kind of study design
2. Two populations being compared
3. Research & Null hypotheses
   - English & In terms of Pop means
4. Test criteria
5. Test results
   - English & Publication format
6. Determine Effect Size
7. Determine the number of subjects you would need to do a study with similar effect size in the future



Effect Size & Power

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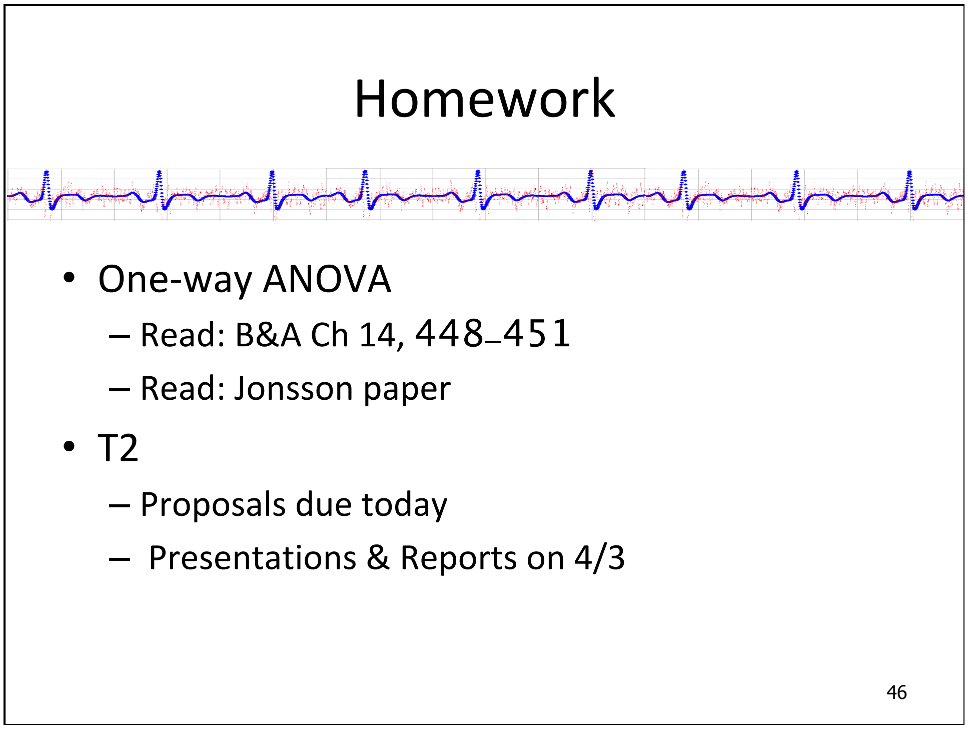

Homework

- One-way ANOVA
  - Read: B&A Ch 14, 448–451
  - Read: Jonsson paper
- T2
  - Proposals due today
  - Presentations & Reports on 4/3