Fall 2019

CS6501: Topics in Human-Computer Interaction

http://seongkookheo.com/cs6501_fall2019

Lecture 5: Quantitative Evaluation 1

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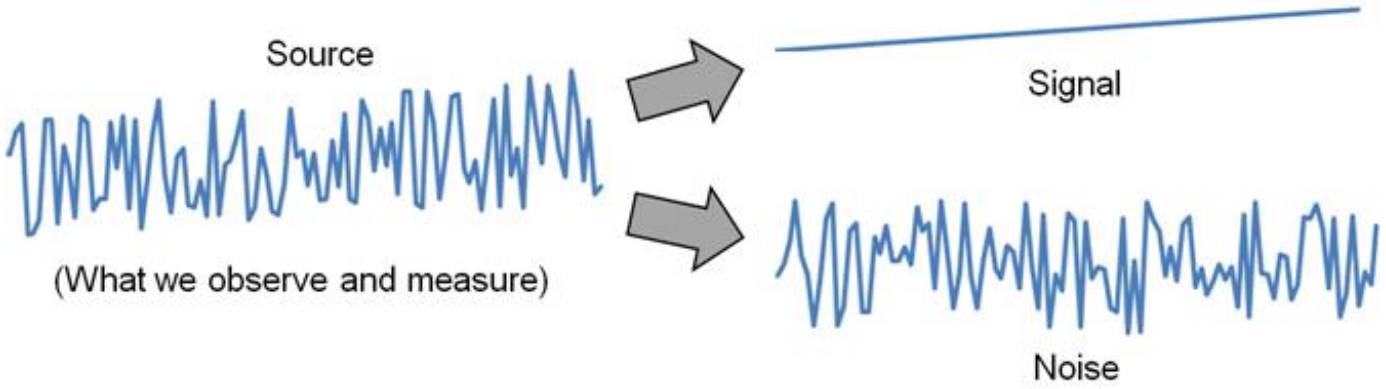
Research Methods

- Observational Method
  - Observe humans interacting with computers in a natural setting.
  - Using interviews, field investigations, case studies, focus groups, etc.
  - Tends to be qualitative.
  - High relevance, but sacrifices precision.
- **Experimental Method**
  - Acquire knowledge through controlled lab experiments.
  - Tests if changes to a manipulated variable result in changes to a response variable.
  - High precision, low relevance.

Signal and Noise Metaphor

- Signal and noise metaphor for experiment design:



- Signal → a variable of interest,
  e.g., task completion time, error rate, learning rate, fatigue, etc.

- Noise → everything else (random influences)

Experimental, Quantitative Evaluation

- What task to evaluate?
  - Depends on application
  - Attempt to find canonical task(s)

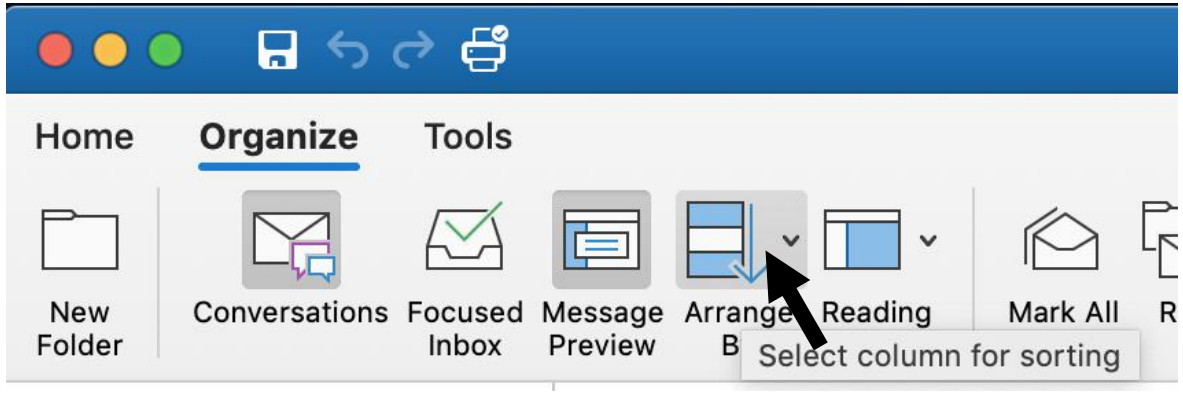
- Common measures
  - Task completion time
  - Error rate
  - Learning rate (novice -> expert transition)
  - Fatigue, comfort?
  - etc.

Example: Pointing Device Evaluation

- Which device is better?

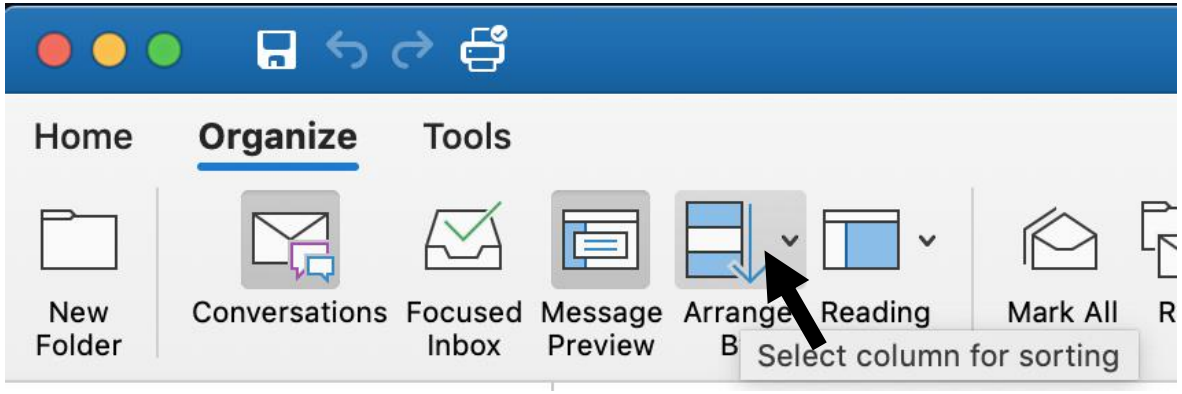
Example: Pointing Device Evaluation

- Real task: interacting with GUI's
  - Pointing is fundamental

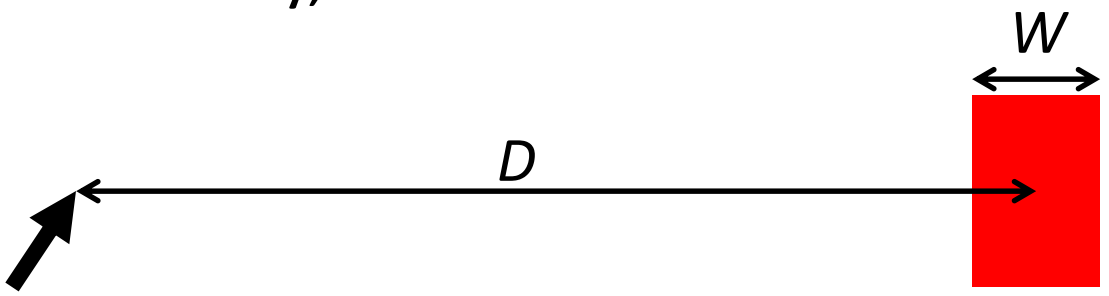


Example: Pointing Device Evaluation

- Real task: interacting with GUI's
  - Pointing is fundamental



- Experimental task: target acquisition
  - Abstract, elementary, essential



What Variables to Manipulate/Measure?

- Independent variables
  - Factors that are manipulated in the experiment
- Dependent variables
  - Factors which are measured
- Chosen based on task
  - Seek external validity

Independent Variables

- Factors that are manipulated in the experiment
  - e.g., W, D in pointing task
- Operational definitions
  - Specific definition of a conceptual variable
  - E.g. Level of experience -> Number of hours of system use
- Pick the most important for the task
- Choose appropriate ranges
  - Realistic range for task
  - A range that shows an effect and trend (but realistic)
  - E.g. Pointing experiment:
    - W ’s range from character size (10) to icons (40) pixels
    - D ’s from short (50) to large (screen size ~800 pixels)

How Many IVs?

- An experiment must have at least one independent variable
- Possible to have 2, 3, or more IVs
- But the number of “effects” increases rapidly with the size of the experiment:

Independent Variables	Effects					Total
	Main	2-way	3-way	4-way	5-way	
1	1	-	-	-	-	1
2	2	1	-	-	-	3
3	3	3	1	-	-	7
4	4	6	3	1	-	14
5	5	10	6	3	1	25

- Advice: Keep it simple (1 or 2 IVs, 3 at the most)

Dependent Variables

- Factors which are measured
  - E.g., Trial completion time, error rate, in a pointing task
  - May depend on independent variables
- May require operational definitions
  - E.g. Time between the first and last click

Dependent Variables

- Single dependent variable
  - Usually hard to find one variable that is indicative of task
- Multiple dependent variables
  - Total time, reaction time, physical movement, eye movement, accuracy, etc.
  - There is often a speed-accuracy tradeoff
- Composite dependent variables
  - Indication of overall performance

Dependent Variables

- Unique dependent variables are also possible:
  any observable, measurable behavior is a legitimate DV

- E.g. Negative facial expressions[1]
  - Application: user difficulty with mobile games
  - Events logged included frowns, head shaking

[1] Duh, H. B.-L., Chen, V. H. H., & Tan, C. B. (2008). Playing different games on different phones: An empirical study on mobile gaming. *Proceedings of MobileHCI 2008*, 391-394, New York: ACM.

Data Collection

- Obviously, the data for dependent variables must be collected in some manner
- Ideally, engage the experiment software to log timestamps, key presses, button clicks, etc.
- Planning and pilot testing important
- Ensure conditions are identified, either in the filenames or in the data columns

Data Collection

```
min_keystrokes,keystrokes,presented_characters,transcribed_characters, ...
55, 59, 23, 23, 29.45, 0, 9.37, 0.0, 2.565217391304347 7, 93.22033898305085
61, 65, 26, 26, 30.28, 0, 10.3, 0.0, 2.5, 93.84615384615384
85, 85, 33, 33, 48.59, 0, 8.15, 0.0, 2.5757575757575757, 100.0
67, 71, 28, 28, 33.92, 0, 9.91, 0.0, 2.5357142857142856, 94.36619718309859
61, 70, 24, 24, 39.44, 0, 7.3, 0.0, 2.9166666666666665, 87.14285714285714
```

Other Variables

- Control variable
  - Variables with constant value
    - e.g. Screen background color in pointing task
- Random variable
  - Variable which takes on a random value
    - e.g. Location of target in a pointing task
  - Usually randomized with constraints
    - e.g. Each location appears same number of times

Participants

- Researchers want experimental results to apply to people not actually tested – a population
- Population examples:
  - Computer-literate adults, teenagers, children, people with certain disabilities, left-handed people, engineers, musicians, etc.
- For results to apply generally to a population, the participants used in the experiment must be
  - Members of the desired population
  - Selected at random from the population

How Many Participants?

- Too few → experimental effects fail to achieve statistical significance
- Too many → statistical significance for effects of no practical value
- The correct number:
  - Use the same number of participants as used in similar research[1]

[1] Martin, D. W. (2004). *Doing psychology experiments* (6th ed.). Pacific Grove, CA. Belmont, CA: Wadsworth.

Within vs. Between Subjects Design

Within-subjects design:

- All subjects do all conditions
- Fewer participants needed
- Prone to learning transfer effects


Condition 1	Condition 2
Subject 1	Subject 1
Subject 2	Subject 2
.	.
Subject 10	Subject 10

Between-subjects design:

- Subjects only do one condition
- More participants needed
- No learning transfer effects
- Can train to high skill


Condition 1	Condition 2
Subject 1	Subject 11
Subject 2	Subject 12
.	.
Subject 10	Subject 20

Order Effects, Counterbalancing

- Only relevant for within-subjects factors
- The issue: *order effects* (aka *learning effects*, *practice effects*, *fatigue effects*, *sequence effects*)
- Order effects offset by *counterbalancing*:
  - Participants divided into groups
  - Test conditions are administered in a different order to each group
  - Order of administering test conditions uses a Latin square
  - Distinguishing property of a Latin square → each condition occurs precisely once in each row and column (next slide)

Counterbalancing

- Fully counterbalanced:
  - Combinatorial explosion when n>4
  - Needs lots of subjects

```
A B
B A
```

```
A B C
A C B
B A C
B C A
C A B
C B A
```

```
A B C D
A B D C
A C B D
A C D B
…
…
…
…
```

Counterbalancing

- Partial counterbalancing. e.g., Latin square:
  - Ensures each level appears in every position in order equally often:

A B C D
B C D A
C D A B
D A B C

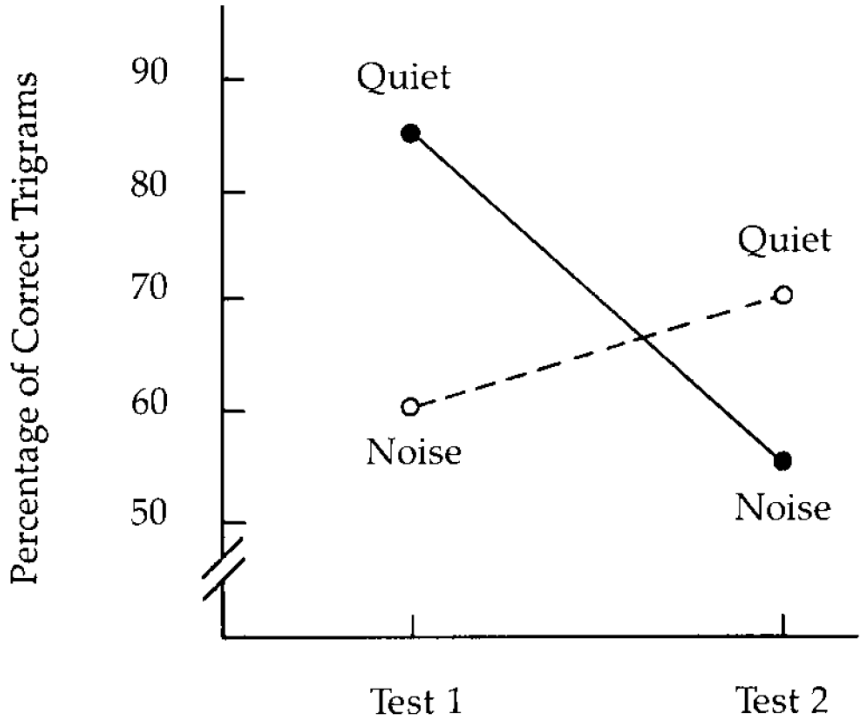
Counterbalancing

- Balanced Latin Square:
  - Each condition precedes and follows each of the other equally often:

A B C D
B D A C
D C B A
C A D B

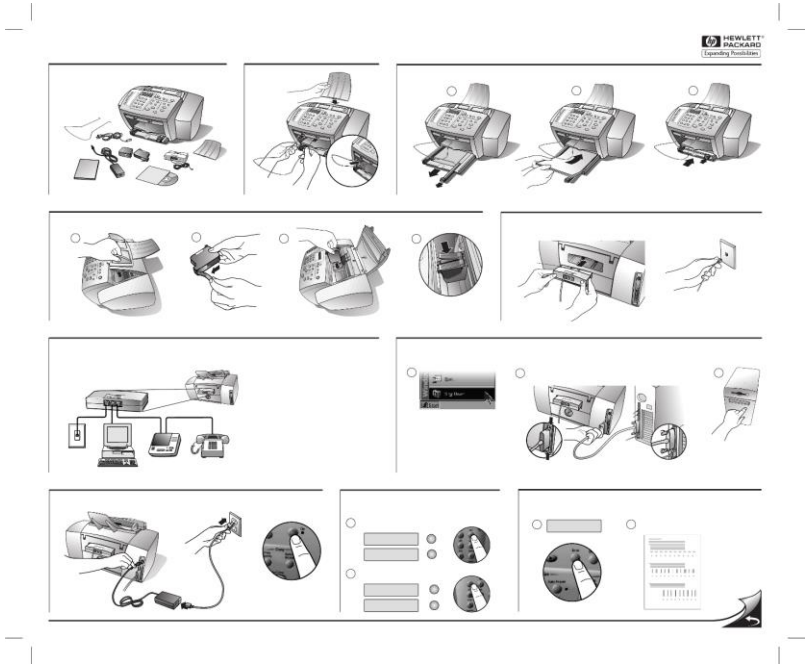
Experimental Design

- Problems with counter balancing
  - Assumes symmetric transfer effects



Experimental Design

- Problems with counter balancing
  - Assumes symmetric transfer effects
  - Initial conditions may invalidate subsequent tasks
    - E.g. Learning to do a task as a novice



Experimental Design

- Problems with counter balancing
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  - Range Effects: People may perform best in middle of range of values

Experimental Design

- Problems with counter balancing
  - Assumes symmetric transfer effects
  - Initial conditions may invalidate subsequent tasks
  - Range Effects: People may perform best in middle of range of values
- In these cases, no counterbalancing will help
  - Must use between-subject design

Summary

Within-Subjects Design

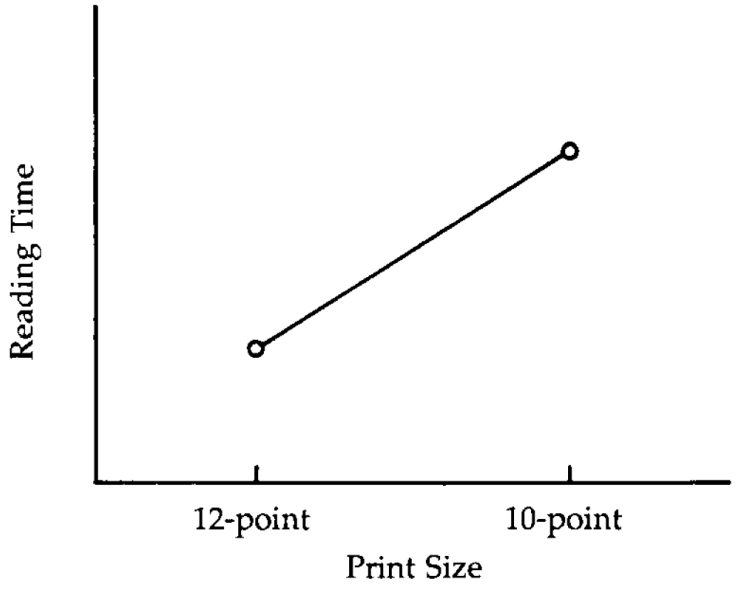
- Pros:
  - Fewer subjects
  - Smaller variability between groups
- Cons:
  - Transfer effects
  - Assumes symmetrical transfer

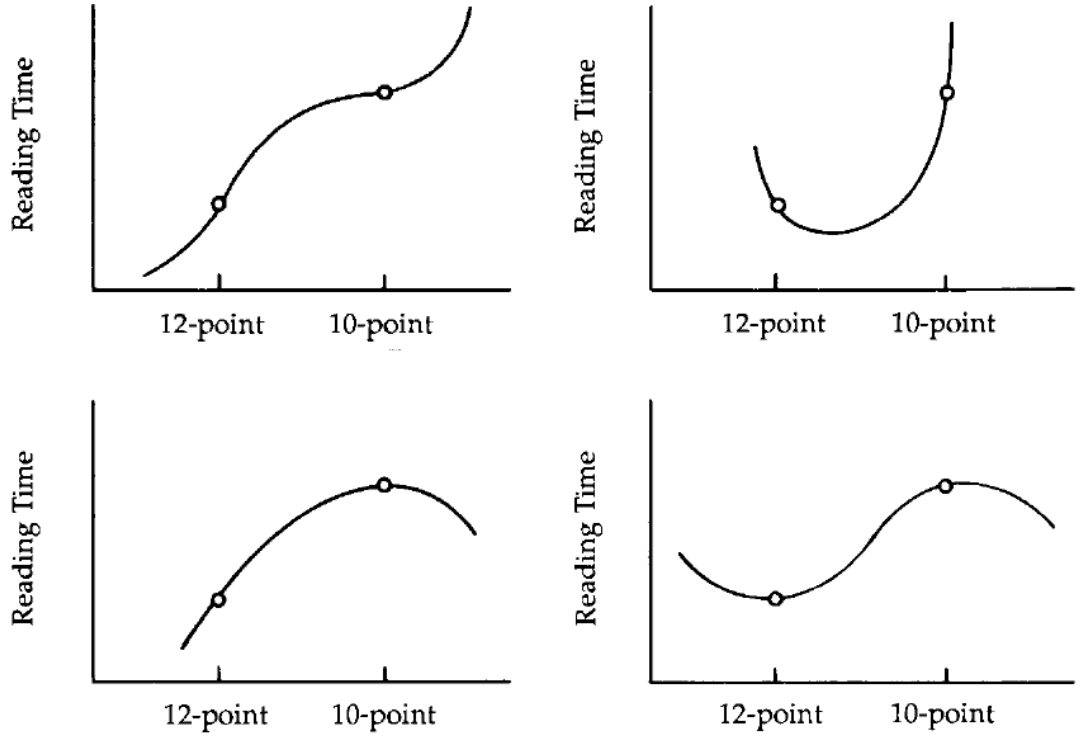
Between-Subjects Design

- Pros:
  - No transfer effects
  - No counterbalancing
- Cons:
  - Group differences
  - More subjects

Multiple Variables

- Two level experiment
  - One variable with two possible values





Multiple Variables

- Two level experiment
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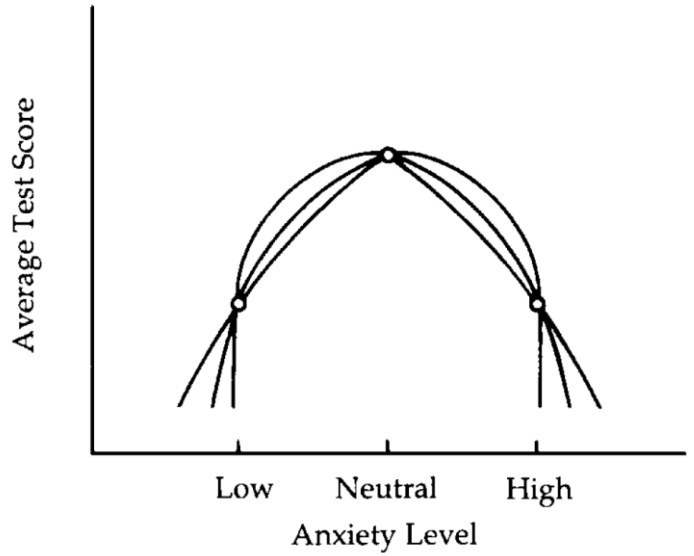
- Multiple level experiment
  - One variable with three or more possible values



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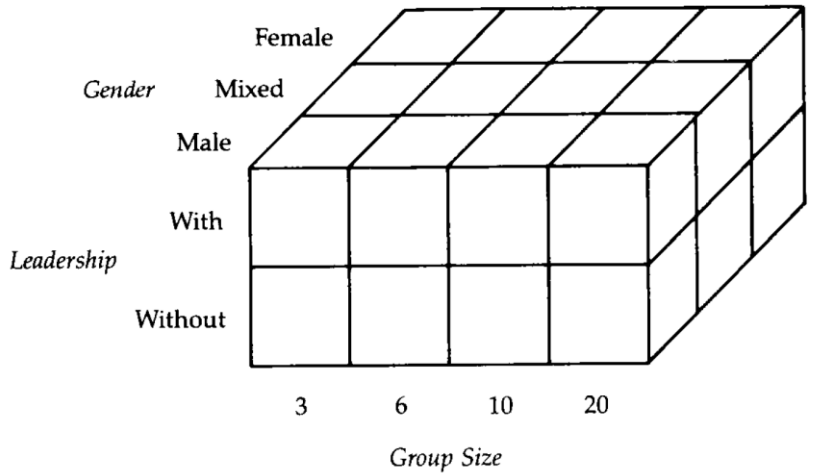
- Factorial design
  - Multiple variables, multiple levels



Multiple Variables

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  - One variable with two possible values
- Multiple level experiment
  - One variable with three or more possible values
- Factorial design
  - Multiple variables, multiple levels
- Converging-Series design
  - Progressively close in on a solution

Factorial Design

- Multiple variables, multiple levels
- 2 x 4 = 8 cells/conditions
- 3 x 4 x 5 = 60 cells/conditions
- Advantages
  - Can analyze interactions
- Disadvantage
  - Experiment size can explode

Converging-Series Design

- Conduct a series of pilot experiments
- Determine set of independent variables
- Determine range of independent variables
- Must be careful of interactions

Other Definitions

- Block
  - A significant section of the experiment
  - Repeated to analyze learning
- Trial
  - An individual measurement for a single condition/cell
- Repetition
  - A trial which is repeated within a block
  - Increase number of data points, reliability
- Determining number of blocks/repetitions
  - Reasonable experiment duration
  - Enough data points for significant effects

Joon-Gi Shin, Eiji Onchi, Maria Jose Reyes, Junbong Song, Uichin Lee, Seung-Hee Lee, and Daniel Saakes. Slow Robots for Unobtrusive Posture Correction. CHI '19

Design Project Team Up

- Team of 3 (or 4)
- Team up based on the interest on which usability problem to solve
- Most liked problems + problems you want to solve

TODO items for you

- No read reading response for week 4
- Put your team name and members on Slack
- Project proposal on Sep 24

Acknowledgements

- Some of the materials are based on materials by
  - Tovi Grossman, Univ. of Toronto
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  - Scott MacKenzie, Human-Computer Interaction: An Empirical Research Perspective

Thank you!