Experimental Process

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Introduction

- Starting-Points for experimentation
  - An idea of a cause-effect relationship
  - A theory, or
  - Able to formulate a hypothesis
- Advantages of Experimentation
  - Control of subjects, objects, and instrumentation -> generalization of conclusions
  - Ability to perform statistical analysis
  - Opportunities for replication

Main Objectives

- **Main objective of experimentation**
  - to evaluate a hypothesis -> hypothesis testing
  - to evaluate a relationship -> relational model building (i.e., regression)
- **Main objective of an experimental process**
  - Provide support in setting up and conducting an experiment

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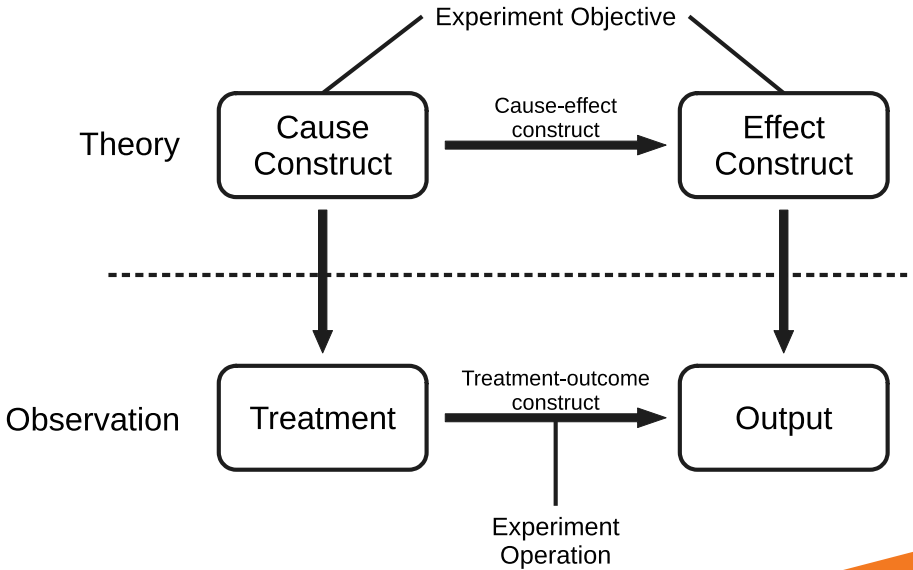
Experimental Principles



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Experimental Design

There are four components to any experimental design:

- Variables
- Treatments
- Objects
- Subjects

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Variables

- In an experiment we study the outcome of the varying of input variables to a process
- There are two kinds of variables in an experiment
  - **Dependent Variables (response variables)** - Those variables we wish to study (often there is only one)
  - **Independent Variables (exploratory variables)** - The variables in a process that are manipulated and controlled

Features and Treatments

- The independent variables which are varied during an experiment are called factors
- The remaining variables are controlled at a **fixed level**, thus allowing us to evaluate cause and effect
- A treatment is one particular value of a factor

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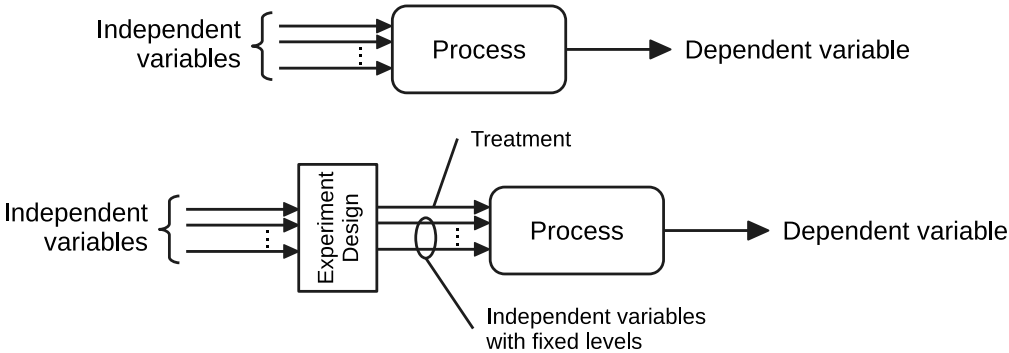
Treatments and Variables



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Objects and Subjects

- Treatments are applied to combinations of **objects** and **subjects**
  - **Object:** An artifact to which a treatment (technique, took, process, etc.) is applied
  - **Subject:** The people that apply the treatment
- The characteristics of both objects and subjects may be encoded as independent variables

Experimental Error

- Experiments consist of **tests** (or trials)
- Each test is a combination of **treatment**, **subject** and **object**
- The number of tests affects experimental error and provides a mean effect of any experimental error
- Experimental error affects the confidence in the results of the experiment

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Experimental Orientation

Human-Oriented Experiments

- Subjects: humans
- apply treatments to objects
- Limited control:
  - variability in skills and abilities
  - humans learn over time -> **learning bias**
  - influences and threats to experiments -> human's try to guess experimenter's motivation

Technology-Oriented Experiments

- Subject: The experimenter
- Easier to control -> technology may be made deterministic
- Independent variable may be the objects selected
- Tools or techniques may be program specific -> thus not applicable to all objects

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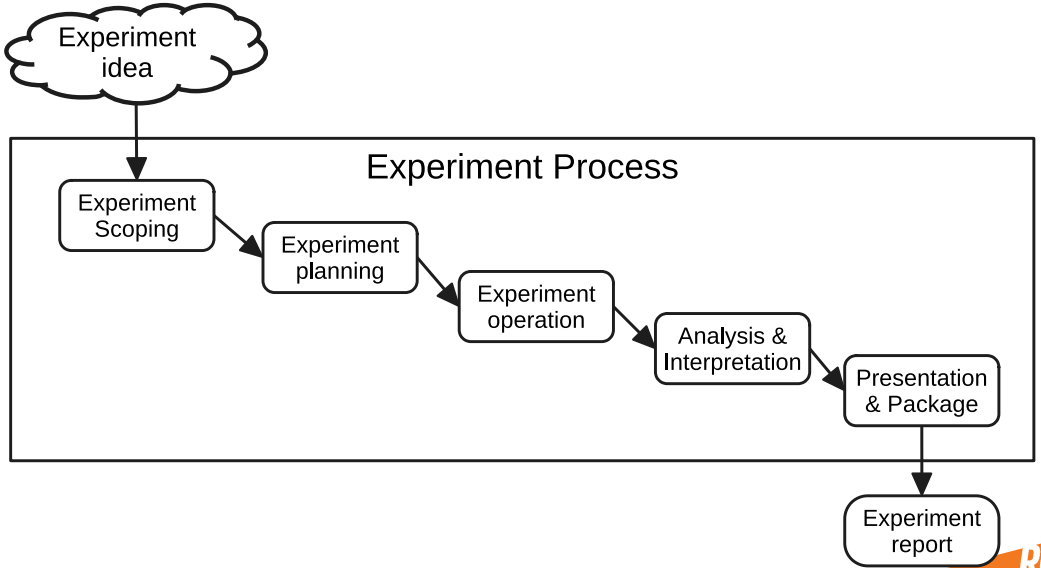
Process

- Processes provide guidelines/checklists of
  - what to do
  - how to do it
- The process of an experiment is similar to all other empirical studies.
- Yet, unlike case studies, rather than an incremental approach experiments execute the process just once.

Process


Experiment idea
Experiment Process
Experiment Scoping
Experiment planning
Experiment operation
Analysis & Interpretation
Presentation & Package
Experiment report

Process

- Starting Point: an insight or idea for an experiment as a means to evaluate what we are interested in
  - Experimentation must be an appropriate empirical method to address the question we are investigating
  - Unfortunately this is usually not obvious as empirical studies are not often used in SE/CS
- Upon having this insight, we must realize that the experiment must be carefully planned

Activities

- The process is not a “true” waterfall approach
  - Each activity need not finish before starting the next
- The order of activities indicates starting order
  - The process is partly iterative
  - You may need to go back and refine a previous activity before continuing
- The only exception to this is:
  - Once the experiment is started you cannot go back to scoping and planning

Scoping

- The first activity
- Hypothesis must be stated clearly but not necessarily formally
- Goal is formulated from the problem to be solved
- Scope capturing framework:
  - Object of Study (what is studied?)
  - Purpose (what is the intentions?)
  - Perspective (whose view?), and
  - Context (where is the study conducted?)

Planning

- lay down the foundation of the experiment
- context is determined in detail (including personnel and environment)
- hypotheses are stated formally (including both null and alternative hypotheses)
- Determine variables and the values they can take, identify scale of variables
  - Independent (inputs)
  - Dependent (outputs)
- Identify subjects

Planning

- Experiment is designed
  - Design type is selected
  - Preparations are made for instrumenting the experiment
  - Objects identified and prepared
  - Guidelines developed
  - Measurement procedures defined

Planning

- Considerations of validity
  - Internal: concerned with the validity of the given environment and reliability of results
  - External: a question of how general the findings are
  - Construct: does the treatment reflect the cause construct and does the outcome provide a true picture of the effect construct
  - Conclusion: concerned with the relationship between the treatment and the outcome

Operation

Three steps

1. **Preparation:** prepare subjects and materials needed (e.g., data collection forms)
   - subjects must be informed about intention, consent must be obtained, they must be committed
2. **Execution:** ensure experiment is conducted according to the plan and design, including data collection
3. **Data Validation:** ensure data collected is correct and provides a valid picture of the experiment

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Analysis and Interpretation

- Input: data collected during operation
- Analysis steps
  - Data Visualization
  - Descriptive Statistics for informed understanding
  - Consider reducing the data set
    - reduce number of variables
    - evaluating variables to identify those which provide information
  - Perform hypothesis testing
- Interpretation
  - Decision Making
  - Conclusions

Presentation and Package

- Documentation of results
  - Research paper
  - Lab package (for replication purposes)

Are there any questions?