Lab 06

Experimental Designs I

Applied statistics and experiments

October 2024

Agenda

1. Experimental design
2. Pre-experimental design
3. True experimental design

Lecture Recap

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Experimental design

- It is the general plan for setting up an experiment and testing a specific hypothesis or research question.
- Blueprint of an experiment.
- Selection of a research design is a compromise between the goal of rigorous **scientific integrity** versus **limited resources and reality**.
- Three design elements:
  - **Manipulation** (the ability to influence or direct the independent variable)
  - **Control** (the ability to direct or influence important extraneous variables and study measurements)
  - **Randomization** (unbiased [random] subject assignment to each group)

Experimental designs

- Pre-experimental designs (a.k.a., non-experimental)
- True experimental designs
- Quasi-experimental designs

Pre-experimental designs

The characteristics of these designs:

- Lack manipulation and randomization
- May also lack control
- Are generally retrospective
- Have the lowest scientific validity

The effect E of the experimental treatment cannot be determined.

X : treatment
O_2 : posttest measurement

One-shot case study

- A single experimental group
- A single posttest measurement after the experiment.
- Analyse only post-test results.
- Compare the post-test results to the expected results.

$$Group\ A \quad X \text{------------------} O$$

X : treatment

O_2 : posttest measurement

One-shot case study

Example:

- A team leader wants to implement a new soft skills program in the company. The employees can be measured at the end of the first month to see the improvement in their soft skills. The team leader will know the impact of the program on the employees.

Experimental group → Treatment (X) → Posttest (O_2)

$$Group\ A \quad X \text{-------------------} O$$

X : treatment

O_2 : posttest measurement

One-shot case study

Possible threats to internal validity:

- **History:** Organizational restructuring or policy changes, may influence the employees' soft skills regardless of the program.
- **Maturation:** employees may naturally develop and improve their soft skills regardless of the program.
- **Selection:** the employees are not randomly selected.
- **Mortality:** employees drop out of the program during the first month.

Experimental group → Treatment (X) → Posttest (O_2)

$Group\ A \quad X \text{ - - - - - - - - - - - - - - - - } O$

X : treatment
O_1 : pretest measurement
O_2 : posttest measurement

One-Group Pretest-Posttest

- A single experimental group
- A pre-test and a post-test are conducted.
- The pre-test will tell how the group was before they were put under treatment.
- The post-test determines the changes in the group after the treatment.
- It sounds like a *true experiment*, but being a pre-experimental design, it **does not have any control group**.
- Compare the post-test results to the pre-test results.

Experimental group → Pretest (O_1) → Treatment (X) → Posttest (O_2)

$$Group\ A \quad O_1\_\_\_X\_\_\_O_2$$

X : treatment
O_1 : pretest measurement
O_2 : posttest measurement

One-Group Pretest-Posttest

Example:

- The team leader here will conduct two tests. One before the soft skill program implementation to know the level of employees before they were put through the training. And a post-test to know their status after the training.
- Now that he has a frame of reference, he knows exactly how the program helped the employees.

Experimental group → Pretest (O_1) → Treatment (X) → Posttest (O_2)

$$Group\ A \quad O_1 \_\_\_ X \_\_\_ O_2$$

X : treatment
O_1 : pretest measurement
O_2 : posttest measurement

One-Group Pretest-Posttest

Possible threats to internal validity:

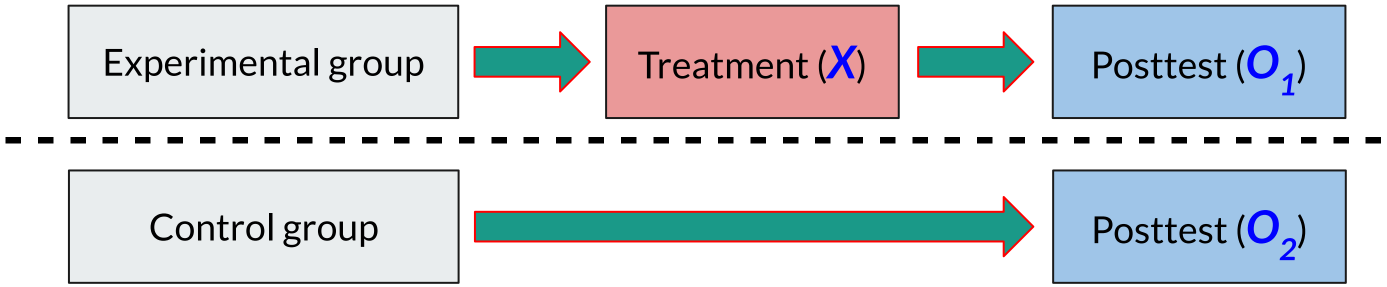
- **History:** between O1 and O2 many events may have occurred apart from X to produce the differences in outcomes.
- **Maturation:** between O1 and O2 employees may naturally develop and improve their soft skills regardless of the program.
- **Testing:** O1 may affect O2.
- **Instrumentation:** O2 is measured using a different instrument w.r.t O1.

Experimental group → Pretest (O_1) → Treatment (X) → Posttest (O_2)

$$Group\ A \quad O_1\text{\_\_\_\_}X\text{\_\_\_\_}O_2$$

Static group comparison

X : treatment
O_1 : posttest measurement
O_2 : posttest measurement

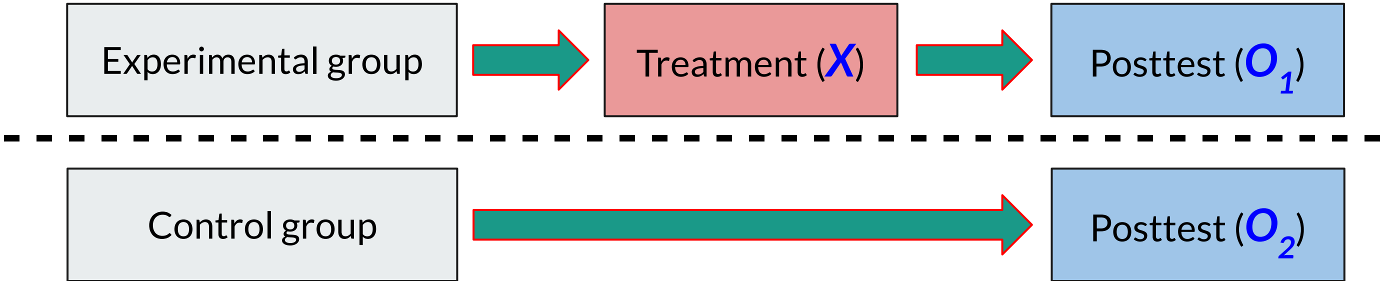


Group A	X	________________	O_1
Group B		________________	O_2

X : treatment
O_1 : posttest measurement
O_2 : posttest measurement

Static group comparison

- An experimental group and a control group.
- The difference between the two groups is the result of the experiment.
- It is generally perceived as a quasi-experimental design
- The groups are not guaranteed to be equivalent.

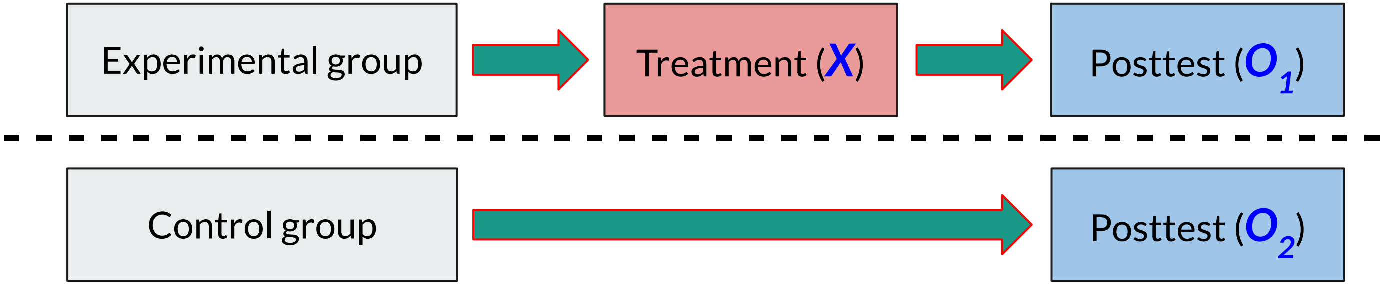


X : treatment
O_1 : posttest measurement
O_2 : posttest measurement

Static group comparison

Example

- The team leader decides one group of employees to get the soft skills training while the other group remains as a control group and is not exposed to any program. He then compares both the groups and finds out the treatment group has evolved in their soft skills more than the control group.

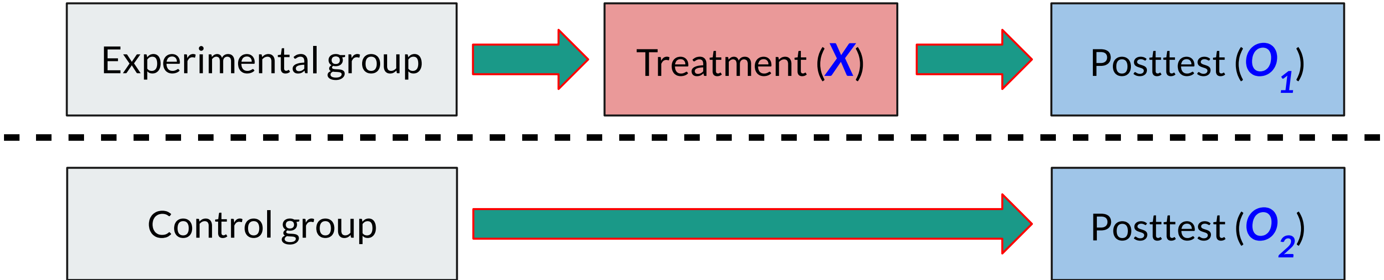


X : treatment
O_1 : posttest measurement
O_2 : posttest measurement

Static group comparison

Possible threats to internal validity:

- **Selection:** groups selected may actually be disparate prior to the treatment.
- **Mortality:** the differences between O1 and O2 may be because of the drop-out rate of employees from the experimental group, which would cause the groups to be unequal.



True experimental designs

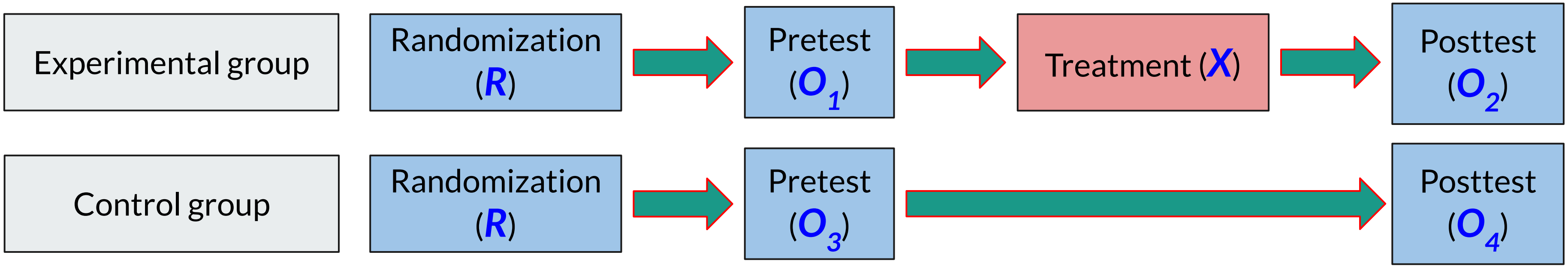
The characteristics of these designs:

- Have all three design elements
- Are always prospective
- Have high scientific validity

Pretest-Posttest Control Group Design

X : treatment
O_1 : pretest measurement
O_2 : posttest measurement
O_3 : pretest measurement
O_4 : posttest measurement
R : randomization

- An experimental group and a control group.
- Equivalence of groups is achieved by randomization.
- Both groups take a pretest and posttest.
- Only the experimental group receives the treatment.

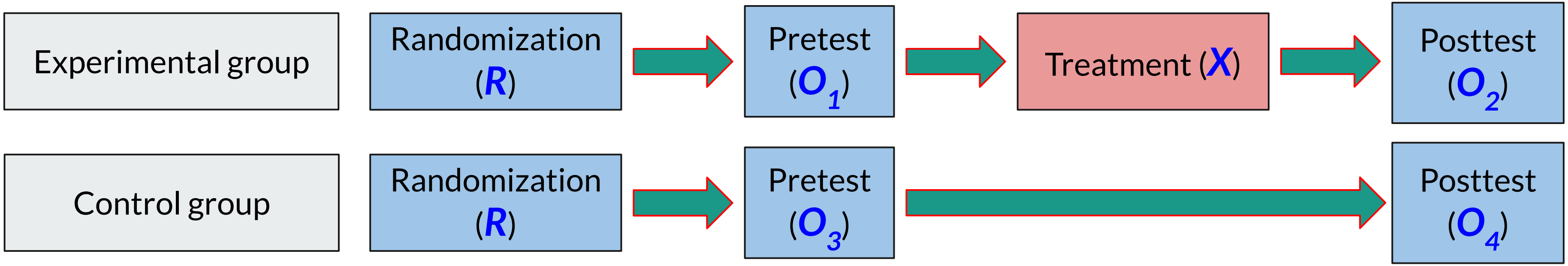


Pretest-Posttest Control Group Design

X : treatment
O_1 : pretest measurement
O_2 : posttest measurement
O_3 : pretest measurement
O_4 : posttest measurement
R : randomization

Threats to internal validity

- **History:** is controlled as historical events that might have produced an O1 – O2 difference would also produce an O3 – O4 difference.
- **Maturation and Testing:** controlled in that they should be manifested equally in experimental and control groups.

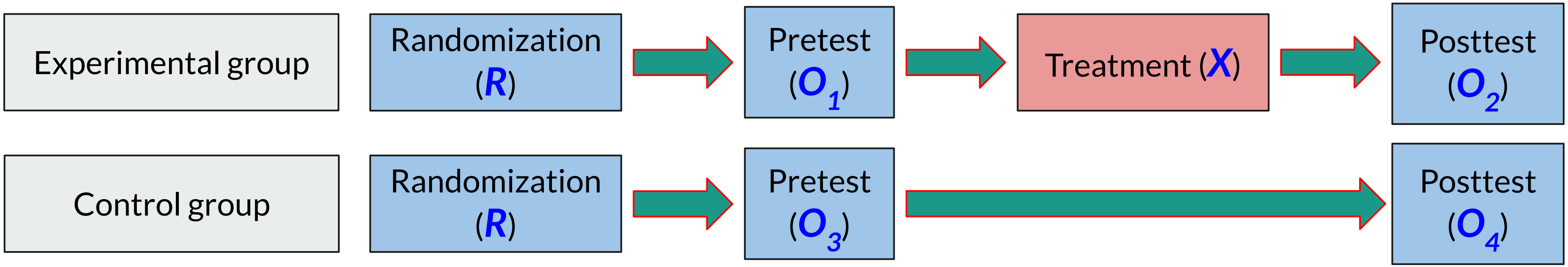


Pretest-Posttest Control Group Design

X : treatment
O_1 : pretest measurement
O_2 : posttest measurement
O_3 : pretest measurement
O_4 : posttest measurement
R : randomization

Threats to internal validity

- **Instrumentation** is controlled.
- **Regression** is controlled as far as mean differences are concerned.
- **Selection** is governed by randomization.
- **Mortality is** controlled as long as the mortality rate from both groups is equal.

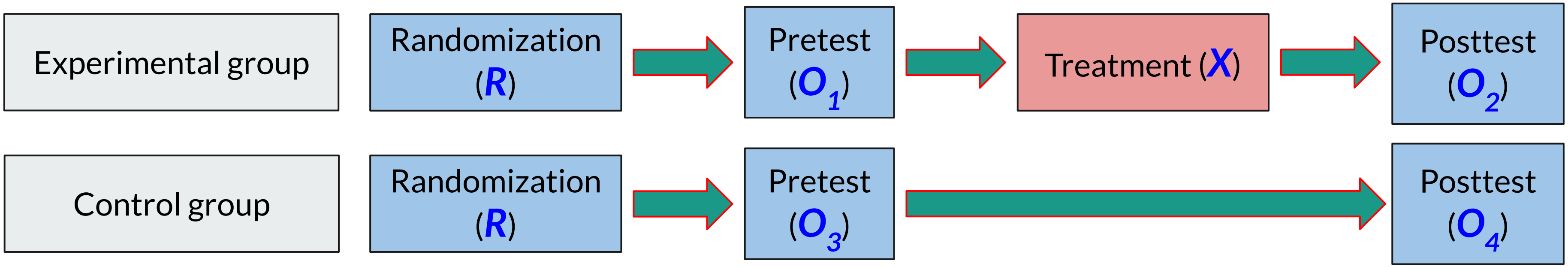


Pretest-Posttest Control Group Design

X : treatment
O_1 : pretest measurement
O_2 : posttest measurement
O_3 : pretest measurement
O_4 : posttest measurement
R : randomization

Threats to external validity

- **Interaction of testing and X:** the interaction between taking a pretest and the treatment itself may affect the results of the experimental group, it is desirable to use a design which does not use a pretest.



Pretest-Posttest Control Group Design

X : treatment
O_1 : pretest measurement
O_2 : posttest measurement
O_3 : pretest measurement
O_4 : posttest measurement
R : randomization

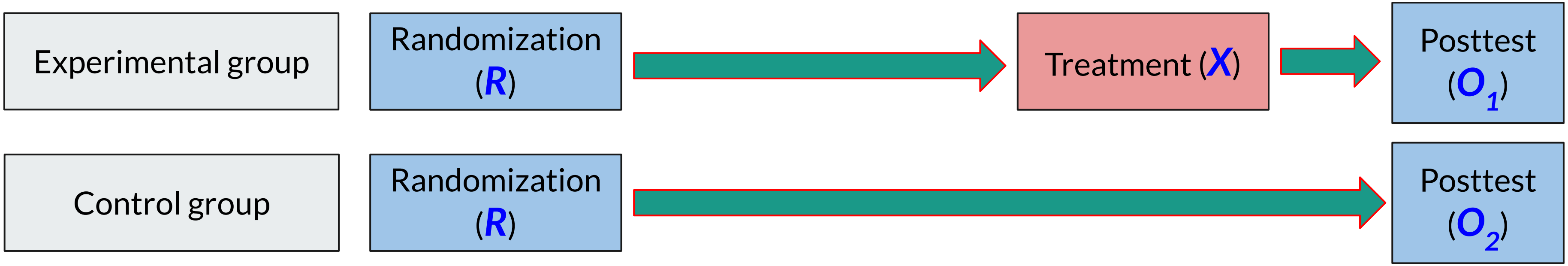
Example

- A teacher splits randomly assigns half of her class to a control group and the other half to a treatment group. She then uses a standard teaching technique and a new teaching technique with each group respectively for one week and then administers a post-test of similar difficulty to all students. She then analyzes the differences between the pre-test and post-test scores to see if the teaching technique had a significant effect on scores between the two groups.
- In the experimental group, the score of pretest is 75, the score of posttest is 80
- In the control group, the score of pretest is 75, the score of posttest is 72.
- Calculate the effect of the treatment E.
- E = (O2 - O1) - (O4 - O3) = 5 + 3 = 8

Posttest-Only Control Group design

X : treatment
O_1 : posttest measurement
O_2 : posttest measurement
R : randomization

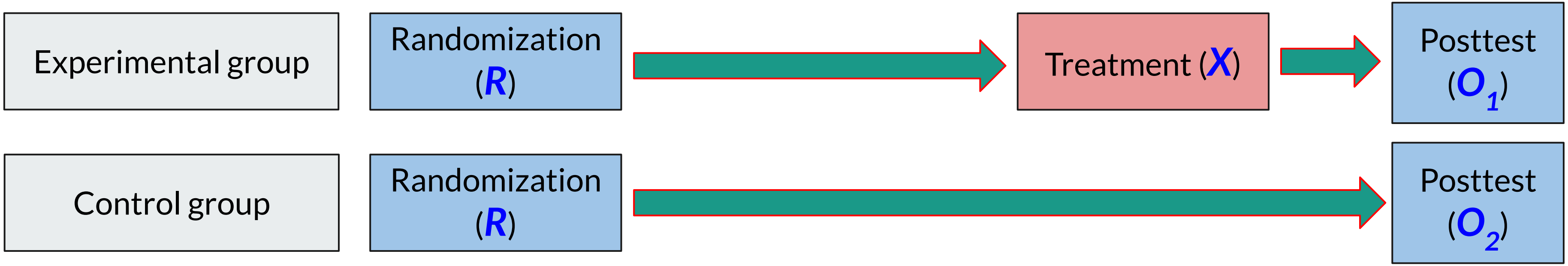
- An experimental group and a control group.
- Equivalence of groups is achieved by randomization.
- Both groups take only posttest.
- Only the experimental group receives the treatment.



X : treatment
O_1 : posttest measurement
O_2 : posttest measurement
R : randomization

Posttest-Only Control Group design

- This design is only adequate if the groups are large enough.
  - For small groups, the pretest is necessary.
- pre-test is impossible because the participants have already been exposed to the treatment, or it would be too expensive or too time-consuming



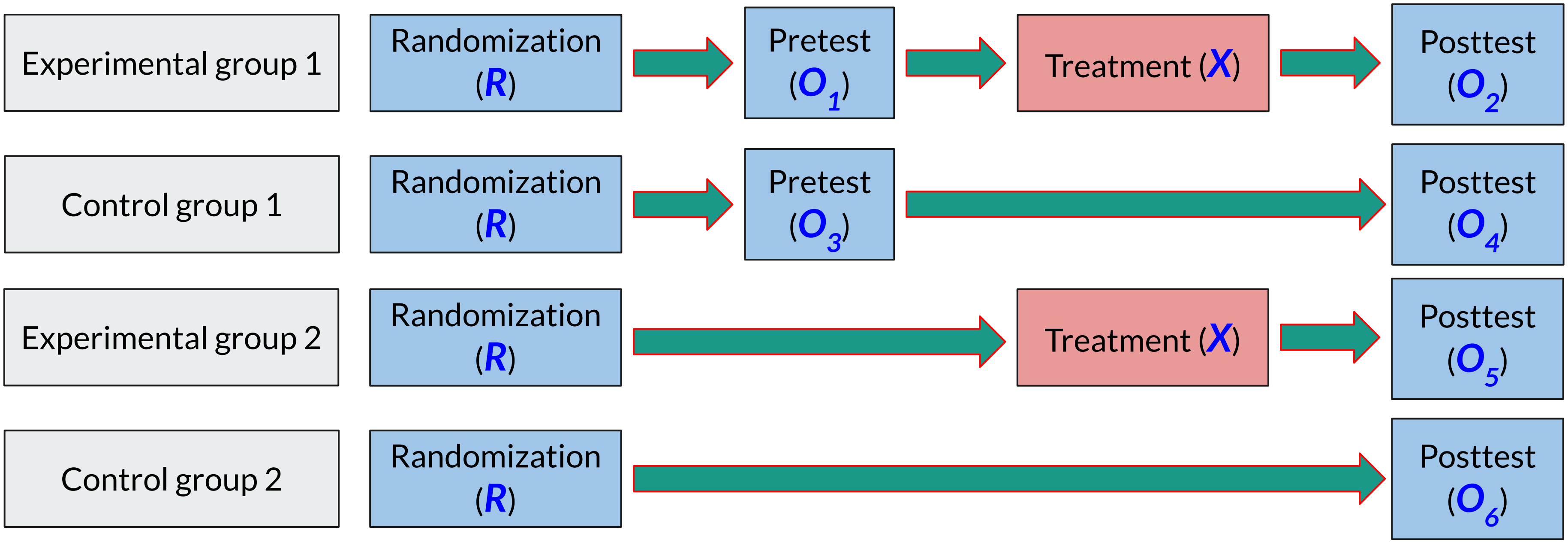
X : treatment
O_1 : posttest measurement
O_2 : posttest measurement
R : randomization

Posttest-Only Control Group design

Example

- In 1993, Topf and Davis used a posttest-only control group design to examine if CCU (Critical Care Unit) noise affects REM (Rapid Eye Movement) sleep. So they randomly assigned 70 women with no hearing or sleeping problems to attempt to sleep in one of the following conditions:
  - noisy environment (the subjects listened to an audiotape recording of CCU sounds): treatment group
  - quiet environment: control group
- Note that this experiment was done in a sleep laboratory. Their results showed that CCU sounds can cause poorer REM sleep.
- The absence of a pretest was justified because participants had no sleeping problems before the experiment.

Solomon Four-Group design



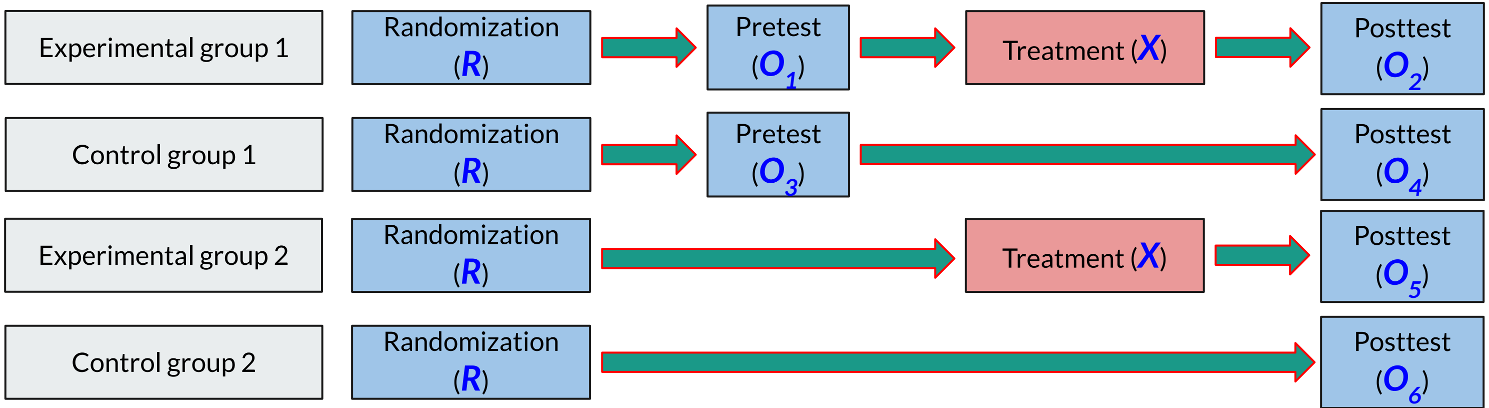
Solomon Four-Group design

- Dehghan et al. (2019) investigated VR (Virtual Reality) technology as a method to reduce anxiety in children undergoing surgery.
- A Solomon four-group design was used in order to control any pretest sensitization.
- The pretest and posttest measured the anxiety score by using a standardized questionnaire.
- The intervention used was a VR technique that simulates step-by-step going into an operation room.
- A Solomon four-group design was used in order to control any pretest sensitization.
- The pretest and posttest measured the anxiety score by using a standardized questionnaire. The intervention used was a VR technique that simulates step-by-step going into an operation room.

If all Es are similar, then the cause-effect relationship is highly valid.

Solomon Four-Group design

- **Effect of the independent variable:**
  - E1 = (O2 - O4)
  - E2 = (O5 - O6)
- **Effect of pretest (testing effect)**
  - E3 = (O4 - O6)
- **Effect of pretest sensitization:**
  - E4 = (O2 - O5)
- **Effect of random assignment**
  - E5 = (O1 - O3)



Example 01

- A study to determine whether reading to children an extra half an hour a day would increase their reading skill. A group of children would be exposed to the treatment (extra reading time) and then measured afterwards to see if there were any effects.

One-shot case study design

Example 02

- A teacher splits randomly assigns half of her class to a control group and the other half to a treatment group. She then uses a standard teaching technique and a new teaching technique with each group respectively for one week and then administers a post-test of similar difficulty to all students. She then analyzes the differences between the pre-test and post-test scores to see if the teaching technique had a significant effect on scores between the two groups.

Pretest-Posttest control group design

Example 03

- A study comparing the effectiveness of two different teaching methods on student achievement in mathematics. One group of students is assigned to receive traditional lecture-based instruction, while the other group receives a more interactive and hands-on approach. The researchers measure the students' test scores after the intervention to determine if there is a significant difference in achievement between the two groups.

static group comparison design

Example 04

- A study evaluating the effects of a stress management program on employee well-being in a high-stress work environment. Employees are asked to attend the program, which includes stress reduction techniques and coping strategies. Employee well-being is measured through self-report questionnaires and physiological markers (such as heart rate variability) after the program to assess the effectiveness of the stress management program.

One shot case study design

Example 05

- A study examining the effects of a new exercise program on weight loss in overweight individuals. Participants are randomly assigned to either receive the exercise program, which includes a combination of aerobic and strength training exercises, or a control group that does not receive any intervention. Weight loss is measured through body weight measurements after the program to determine if the exercise program has a significant impact on participants' weight loss.

Posttest-only control group design

Upcoming class

- Quasi-experimental design
- Factorial design

References

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- https://pressbooks.pub/scientificinquiryinsocialwork/chapter/12-2-pre-experimental-and-quasi-experimental-design/
- https://allpsych.com/research-methods/experimentaldesign/preexperimentaldesign/
- https://www.voxco.com/blog/pre-experimental-design-definition-types-examples/#:~:text=What%20is%20Pre%2Dexperimental%20Design,not%20have%20a%20comparison%20group.
- https://www.scribbr.com/
- https://explorable.com/
- https://hugoquene.github.io/QMS-EN/ch-design.html#sec:betweenwithinparticipants

Attendance

https://baam.duckdns.org

Questions?