

# Introduction to experimental design

## **Session 1**

MATH 80667A: Experimental Design and Statistical Methods  
for Quantitative Research in Management  
HEC Montréal

# Outline

**Class details**

**Motivation**

**Review**

**Key concepts in experimental designs**

# Class details

# Course content

## Content

- Basics of experimental design
- Statistical inference
- Completely randomized designs
- Analysis of variance
- Blocked designs
- Analysis of covariance
- Mixed models
- Intro to causal inference
- Mediation analysis

## Cross-disciplinary skills

- Scientific workflow
- Peer-review
- Reporting
- Statistical fallacies
- Reproducibility

# Prerequisites

## Math skills

Basic algebra

## Computer science

None

## Statistics

At the level of OpenIntro Statistics (Chapter 1)

# Motivation

# Experiments as gold-standard



BJOG Research Methods Guides | [Free Access](#)

## Randomised controlled trials – the gold standard for effectiveness research

Study design: randomised controlled trials

Eduardo Hariton, Joseph J Locascio

First published: 19 June 2018 | <https://doi.org/10.1111/1471-0528.15199> | Citations: 121

*Randomised controlled trials (RCTs) are the reference standard for studying causal relationships between interventions and outcomes as randomisation eliminates much of the bias inherent with other study designs.*

# History

## Experiments on agricultural trials in Rothamsted ongoing since 1843

### ECN ROTHAMSTED

Rothamsted (Latitude 51° 48' 34.44" N; Longitude 0° 21' 22.76" W) is located about 35 km North of London, UK. It covers about 330 ha, all of which is included within the Rothamsted ECN site. The estate contains several ecosystems, including managed arable and grassland fields, naturally regenerated and ancient woodland, the river Ver and more recently energy crops e.g. short rotation coppice willow and miscanthus grass. The Park Grass Hay Experiment (est. 1856) is the principal target sample site (TSS) for the majority of the [ECN protocols at Rothamsted](#). This experiment is widely acknowledged to be the oldest continuing agro-ecological experiment in the world; it is recognised internationally as an important site for long-term studies on biodiversity and ecology. The experimental plot on Park Grass of most interest to the ECN, in relation to physical and atmospheric inputs is Plot 3, Section d (Plot 3d). This plot receives no inorganic or organic inputs apart from atmospheric deposition.






# Modern experiments: A/B testing

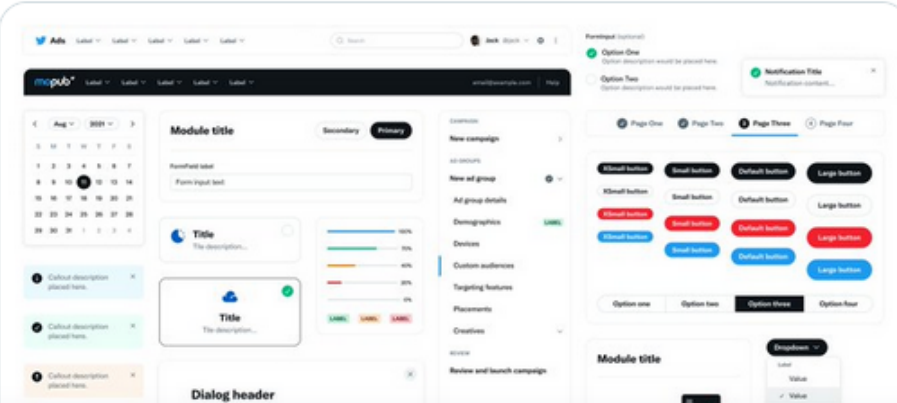
204 631 1,8 k

[Afficher cette discussion](#)

Twitter Design a retweeté

 **Joey Banks** @joeyabanks · 11 août

I think one of the most exciting challenges in design system work is an opportunity to create alignment between platforms when it comes to shared patterns. With today's visual update, the components powering Twitter's revenue & developer products received a redesign, too! ✨



## Vous pourriez aimer



**Twitter API** ✓  
@TwitterAPI

Suivre



**Twitter Live** ✓  
@TwitterLive

Suivre



**Twitter TV** ✓  
@TwitterTV

Suivre

[Voir plus](#)

## Ce qui se passe

Actualité internationale · Hier soir  
**Looking at the history of the Taliban in Afghanistan**



# Evidence-based policy

**RAND health insurance study**

**Student Teacher Achievement Ratio (STAR)**

# Nobel memorial prize



Business

## 3 share Nobel Prize in economics for 'experimental approach' to solving poverty

Esther Duflo, who at 46 is the award's youngest winner, shares the honor with fellow MIT economist Abhijit Banerjee and Harvard's Michael Kremer



# Review

# Population and sampling

**Defining a population**

**Sampling frame**

**Randomization**

**Convenience samples**

**Non-response bias**

# Sampling scheme

**Simple random sampling**

**Stratified sampling**

**Gender, ethnicity, etc.**

**Cluster sampling**

**Villages, housing block, classrooms, etc.**

**Multi-stage sampling**

# Judging the quality of a sample

## Summary statistics

Reported to check representativeness of the sample relative to population.

## Raw data

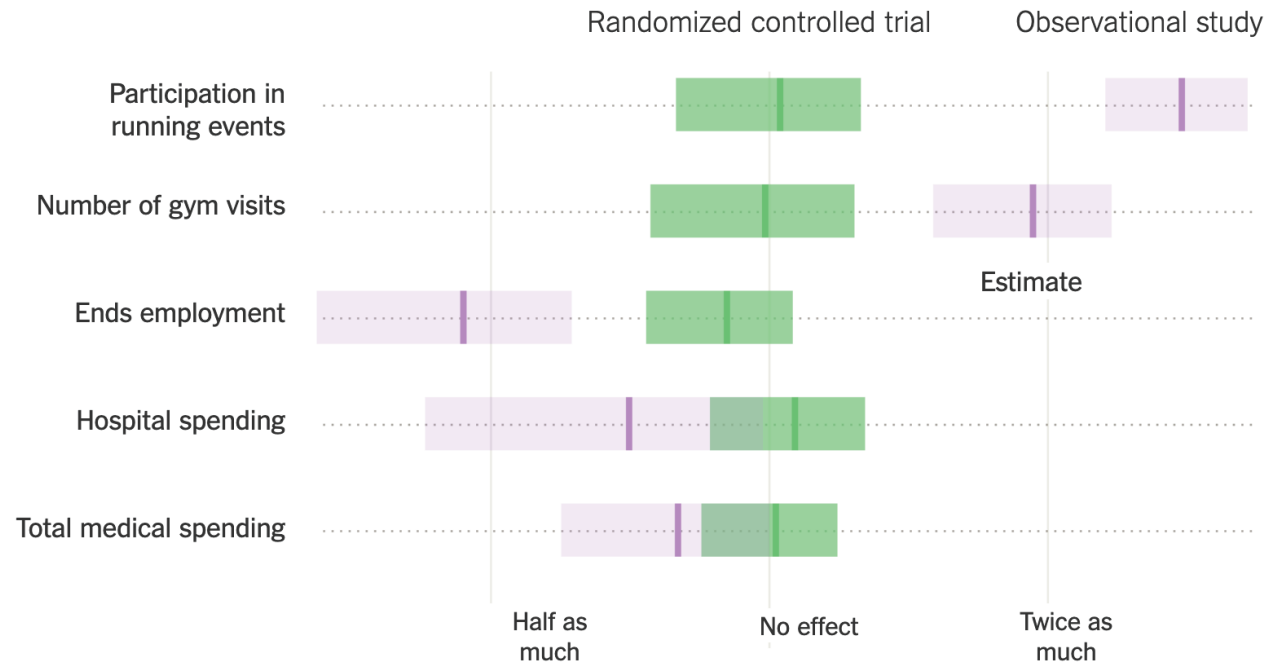
Used for reproducibility and to assess whether data is fraudulent.

## Pre-testing

Check whether sampling allocation is sufficiently random.

# Experimental versus observational

How the Illinois Wellness Program Affected ...



Source: What Do Workplace Wellness Programs Do? Evidence from the Illinois Workplace Wellness Study



# Study type versus sampling

<i>ideal experiment</i>	Random assignment	No random assignment	<i>most observational studies</i>
Random sampling	Causal conclusion, generalized to the whole population.	No causal conclusion, correlation statement generalized to the whole population.	Generalizability
No random sampling	Causal conclusion, only for the sample.	No causal conclusion, correlation statement only for the sample.	No generalizability
<i>most experiments</i>	Causation	Correlation	<i>bad observational studies</i>

# Key concepts in experimental design

# Technical vocabulary

**Experimental unit**

**Observational unit**

**Factor / treatment**

**Treatment group**

**Control group**

# Impact of encouragement on teaching

From Davison (2008), Example 9.2

In an investigation on the teaching of arithmetic, 45 pupils were divided at random into five groups of nine. Groups A and B were taught in separate classes by the usual method. Groups C, D, and E were taught together for a number of days. On each day C were praised publicly for their work, D were publicly reprimanded and E were ignored. At the end of the period all pupils took a standard test.

# Exercise

In pairs, identify

- the experimental and observational units
- the treatment levels
- the response variable

03 : 00

# Comparing treatments

- Without treatment, **variability** in output from one observation to the next.
- Differences between treatment are **comparatively stable**.

# Choices in experimental designs

- **treatments** for comparison
- observations to be made (number of repetitions, etc.)
- experimental units

# Requirements for good experiments (1/2)

## Absence of systematic error

Achieved via randomization

## Precision

- depends on the intrinsic variability
- function of
  1. accuracy of experimental work
  2. number of experimental units / repetitions per unit
  3. design and methods of analysis



# Requirements for good experiments (2/2)

## Range of validity

- What is population?
- Identify restrictions
- Extrapolation only if proper sampling scheme

## Simplicity of the design

- Simple designs lead to simple analyses