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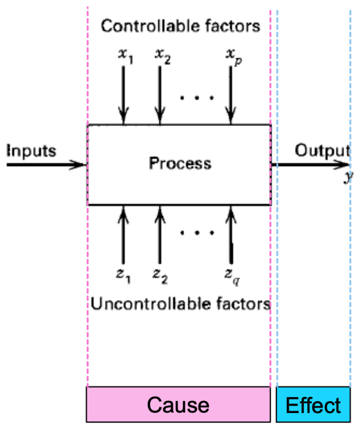
1 Introduction

This document is a summary of the 2022 edition of the lecture *Applied Analysis of Variance and Experimental Design* at ETH Zurich. I do not guarantee correctness or completeness, nor is this document endorsed by the lecturers. If you spot any mistakes or find other improvements, feel free to open a pull request at TODO: INSERT LINK.

2 Learning from Data

From an abstract point of view, we are in the situation where we have a system or a process with many input variables (**predictors**) and an output (**response**). We want to find **cause-effect relationships**, meaning that when we actively change one of the inputs (intervention), this will cause the output to change. This is what we do in **experimental studies**. If we can just observe a system under different settings (observational studies), it is much harder to make a statement about causal effects. With observational data, we can typically just make a statement about an association between two variables. One potential danger is the existence of **confounders** (a common cause for two variables).



2.1 Experimental Studies

Before designing an experimental study, we must have a precise research question that is actually testable, i.e., that we can do the appropriate interventions and that we can measure the right response.

An experimental study consists of:

- **Treatments / Predictors**: the different interventions on the system
- **Experimental units**: the actual objects on which we apply the treatments
- A method that assigns experimental units to treatments, typically **randomization**
- **Response(s)**: the output that we measure

2.1.1 Treatments or Predictors

We distinguish between the following types of predictors:

- Predictors that are of primary interest and that can (ideally) be varied according to our wishes
- Predictors that are systematically recorded such that potential effects can later be eliminated in our calculations (**covariates**)
- Predictors that can be kept constant and whose effects are therefore eliminated
- Predictors that we can neither record nor keep constant

2.1.2 Randomization

Randomization ensures that the only systematic difference between the groups is the treatment. This protects us from confounders and is the reason why a properly randomized experiment allows us to make a statement about a cause-effect relationship between treatment and response. Typically, we then do a randomization within homogeneous blocks. This restricted version of randomization is called blocking. A block is a subset of experimental units that is more homogeneous than the entire set.

2.1.3 Experimental and Measurement Units

An **experimental unit** is defined as the object on which we apply the treatments by randomization. On the other hand, a **measurement unit** is the object on which the response is being measured.

2.1.4 Experimental Error

Different experimental units will give different responses to the same treatment (**experimental error**). Therefore we need multiple replicates receiving the same treatment. If the difference between the treatments is much larger than the experimental error, we can conclude that there is a treatment effect.

2.1.5 Blinding

Blinding means that those who measure the response do not know which treatment is given. With humans it is common to use **double-blinding** where in addition the patients do not know the assignment either. Blinding protects us from (unintentional) bias due to expectations.
A **control treatment** is typically a standard treatment with which we want to compare. It can also be no treatment at all.