Philosophy of Science Colloquium
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Modelling Experimental Interventions:

Results and Challenges

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1 Interventions and confirmation

The idea that interventions provide preferred epistemic access is almost a commonplace.

- The history of science shows the strong ties between the experimental tradition and the birth of modern science.
- Philosophers of experiment emphasize that controlled intervention reveals, or even constructs, reality.
- Studies in cognitive and developmental psychology show that learning is more efficient in tandem with interventions.

This paper aims for a fuller understanding of this idea by presenting a formal model of experimentation.

Traditional confirmation theory
In traditional confirmation theory, observation data and intervention data are not treated differently. Some exceptions:

- Bayesian treatments of the Duhem-Quine problem, triangulation, and calibration.
- Erotetic approaches, likening scientific experiment to a game of questions and answers.
- General philosophy of science on the role of physically realised models.

None of these approaches clarifies the special confirmatory virtues of intervention data.

Experimentalism and statistics

In the philosophy of statistics we do find particular attention for the confirmatory virtues of experimentation.

- Experimentation as putting hypotheses to severe tests and a way to provoke error.
- Attention, often critical, for experimental design as a means to generate representative samples.
- The use of causal Bayesian networks to model experimental interventions.

For revealing the confirmatory virtues, the latter perspective is most promising.

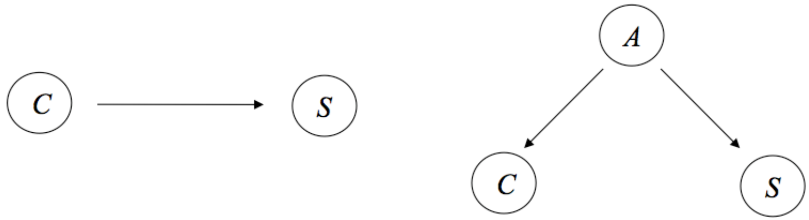
2 Interventions and causal structure

Bayesian networks can be used to choose between different causal structures.

Example from “The Effect of Country Music on Suicide” in Stack and Gundlach (1992) *Social Forces* 71(2): 211–218.

Discovery by intervention

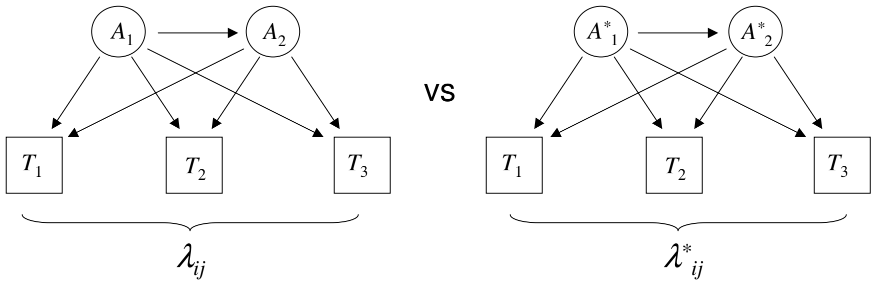
By intervening on the control variable *C* and observing the effect variable *S* we may detect the existence of a causal link between the two, or else the existence of a common cause *A*.



The two candidate networks entail distinct and testable implications for the interventions.

3 Unidentifiability in factor analysis

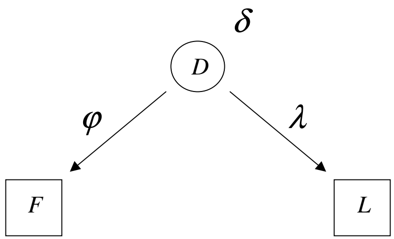
Romeijn and Williamson (20XX) argue that interventions can be also used to resolve problems of underdetermination.



They illustrate this by a case study on the rotation problem in factor analysis.

Fear and loathing in Bayesian networks

Say that fear F and loathing L are both binary manifest variables, and consider a single latent cause, depression D.



Observations are of individuals being fearful and loathsome or not, so there are four categories.

Unidentifiability in Bayesian networks

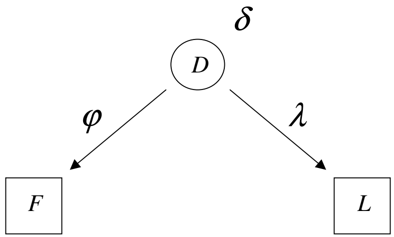
We have a total of five parameters in the statistical model:

- the chance of an individual for being depressed,
- two separate chances for being loathsome, depending on whether the subject suffers from depression, and
- two such chances for being fearful.

But we have only 4 observed relative frequencies, with the restriction that they add up to 1. There is in fact a 2-dimensional continuum of hypotheses that fit the data perfectly.

4 Using intervention data

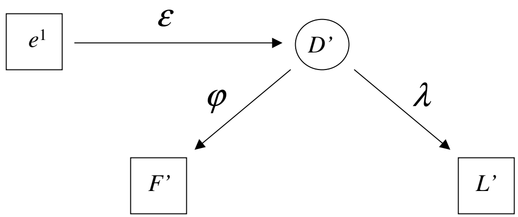
An intervention changes the the probability for depression but keeps the probability of fear and loathing conditional on depression fixed.



To accommodate the intervention data, we therefore have a smaller space of parameters available.

Drugs to the rescue

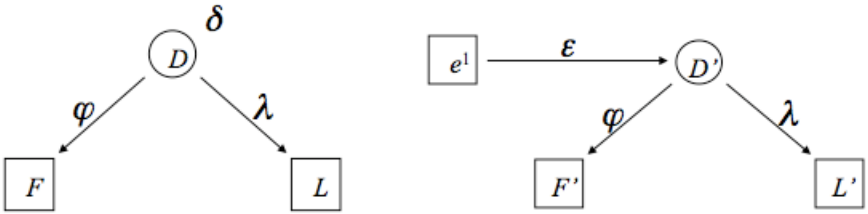
We intervene on the depression by administering a drug E. We model this by an additional node, setting the probability for depression to a new but unknown value $\varepsilon < \delta$.



In order to frame the intervention, we assume that the latent variable model is correct and that we intervene only on the depression node.

Unidentifiability resolved

Because we observe the fear and loathing of the individuals after the intervention, we have 3 new and additional observed relative frequencies.



We have a total of 6 observed relative frequencies. But we have only one additional parameter in our problem: ε. The total number of parameters is 6 as well, so there is a unique best fit!

5 A formal philosophy of experiment?

Such results on formalising experimentation invite a similar approach to other problems in the philosophy of experiment.

- The experimenter's regress: what are we measuring in experiment if, in the act of measuring, we investigate what we measure?
- The isolation of theoretical concepts: how do experiments help to fix the reference of the theoretical terms in our theories?
- Methods for experimatation: what is the correct statistical tool for incorporating evidence from experiment into our theories?

Instead of embarking on these bigger projects, I indicate some problems with the framework just laid down.

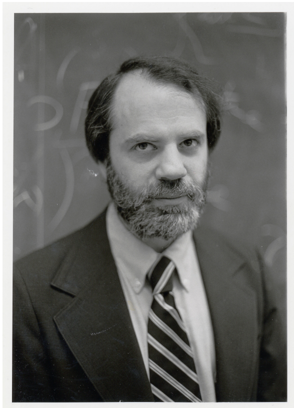
6 Externalism and ignorance

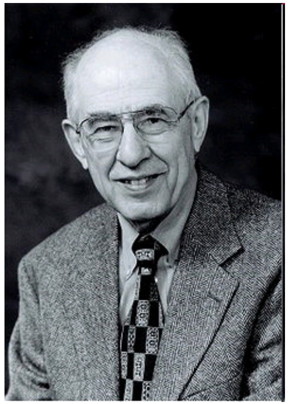
As illustrated by the example, the use of experimental data relies on the presupposition of a causal structure.

- It determines how the system under scrutiny is affected.
- It provides the link between the data sets before and after intervention.

I argue that we cannot explicitly model this aspect of experimentation.

Meaning externalism
The meaning of terms in our language may well be fixed by states of affairs in the world rather than facts of the matter about the world.





So in our use of language, we rely on the world having a particular structure.

Confirmational externalism
Experimental science also relies on external structure: it need not be clear to the experimenter what exactly is being manipulated.

- It may not yet be clear in what domain of things the system is located.
- And even if it is, it will often not have been structured according to a fixed set of variables.

In a formal model such ignorance is captured in an uncertainty measure over a parameterised domain. This is Carnap's curse: first the language, then philosophy.

7 Modality and agency

All data are gathered in the same actual world, but experiments seem to deliver knowledge of counterfactuals.

- We assume that if we had not perturbed the system, nothing out of the ordinary would have happened.
- We intervened in order to observe how the system diverges from this null option.

I argue that this seeming contradiction cannot be resolved in an empiricist model of experimentation.

Exogenous experimenter?

In an empiricist model the data are given, and the experimenter is exogenous. The experimenter can therefore frame the data as pertaining to multiple worlds.

In a more appropriate picture, experimenter and experiment respond to each other to arrive at stable natural laws. The experimenter does not merely record, but becomes endogenous to the expertimental setup.

8 Formal methods in philosophy

I fear that these problems are not idiosyncratic for the programme of using causal Bayesian networks to model experimentation. They are endemic to much of formal philosophy of science.

- The priority of language in formal modelling flies in the face of the externalist aspects of much of scientific activity.
- The traditional empiricist backdrop of formal models is at variance with the role of agency in scientific knowledge.

Of course, this is a rather negative reading of the foregoing. Instead, the audience is welcome to consider the criticisms as challenges!

Thank you

The slides for this talk will be available at http://www.philos.rug.nl/∼romeyn and the full paper will also be posted there. For comments and questions, email j.w.romeijn@rug.nl.