Title: What, in the world, is a violation of causal faithfulness?

Speakers: Patrick Fraser

Series: Quantum Foundations, Quantum Information

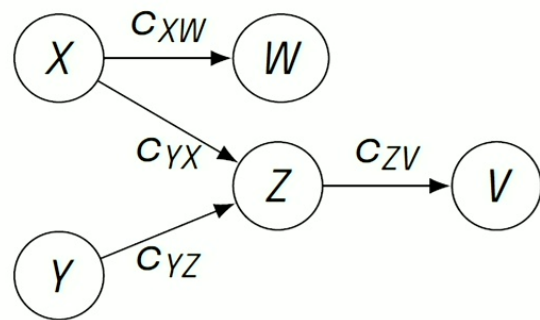Date: September 17, 2024 - 1:45 PM

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What, in the world, is a violation of causal faithfulness?

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$$Y = c_{YX}X + c_{YZ}Z$$

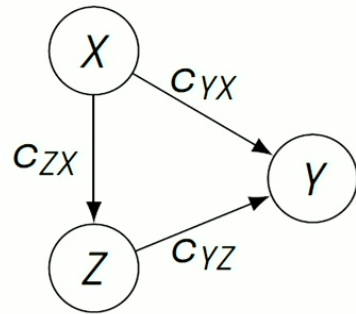$$W = c_{WX}X, \quad V = c_{VZ}Z$$

What, in the world, is a violation of causal faithfulness?

Causal Faithfulness Condition

Two variables in a causal model are probabilistic independent only if they are causally independent.

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$$Y = c_{YX}X + c_{YZ}Z$$

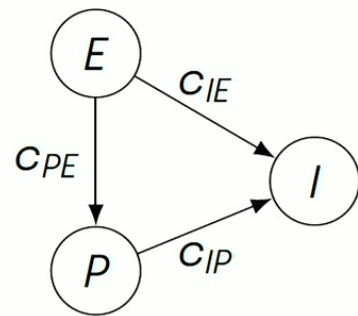$$Z = c_{ZX}X$$

$$c_{XY} = -c_{XZ}c_{YZ}$$

What, in the world, is a violation of causal faithfulness?

There are processes which violate the CFC (Cartwright 1999, Hoover, 2001, Steel 2006).

What, in the world, is a violation of causal faithfulness?

External sodium concentration E, outward sodium channel permeability P, internal sodium concentration I:

$$I = c_{IE}E + c_{IP}P$$

$$P = c_{PE}E$$

$$c_{IE} = -c_{PE}c_{IP}$$

What, in the world, is a violation of causal faithfulness?

Why are we warranted in assuming the CFC?

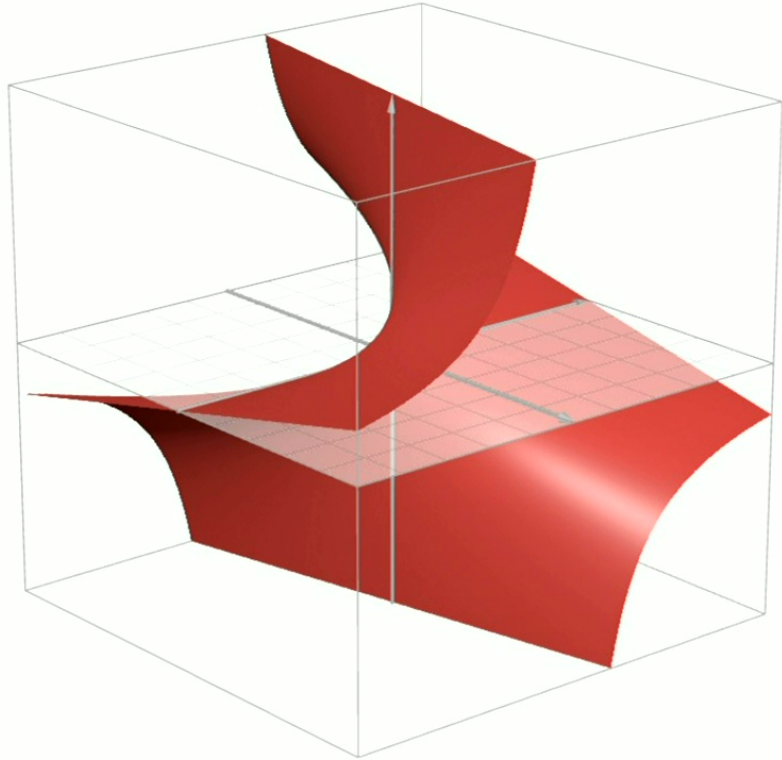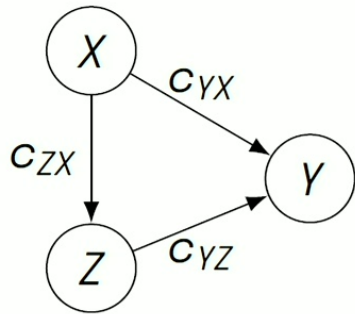What, in the world, is a violation of causal faithfulness?

Measure Zero Argument (SGS 2001)

Fix a causal graph G, and let $\mathbb{R}^n$ be the set of all structural coefficient values one can assign to G.

- A violation of the CFC entails that a polynomial in structural coefficients is zero.

- The set of points in $\mathbb{R}^n$ which satisfy this constraint is Lebesgue measure zero.

- Thus, the CFC-violating models over G are negligible.

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$$c_{XY} = -\,c_{XZ}c_{YZ}$$

What, in the world, is a violation of causal faithfulness?

Even though CFC violations are possible, they are exceedingly rare and can be safely ignored.

Is this really what the measure-zero argument shows?

No!

Problem

Not all models in this model space are representationally viable for every target system of interest. Many choices of structural coefficients require violating kinematic requirements.

The SGS argument requires that what is atypical across the space of all mathematically possible causal models is negligible.

However, not all of the mathematically possible causal models over a particular graph are representationally viable for a given target system.

If the representationally viable models are atypical, then the SGS argument fails.

In many cases, causal variables cannot take on arbitrary real values.

- Ion concentrations in cells must be rational numbers.
- Predator/prey populations are always natural numbers.
- Realistic measurements can only distinguish finitely many values.

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Such restrictions constrain viable choices of structural coefficients. One cannot allow that some permissible choice of values for some causal variables requires that another causal variable takes on an impermissible value.

Suppose X is the only cause of Y, and that both can only take on values in $\mathbb{Z}$.

Then c_{YX} must be such that for all $x \in \mathbb{Z}$, one has $c_{YX} \cdot x \in \mathbb{N}$.

Not all real values of c_{XY} achieve this (e.g. $c_{XY} = \pi$ is prohibited).

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Allowing structural coefficients to take on arbitrary real values generates a space of models which includes all representationally viable models and many more.

Assuming that coefficients can take on arbitrary real values introduces surplus structure. The SGS argument relies on this surplus structure.

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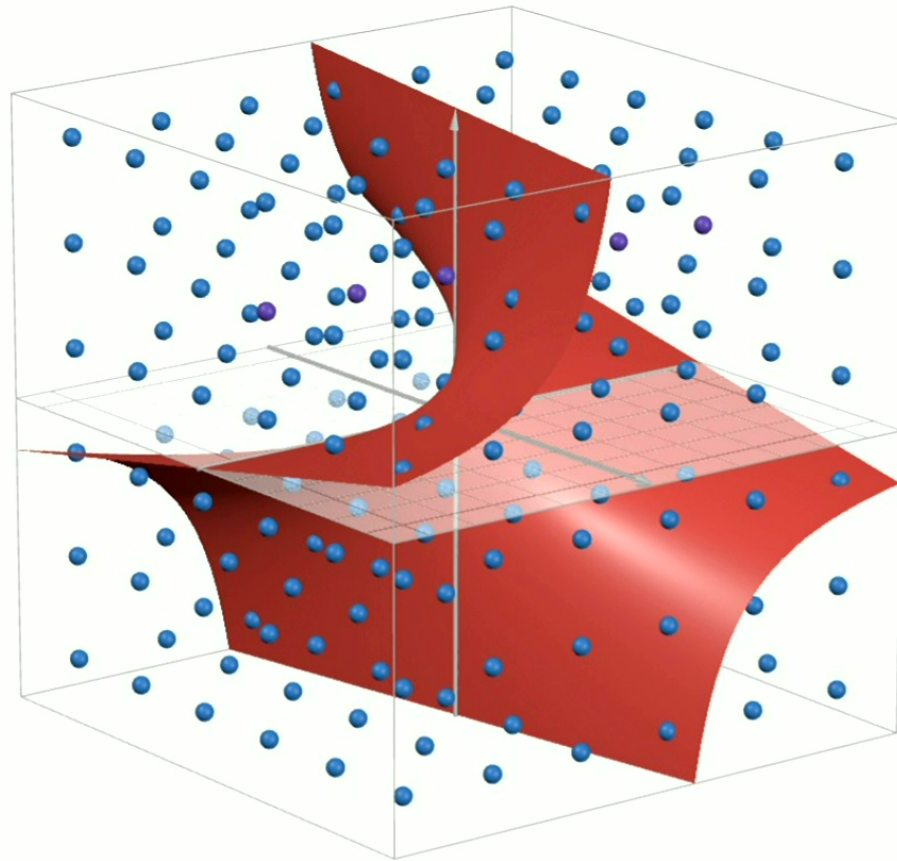
The space of viable models will generally not be $\mathbb{R}^n$.

The space of viable models will often be countable or finitely.

CFC-violating models will either be trivially measure zero or else measure non-zero.

In both cases, the SGS argument fails to establish that CFC violations are negligible.

The kinematics of the target systems whose causal dependencies we wish to study renders certain causal models non-viable.

This diffuses the SGS measure zero argument.

CFC violations are not negligible.

(Although we should only expect them in certain contexts.)

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1997   Scheines, "An introduction to causal inference."

1999   Cartwright, "Causal diversity and the Markov condition."

2001   Spirtes, Glymour, & Scheines, *Causation, Prediction, and Search*.

2001   Hoover, *Causality in Macroeconomics*.

2006   Steel, "Homogeneity, selection, and the faithfulness condition."

2013   Andersen, "When to expect violations of causal faithfulness and why it matters."

2018   Weinberger, "Faithfulness, coordination and causal coincidences."

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