

Causal Interpretations and the Interpretation of Causal Mechanisms in Measurement

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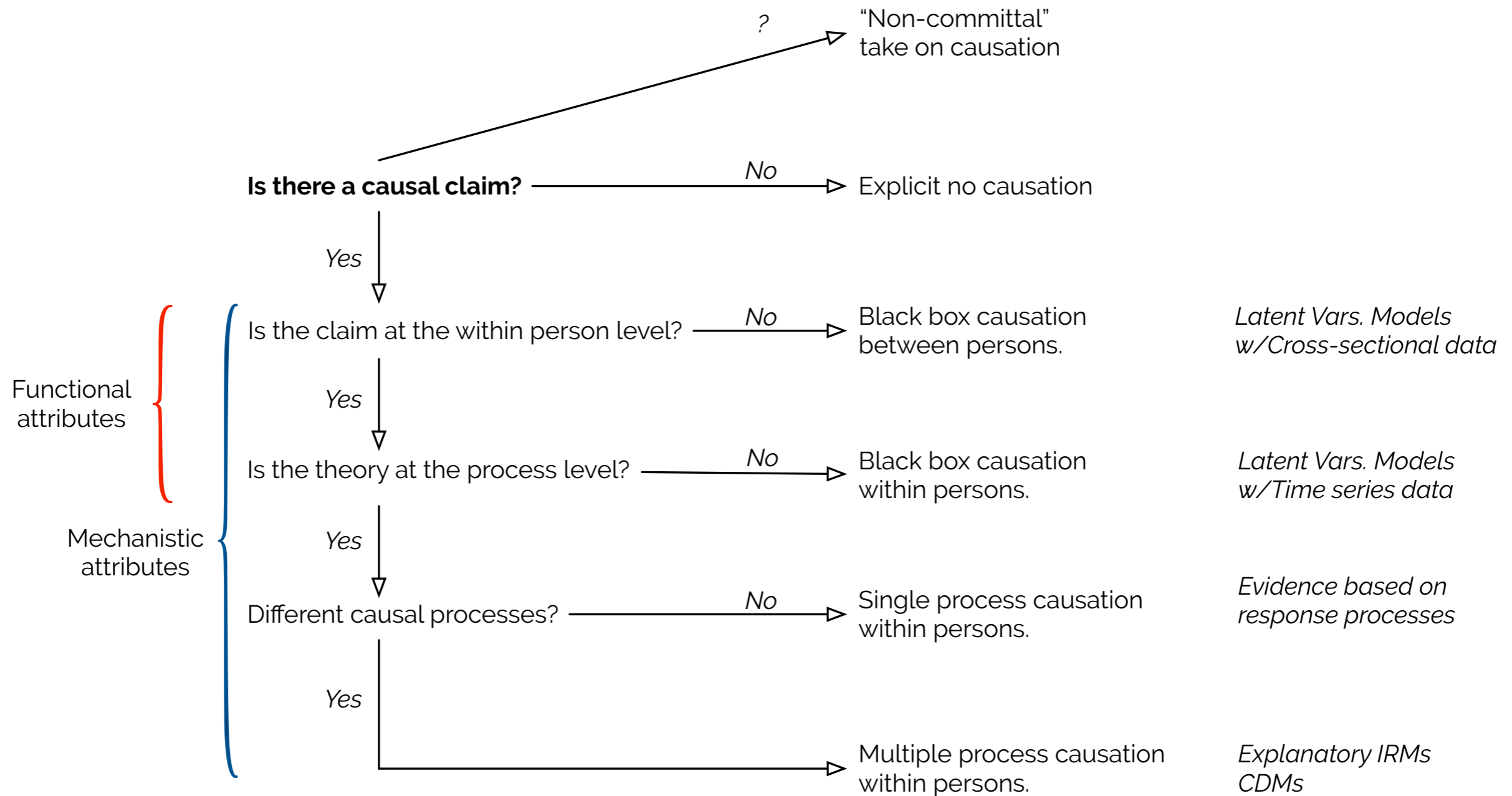
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Outline

- ▶ Focus on causal interpretation of reflective latent variable models.
- ▶ Three distinctions about *types of attribute*, *types of causal account*, and the *level of analysis*.
- ▶ Where one stands in these distinctions will demand different kinds of evidence.
- ▶ We will close by suggesting how to organize these ideas in an applied context.

Mapping the options

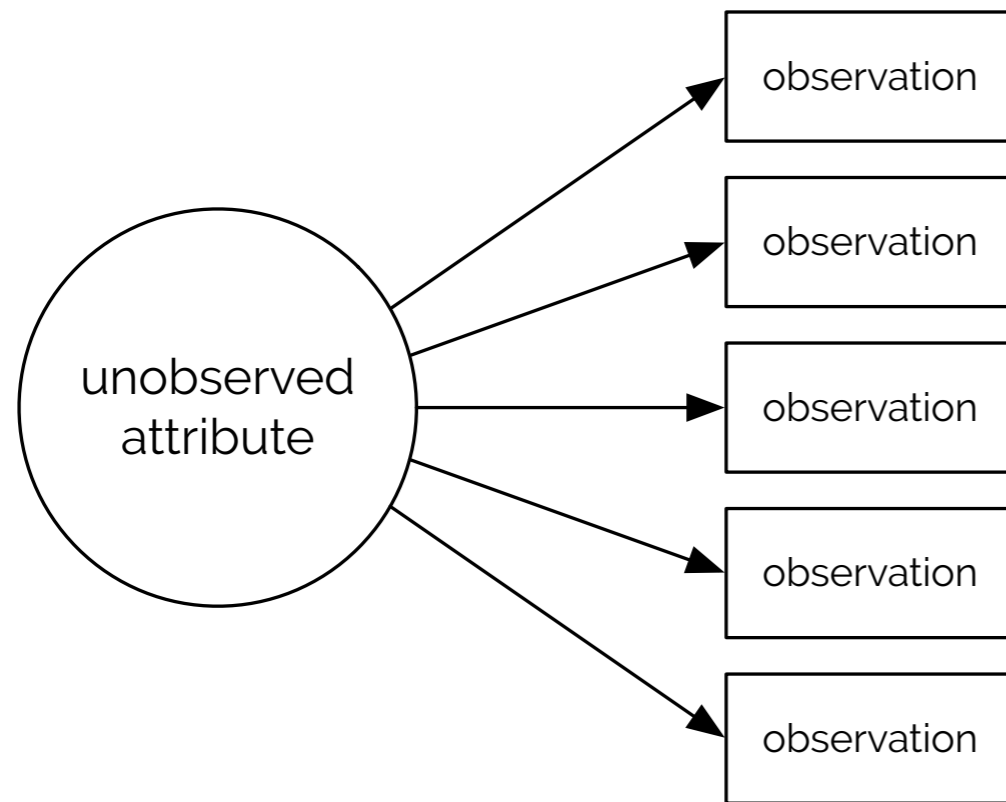


Measuring unobservable attributes

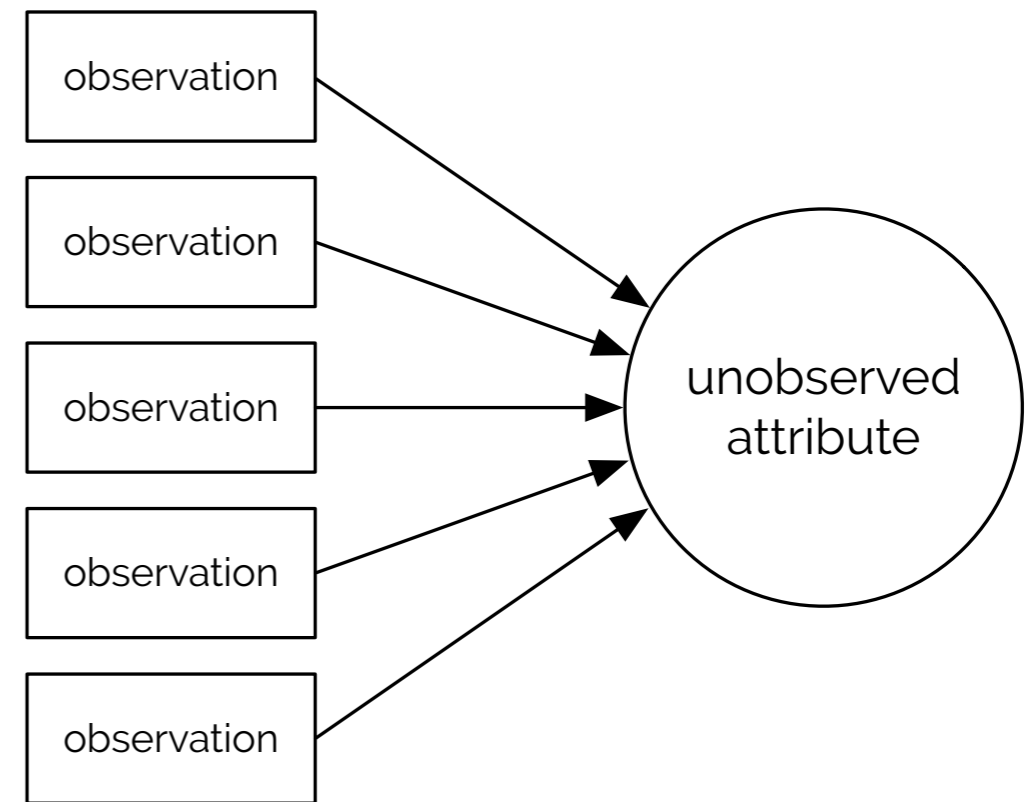
- ▶ *Latent variable models* offer a mathematical formalization of the intuition that we can measure mental attributes through the use of a regression model.

Reflective and Formative Models

Reflective Models



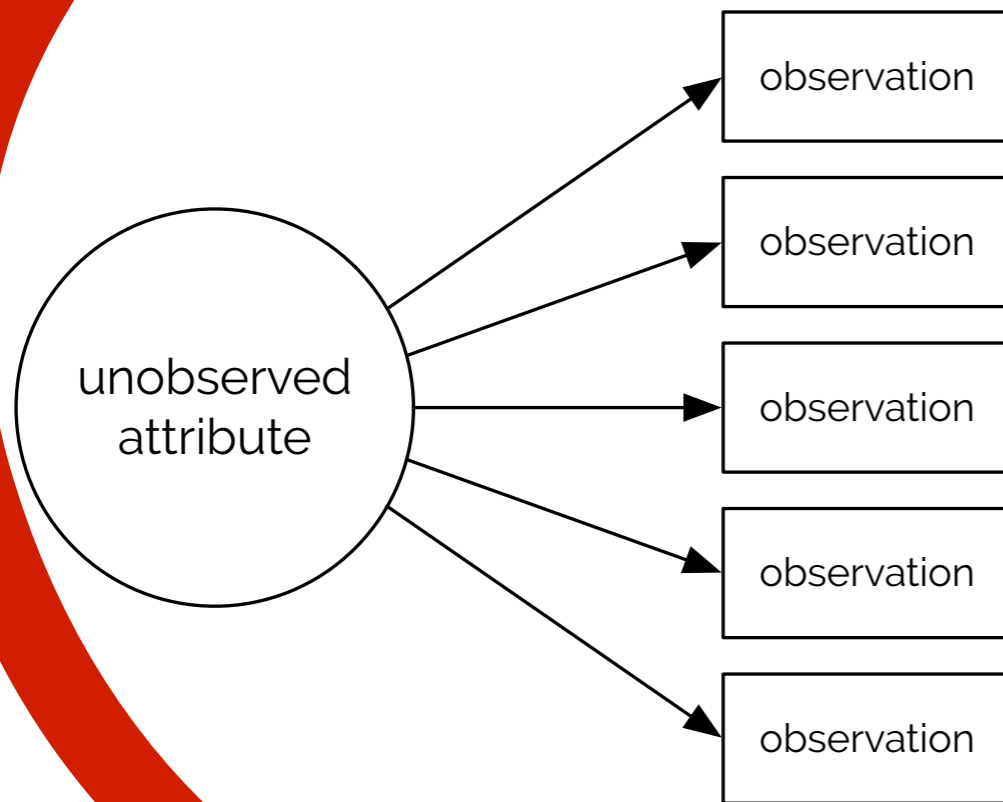
Formative Models



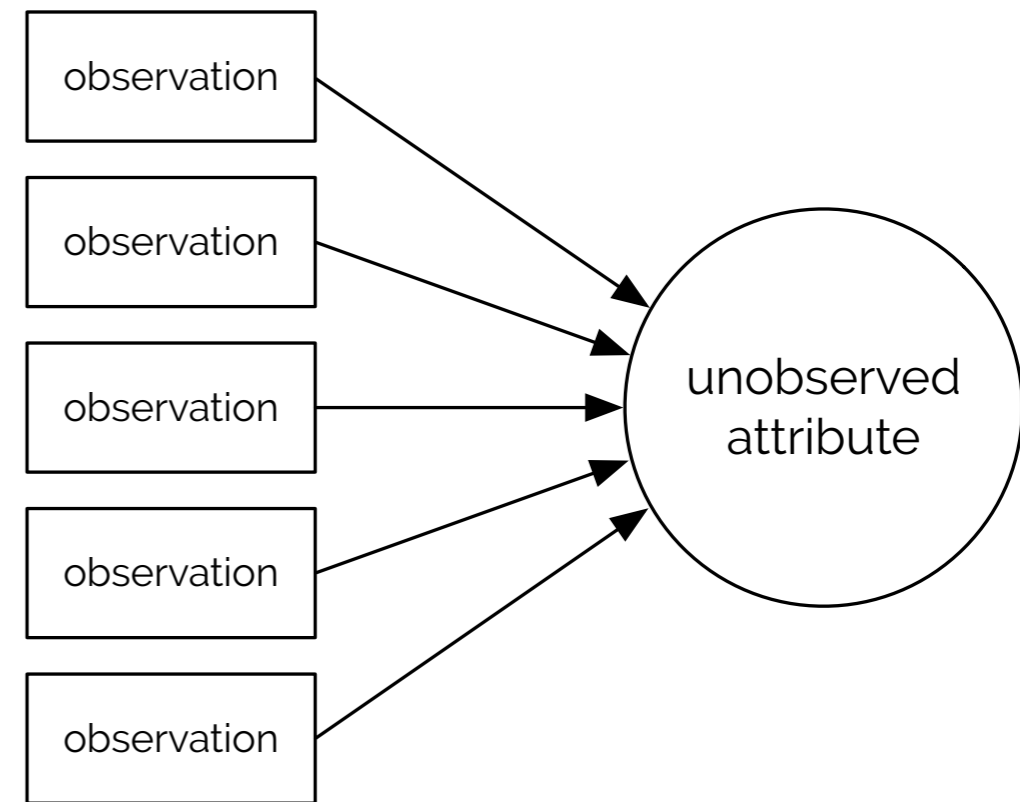
Edwards, J. R., & Bagozzi, R. P. (2000). On the nature and direction of relationships between constructs and measures. *Psychological Methods*, 5(2), 155.

Reflective and Formative Models

Reflective Models



Formative Models



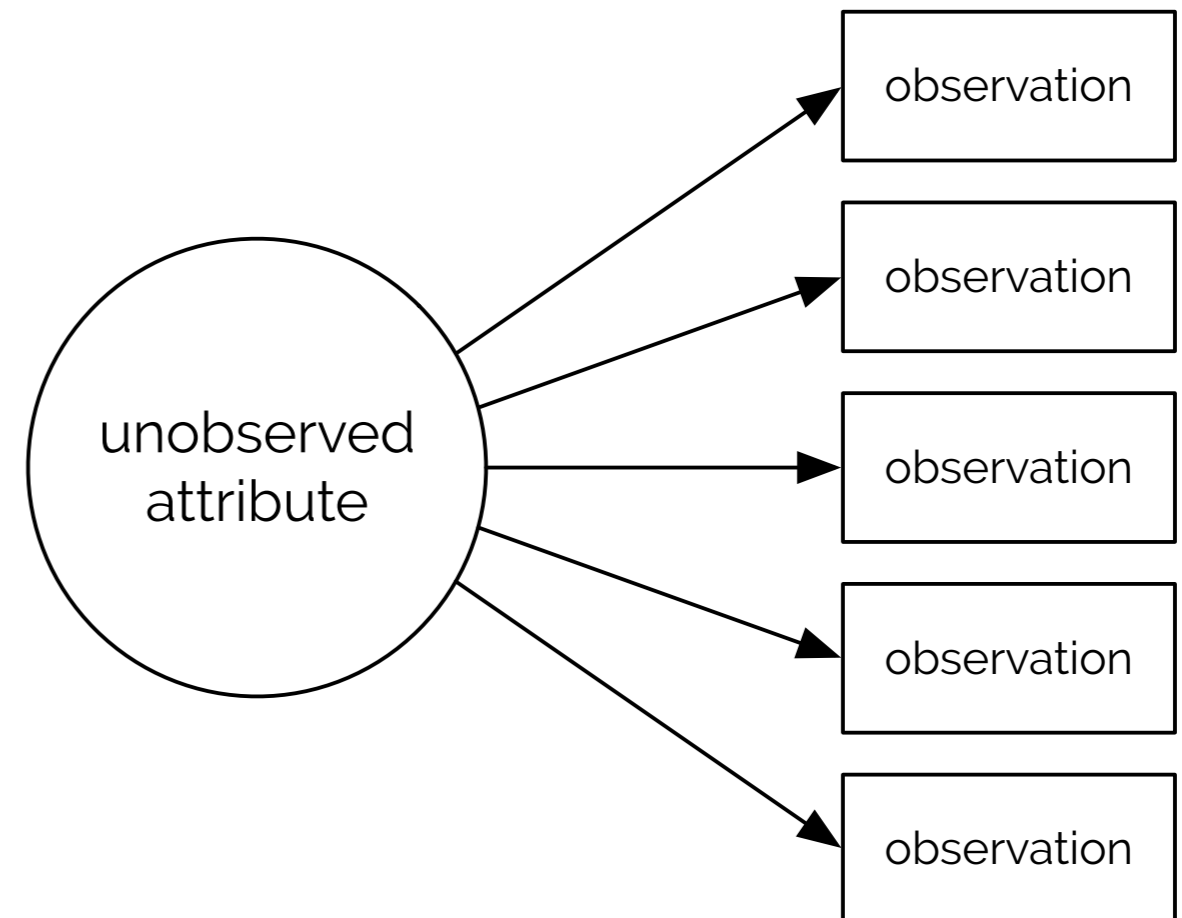
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What do we mean by model?

- ▶ From a Pragmatic perspective a model is a type of tool that can be used to answer questions that we find interesting about a particular object (Minsky, 1968).

Beyond a formal specification

- ▶ The mathematical expression of a regression may offer a **deceiving sense of clarity**.
 - ▶ What does the circle represent?
 - ▶ What about the arrows?
- ▶ What is the story that we tell when using and interpreting the model?



THE MATHEMATICAL MODEL IS NOT ENOUGH

We need ~~some~~ quite a bit of storytelling.

Every model needs a story

Morgan, 2001 / Cartwright, 2008

...models need stories to tell us what to do with them and how to draw conclusions about the target from what we do.

— Cartwright, 2008

Every model needs a story

- ▶ Our models require both:
 - ▶ **Formal components:** The mathematics and DAGs
 - ▶ **Narrative components:** The story we use to interpret the formal model in order to answer the question that motivates the measurement.

...it is senseless to seek in the logical process of mathematical elaboration a psychologically significant precision that was not present in the psychological setting of the problem.

— Boring, 1920

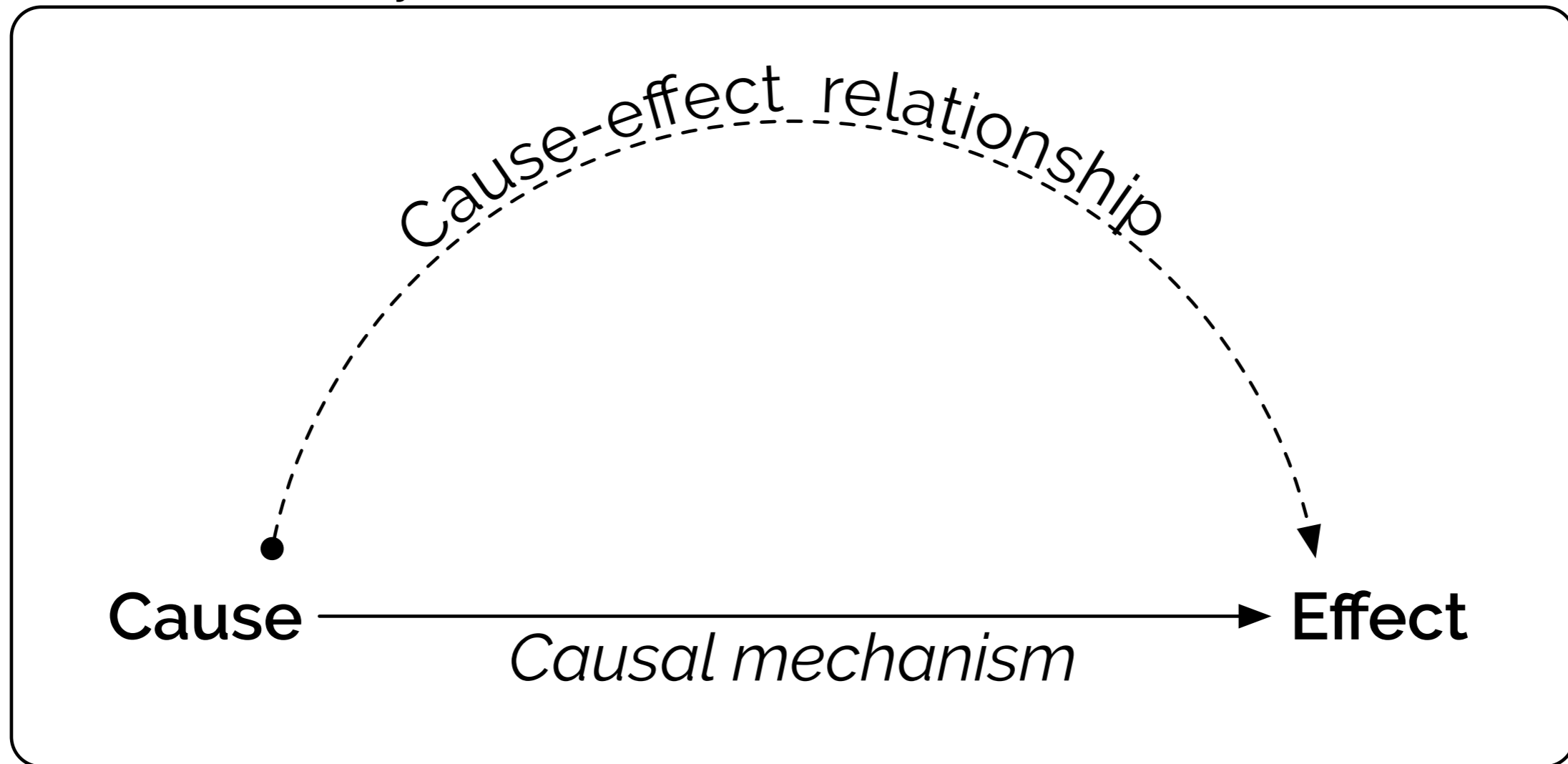
CAUSALITY AND THE STORIES WE TELL

How do we interpret the arrows?

Interpreting directional relations

- ▶ The most popular and useful story (though not the only one) that we can tell in a measurement context is about **causality**.
 - ▶ The unobserved attribute causes variation on the observed outcomes.
 - ▶ The causal relation between the attribute and the outcome operates through processes (or mechanisms) x , y and z .

Causal story



Protzko, J. (2016). Disentangling Mechanisms from Causes: And the Effects on Science. *Foundations of Science*.

Causal effects and causal mechanisms

Focus on cause-effect relations.

- ▶ We may make a claim on the causal relation between the position of a light-switch and the on-or-off status of a light bulb without having to explain what electricity is or how the circuit works.

Focus on causal mechanisms.

- ▶ If we describe how electricity works and indicate how a circuit connects a light switch to a light bulb, we would use this account of the process to indicate that the light-switch has a causal role.

TOXICITY AS AN ATTRIBUTE

There are many ways to get poisoned

Toxicity and the Median Lethal Dose

- ▶ Consider toxicity as an attribute. The concept covers a wide variety of chemical and biological materials, or potentially any material:

What is there that is not poison? All things are poison and nothing [is] without poison. Solely the dose determines that a thing is not a poison.

— Paracelsus

- ▶ It is often quantified as the *Median Lethal Dose*, or LD-50 for short.

The causal story of toxicity?

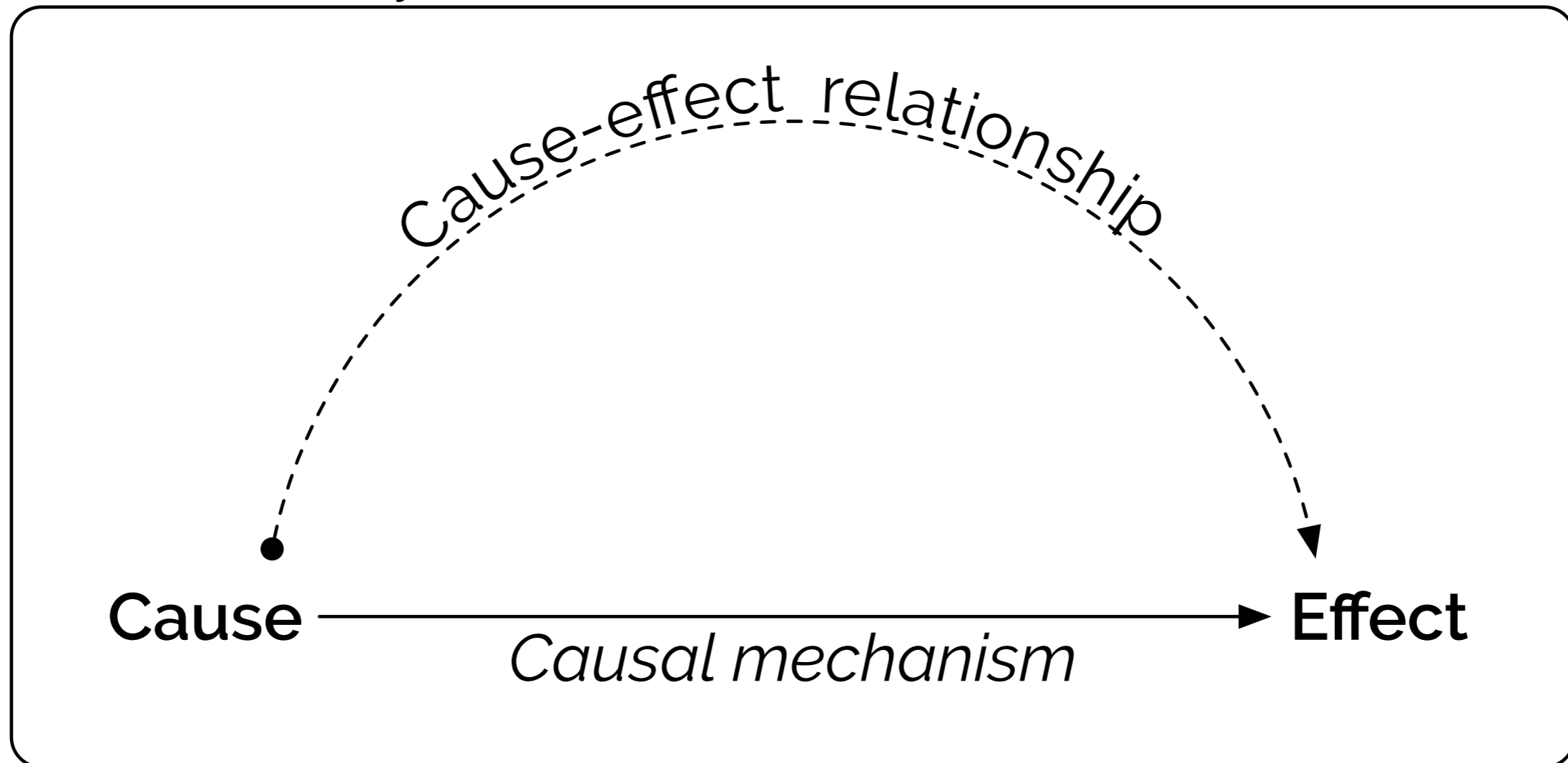
- ▶ We do not assume that there is a commonality in the way all toxic materials operate; we think of them as related by their effects.

By Randall Munroe — <https://xkcd.com/1260/>



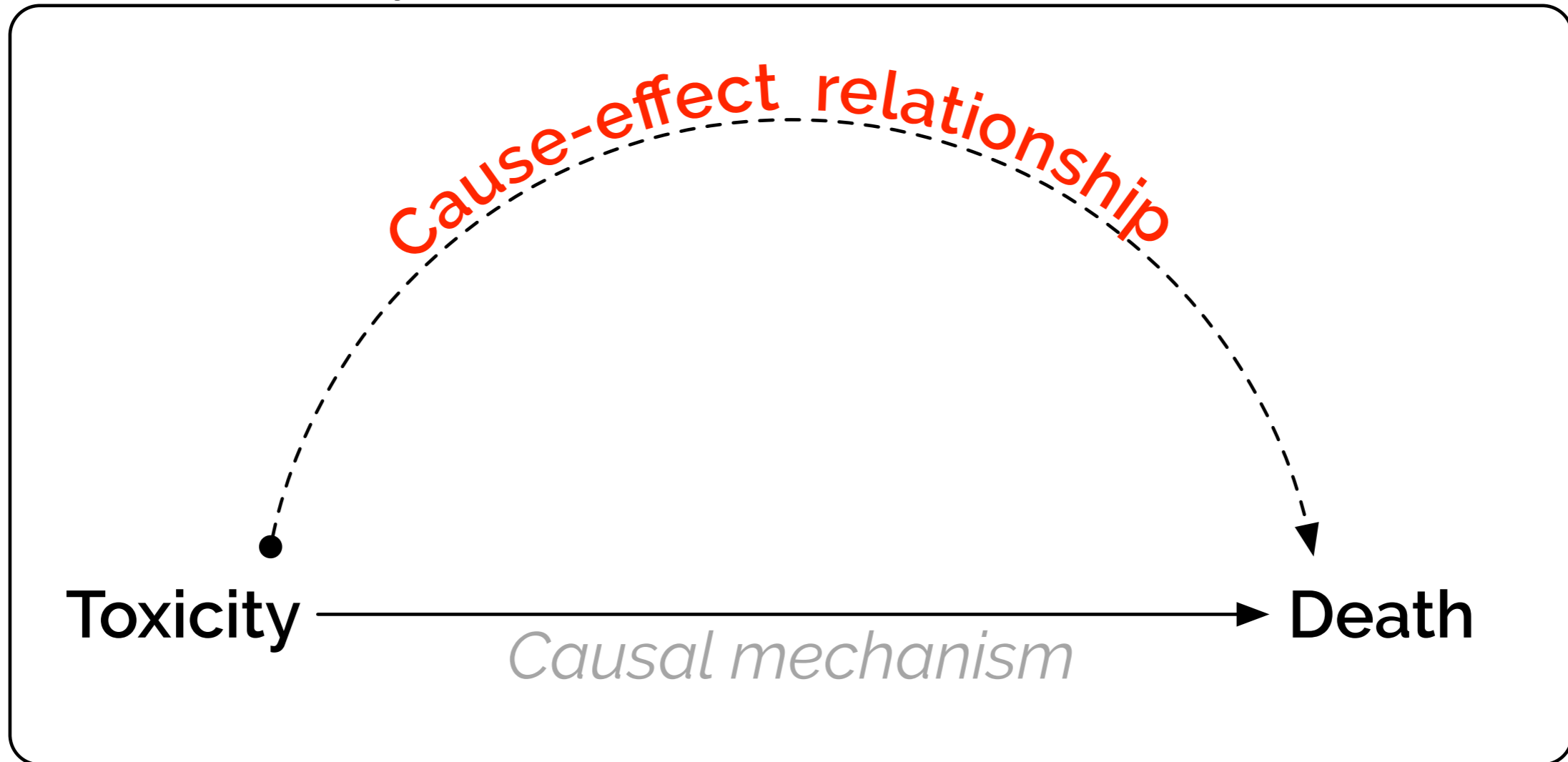
THE LD₅₀ OF TOXICITY DATA IS
2 KILOGRAMS PER KILOGRAM.

Causal story

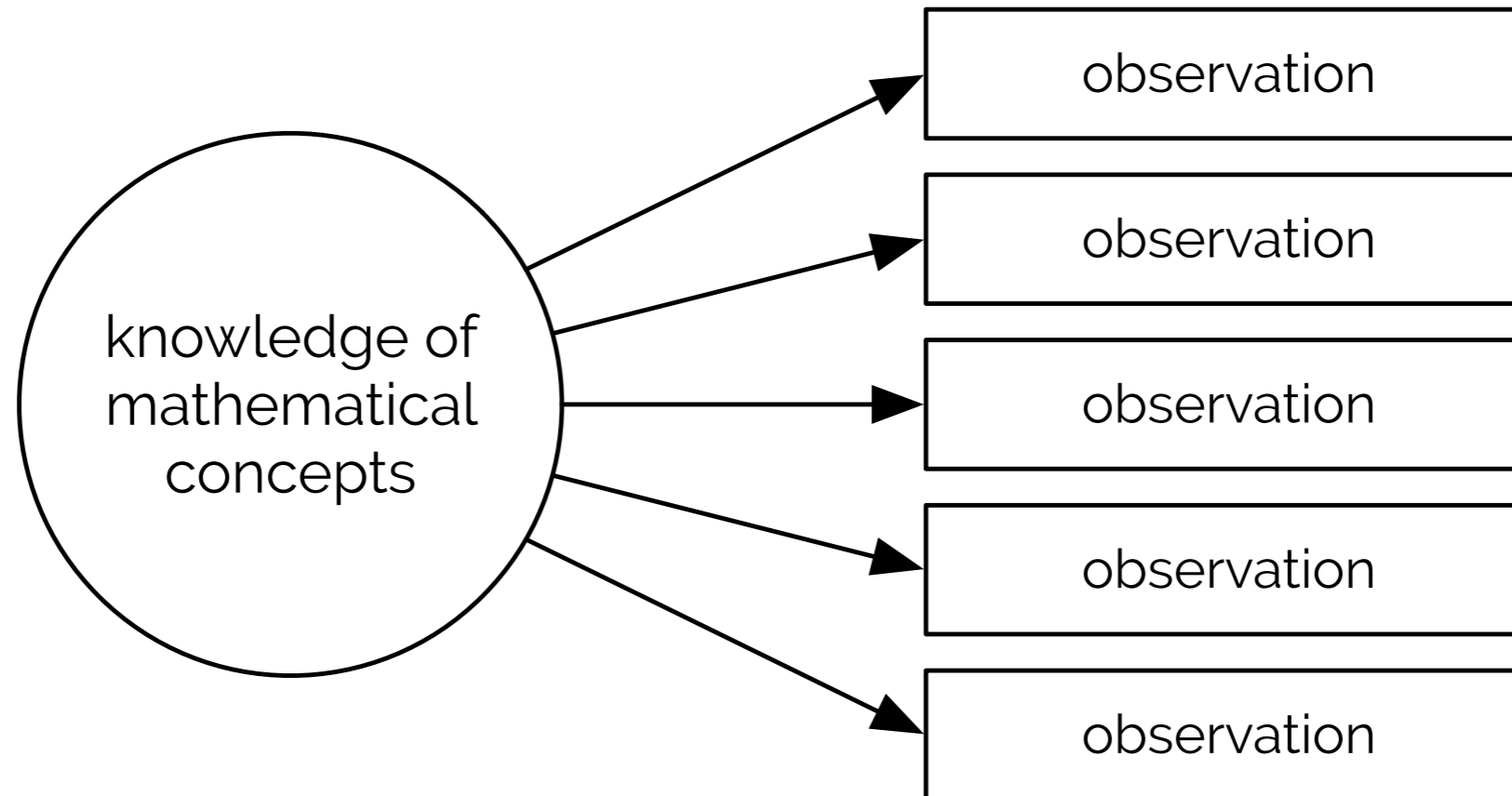


Protzko, J. (2016). Disentangling Mechanisms from Causes: And the Effects on Science. *Foundations of Science*.

Causal story



Causal story?



So, where are we going with this?

- ▶ The example of toxicity touches on multiple issues on the interpretation of measurement models in general.
- ▶ We want to highlight three important distinctions:
 - ▶ One about the attribute
 - ▶ One about the causal account
 - ▶ One about the level of explanation
- ▶ And end with an heuristic way to organize them in practice.

THE DISTINCTION ABOUT THE ATTRIBUTE

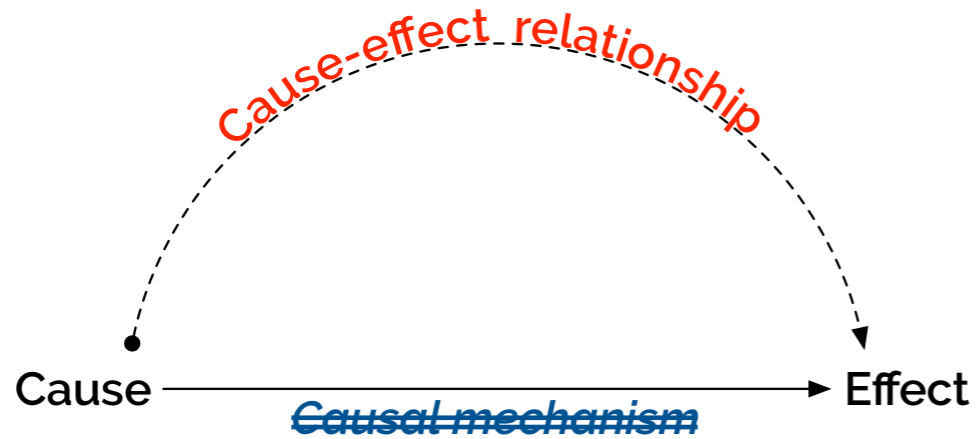
What are we measuring?

How are we defining 'attribute'?

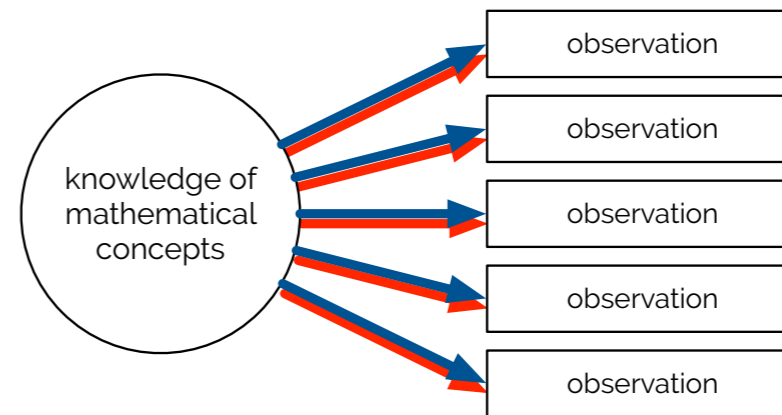
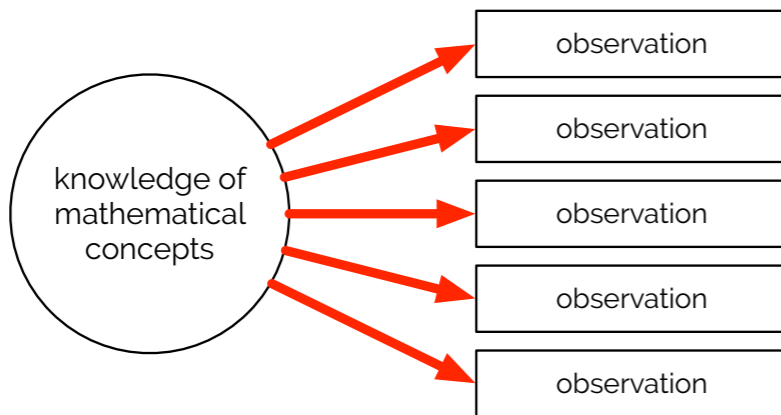
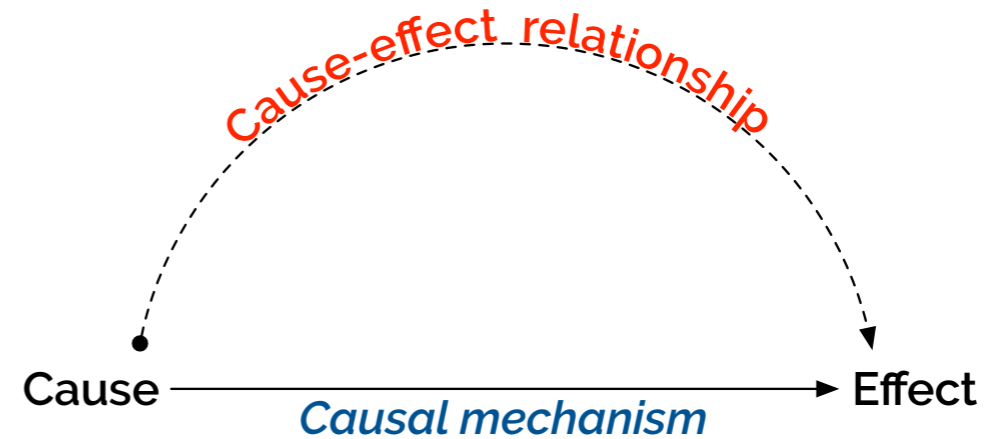
- ▶ What does it mean for this property to exist (see Maul, 2013; Michell, 1990)?
- ▶ We will focus on a specific aspect of these questions; whether we are interested just in what the attribute does (its function) or also in how it does it (its mechanisms).
 - ▶ Functional attributes
 - ▶ Mechanistic attributes

Two types of attributes

Functional attribute



Mechanistic attribute



THE DISTINCTION ABOUT THE CAUSAL ACCOUNTS

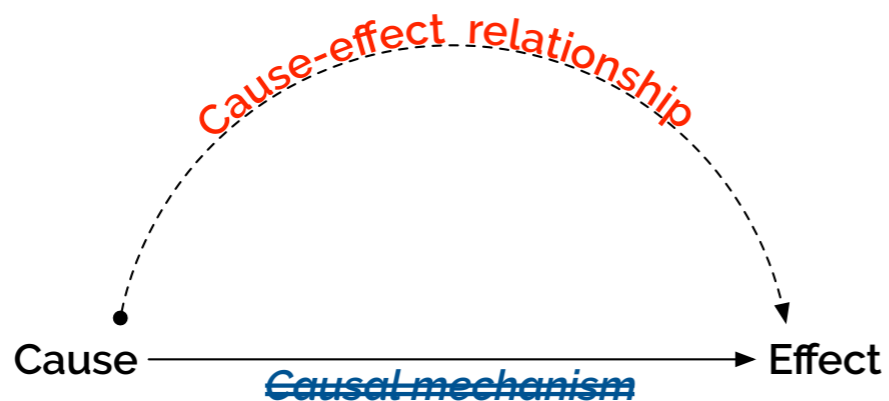
How are we explaining the effects?

Theories of causality

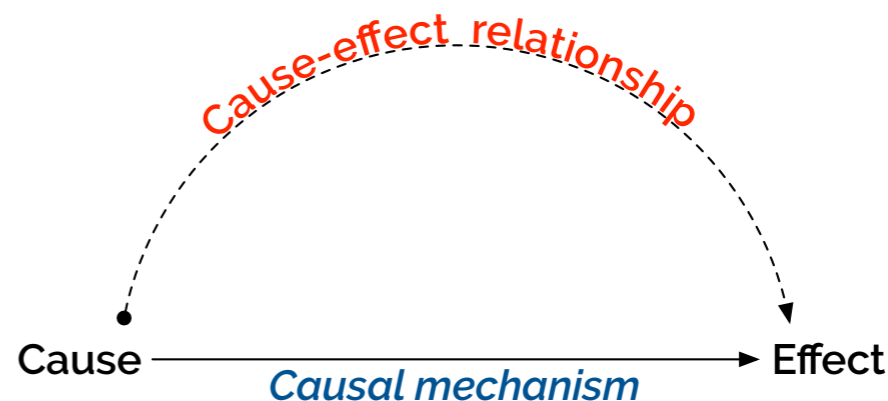
- ▶ Different kinds of attributes lend themselves to different kinds of causal accounts.
 - ▶ Functional attributes support only “black box” accounts of causality.
 - ▶ Mechanistic attributes can support both “black box” accounts and “mechanistic” accounts.
- ▶ Different theories of causality (e.g., regularity, counterfactual) make different assumptions and entail different claims (Markus and Borsboom, 2013).

Two types of attributes

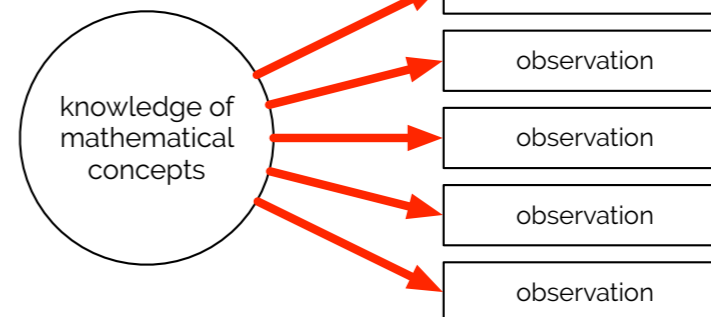
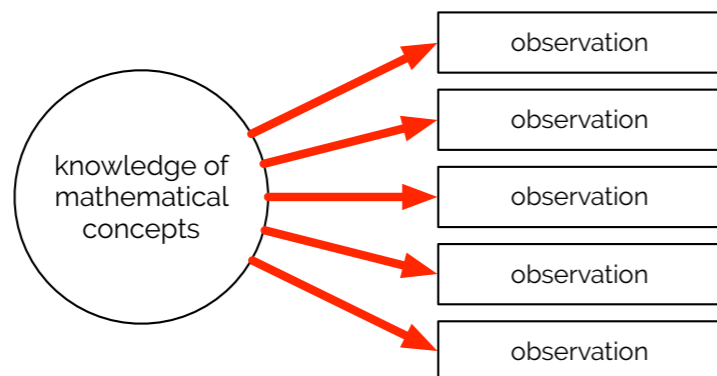
Functional attribute



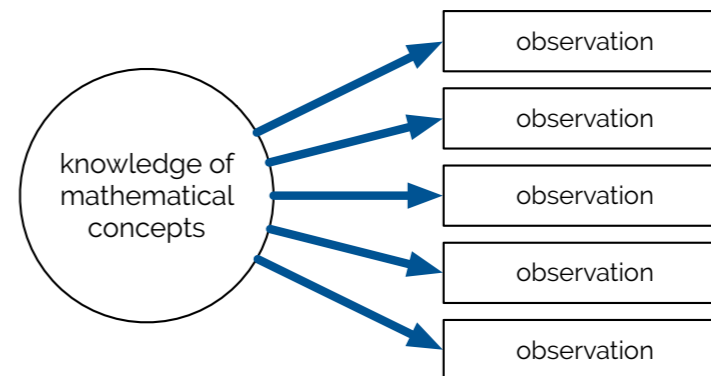
Mechanistic attribute



Black box account



Process account



THE DISTINCTION ABOUT LEVELS

Between and within person levels

- ▶ In the literature this distinction has been made in terms of between-person and within-person causal relations (Borsboom, Mellenbergh & Van Heerden, 2003; Borsboom, 2005; Holland, 1990).
- ▶ *Mathematical problem solving* could be considered at between-person level, useful in terms of characterizing the different outcomes, while at the same time assuming that different persons used different strategies.

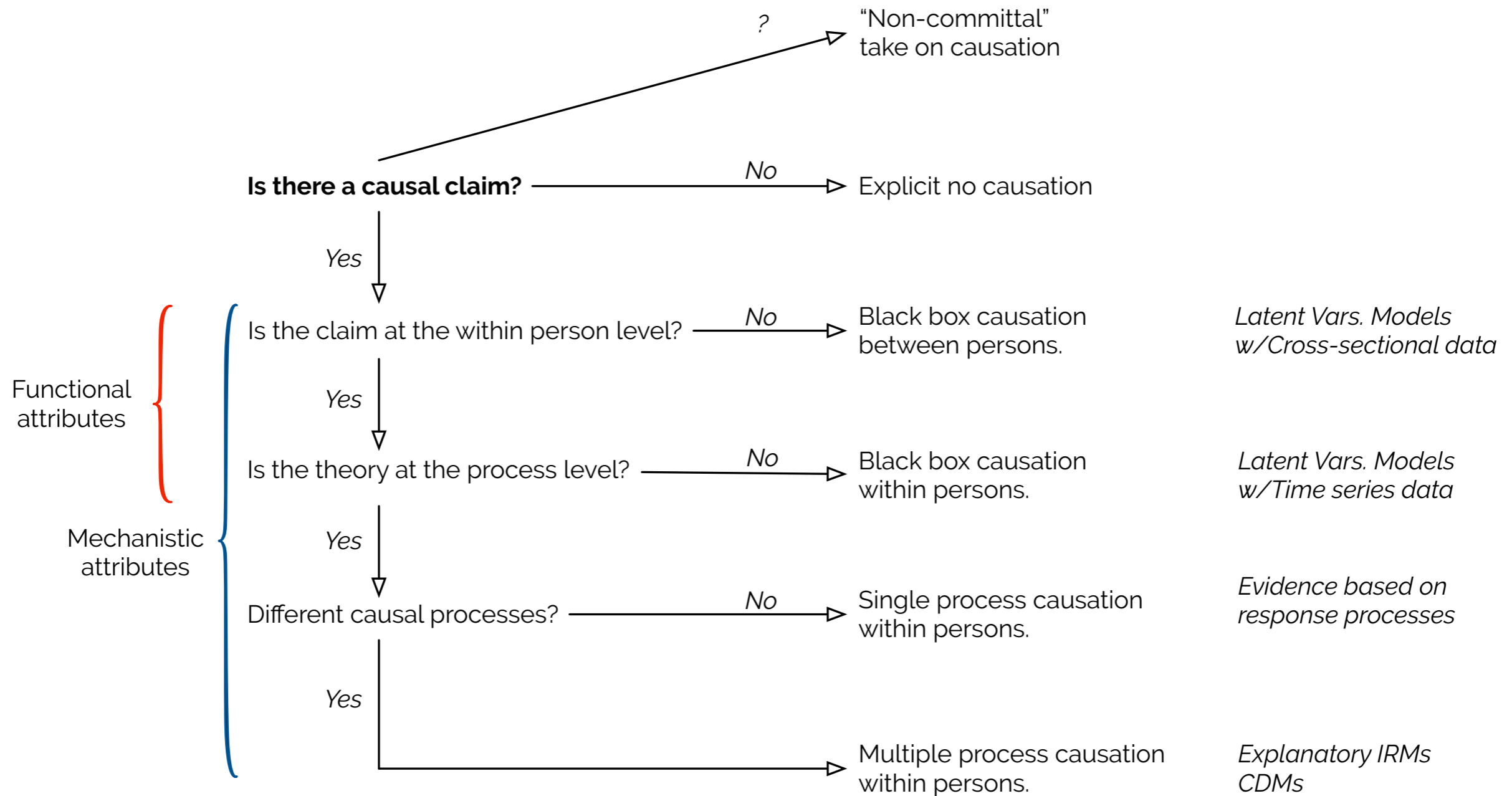
APPLICATION

Bringing the distinctions together into practice.

The worry is not so much that we adopt wrong images with which to represent the world, but rather we will choose wrong tools with which to change it.

— Cartwright, 1999

Mapping the options



Discussion

- ▶ We have attempted to organize several important distinctions associated with causal interpretations in reflective latent variable models.
- ▶ We have argued that different causal inferences demand different kinds of evidence.
- ▶ Dealing with the causal inferences that underlie measurement models is a challenging task, but a necessary one to clarify the scope of our measurement models and their results.

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