Probability, Correlation, Causation: Theoretical Bases

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Three concepts

- Probability
  - An event's probability is the measure of how probable or likely it is that the event will happen
  - It has multiple philosophical analyses; it's not clear what it *is*
  - However, it has a (fairly) unified mathematical treatment, so it can be used
- Correlation
  - A statistical concept: a statistical association between two variables
    - The values taken by one vary in the same way as the values taken by the other
  - Can be calculated
  - Can be used for inferences: predictions; causal inferences
  - But can also be treacherous: certain predictions are *not* reliable, as we will see
- Causation
  - This is not mathematised
  - It is not clear *what* causation is
  - It is not clear *how we can find out about* causal relationships
  - Especially, it is not clear how we move from correlations and probabilities to causation

What is causation?

- I drank a lot of beer and then fell over
- I drank a lot of beer and then a red car drove past

- I studied hard for my test and got a good mark
- I studied hard for my test and it rained

- The President fired the Finance Minister and the currency lost value
- The President fired the Finance Minister and Manchester United lost to Chelsea

Causation is the difference between each of these pairs

Why should we care?

- An association (correlation) was found between caffeine consumption in early pregnancy and low birth weight
- This also means that the probability of low birth weight is higher among children of mothers consuming more coffee
- Is the following true or false?
  - "If women reduce caffeine consumption during pregnancy, low birth weight will become less common"
- This study failed to separate smokers from non-smokers, and smoking causes low birth rate
- So the study provides no reason to support this intervention

Causal knowledge is needed for

predictions

about the outcomes of

interventions

What we'll explore today

1. What is causation?
2. What causal problems arise in occupational health and medicine?

1. What is causation?

Regularity Theory

Counterfactual Theory

Other theories

David Hume's scepticism about "necessary connection"

- We can't *see* a connection (no empirical evidence)
- We can't *logically prove* that a connection is there (no logical argument)
- So, said Hume: we don't have a good reason to believe in "necessary connection" between cause and effect.
- Hume's conclusion: scepticism. But how can we accept this?

$$R_{\max} = \sqrt[4]{\frac{P_S \cdot G^2 \cdot \lambda^2 \cdot \sigma}{P_{E_{\min}} \cdot (4\pi)^3}}$$

The Core Problem

The core problem is reconciling these two claims:

1. Hume's scepticism about causation is persuasive, yet…

2. Causation is objective and mind-independent.

The Regularity Theory

- "we may define cause to be *an object, followed by another, and where all objects similar to the first are followed by objects similar to the second*" (Hume 1748, S. VII Pt. II)
- Causation is just one thing followed by another, without exception

- This is the Regularity Theory of Causation. The simplest version says:
- **C causes E if and only if C's are always followed by E's.**
  - E.g. drinking 10 bottles of beer causes me to fall over (on a particular occasion) if and only if drinking 10 bottles of beer is always followed by me falling over
  - This is what is meant by a *regularity*

Problem 1: coincidences

- I studied hard for my test and it rained
  - In fact, *every time* I study hard for my test, it rains!
- Cause or coincidence? Is there a difference, on the Regularity Theory?
  - We would not employ you to help end the drought…
  - …but can the Regularity Theory explain why?
- Notice that some "regularities" only happen once. E.g. every time I study hard for a 2b philosophy exam in 2016, it rains.

- **SO: the Regularity Theory is can't easily say what the difference is between cause and coincidence**
- ONE RESPONSE: insist that causes are part of BIG regularities. But…

Problem 2: exceptions

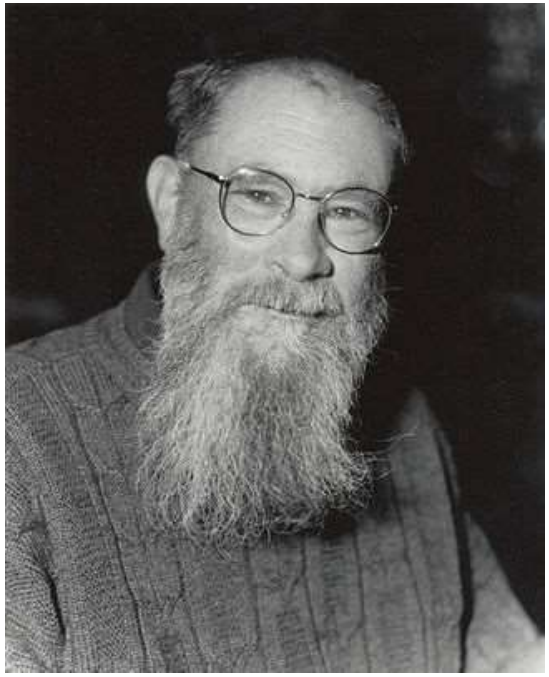
- When I study hard for my test, I get good marks…
  - …except for that time when I drank lots of beer right after I finished studying
- It's quite common for C to cause E, and yet not be followed by E every time. You can easily think of examples.
- One option (proposed by John Stuart Mill in 19th C): insist that "C" must be the *whole cause.*
  - E.g. studying hard and being in good health and not being hungover is always followed by good performance
- But if we go this route, then we specify C in such detail that it only happens once—and we have the coincidence problem again

Problem 3: effects of a common cause

- A barometer is a device that predicts the weather by measuring air pressure. Low air pressure causes storms. So a low barometer reading indicates that a storm is coming.
- Low barometer readings are followed by storms. That's what makes barometers so useful.
- However, a low barometer reading does not *cause* a storm.
  - Rather, both are caused by a drop in air pressure
- The Regularity Theory struggles to distinguish between cause/effect pairs, and effects of a common cause

The Counterfactual Theory

- A counterfactual conditional = a claim about what would have happened, if…
  - E.g. “If I had grown up in New York, I would have had an American accent”
- The Counterfactual Theory of Causation says that causation is counterfactual dependence
- Simplest version:
  - C causes E if and only if, if C hadn’t happened, then E wouldn’t have happened
- David Lewis developed this idea



Dealing with coincidences and exceptions

- If I hadn't studied for my exams, I wouldn't have done well
  - If I hadn't studied for my exams, it might still have rained
  - So, the rain was a coincidence

- Last time I studied for my exams I didn't do so well because I drank beer after studying…
  - …but that doesn't matter: it's still true that on this occasion, if I hadn't studied, I definitely wouldn't have done so well.
  - The Counterfactual Theory doesn't make causation a matter of what happens on *other occasions*, but on *this occasion*
  - So it doesn't say anything about causes being part of exceptionless regularities. There can be exceptions.

Dealing with effects of a common cause (=confounding)

- If the barometer hadn't fallen, the storm would still have occurred…
- Really?
- We need to hold fixed the falling air pressure and ask what would have happened if the barometer hadn't occurred.
  - Lewis says that this is automatic, because there is no "backtracking"
- Then the storm would still have occurred
- (Problem: in the real world, how do we know whether there is some background event that we need to "hold fixed"?)

But now there's another problem: preemption

- Able and Baker are having a competition.
  - Able throws a rock at a bottle, and smashes it
  - Baker throws a moment later, on target, but late
- So if Able hadn't thrown… the bottle wouldn't have smashed
- The problem with the counterfactual theory is: sometimes, if the cause hadn't happened, the effect would have happened *anyway*
- E.g. paracetamol, ibuprofen, and asthma…

The two theories: pros and cons

Regularity Theory

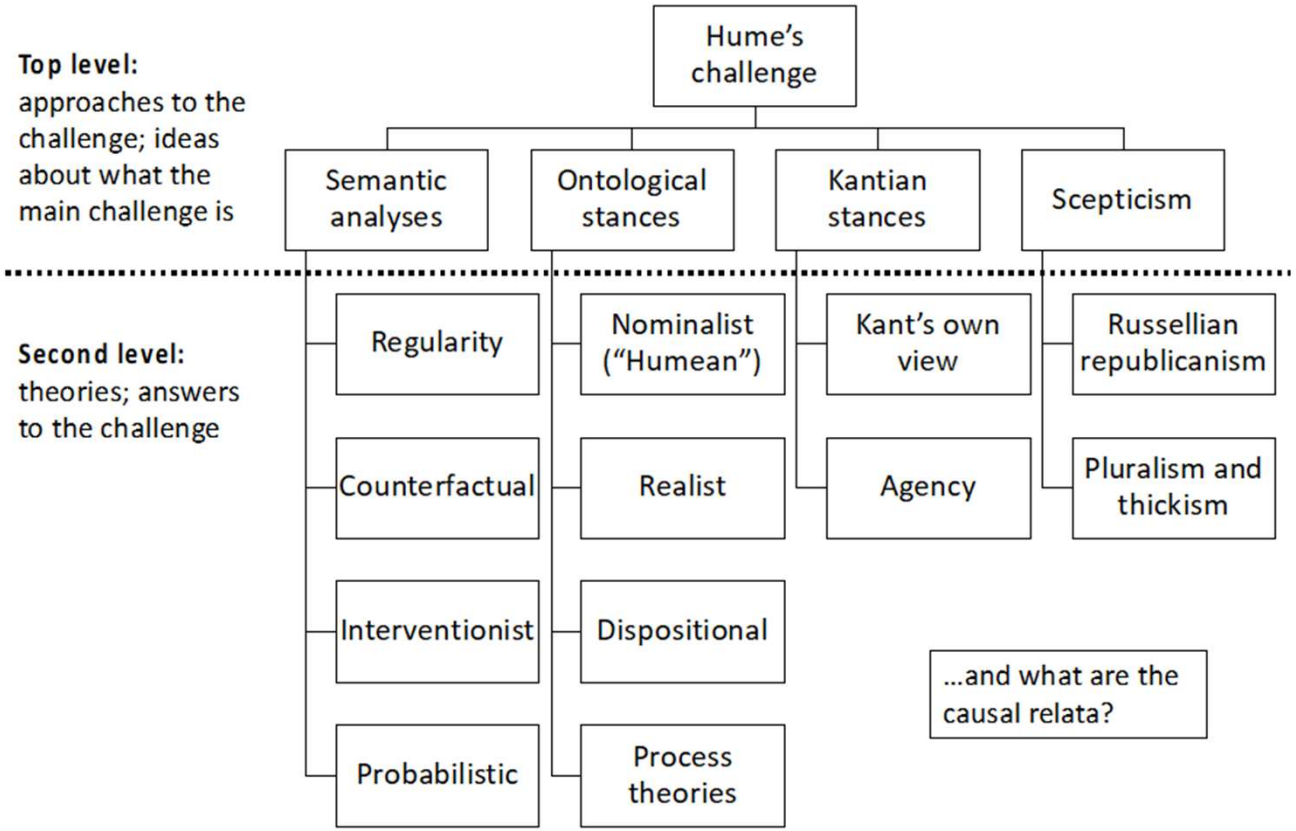
- C causes E iff C's are always followed by E's
- Struggles with
  - Coincidences
  - Exceptions
  - Effects of a common cause

Counterfactual Theory

- C causes E iff, if C hadn't happened, then E wouldn't have happened
- Struggles with
  - Pre-emption

These are the main two ideas answering the question "What is causation?" where that's taken to mean something like "What does 'cause' mean?"

There are many others!



2. What causal problems arise in occupational health and medicine?

Association and causation

Knowledge and action

Populations and individuals

Three Problems

1. Which associations are causal?

2. How do we move from knowledge to action?
   - What will happen if we act?

3. How does population-level causation relate to individuals?

Which associations are causal?

- No easy answer
- The “evidence” movement says: associations identified by randomized controlled trials are causal
- But for many occupational exposures, randomized controlled trials are impossible
- Austin Bradford Hill’s list of nine “viewpoints” remains an extremely practical final step in assessing whether a given association is causal
  - And can also be used to evaluate claims made on the basis of a study, or by an interest group, or…

Hill’s “viewpoints”:

1. Strength of association
2. Consistency
3. Specificity
4. Temporality
5. Biological gradient
6. Plausibility
7. Coherence
8. Experiment
9. Analogy

None is necessary; none is sufficient

They are *not* criteria!

How do we move from knowledge to action?

- Causal knowledge saves us from the coffee/birthweight problem (common cause; confounding)
- But there are still difficulties with some effect measures, especially attributable risk
  - E.g. 10% of mortality is attributable to obesity. But reducing obesity by increased exercise may have a different effect on mortality than by reduced energy intake.
  - E.g. effect of sugar tax may be quantified, but what should one do to optimise the tax?
- Here there is a good answer: frame your causal claim in terms of a (hypothetical) intervention

How do we move from population to individual?

- Suppose there is evidence that depressants cause a reduction in depression risk in a population
- How do you know whether this particular person will benefit?
- No easy answer. But consider:

1. The “evidence” from population-level studies should never be applied to individuals without thinking about their individual characteristics
   - E.g. an “ergonomic” chair may still harm very tall persons
2. Individual evidence and anecdotal evidence matter!
   - Something beneficial for a population may be harmful for subgroups (e.g. ergonomic chair again), or vice versa

Thank you