The Common Cause Principle

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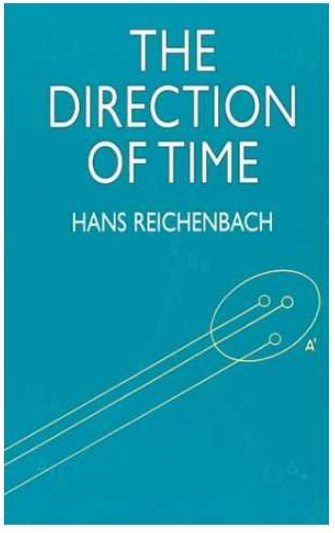
Reichenbach: The Direction of Time



The Common Cause Principle

”If an improbable coincidence has occurred, there must exist a common cause” (p. 157)

Two examples: ”Suppose both lamps in a room go out suddenly. We regard it as improbable that by chance both bulbs burned out at the same time and look for a burned out fuse or some other interruption of the common power supply. The improbable coincidence is thus explained as the product of a common cause.” (p. 157)

”Or suppose several actors in a stage play fall ill showing symptoms of food poisoning. We assume that the poisoned food stems from the same source – for instance, that it was contained in a common meal – and then look for an explanation of the coincidence in terms of a common cause.” (p. 157)

Reichenbachian Common Cause

Classical probability measure space: (Ω, Σ, p)
Positive correlation: $A, B \in \Sigma$

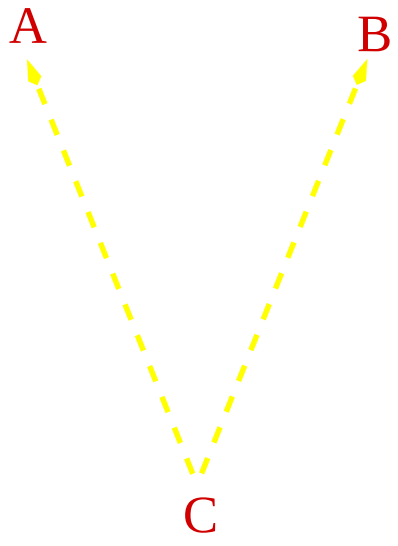
$$p(AB) > p(A)\,p(B) \tag{1}$$

Reichenbachian common cause: $C \in \Sigma$

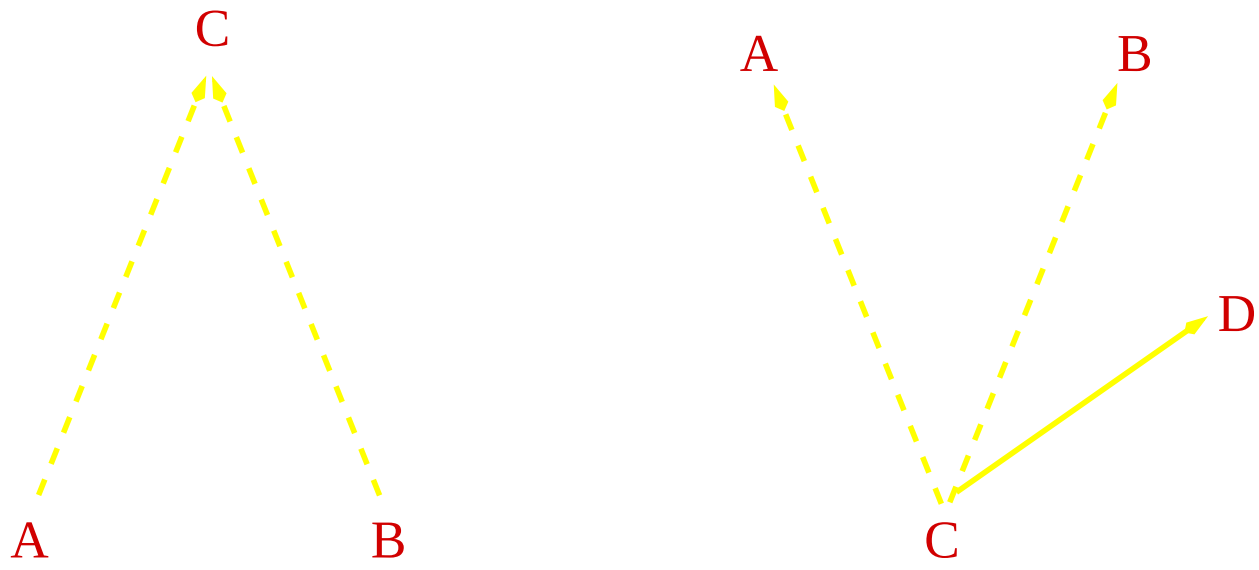
$$\begin{aligned} p(AB|C) &= p(A|C)p(B|C) && (2)\\ p(AB|C^{\perp}) &= p(A|C^{\perp})p(B|C^{\perp}) && (3)\\ p(A|C) &> p(A|C^{\perp}) && (4)\\ p(B|C) &> p(B|C^{\perp}) && (5) \end{aligned}$$

The Common Cause Principle

”If coincidences of two events A and B occur more frequently than would correspond to their independent occurence, that is, if events satisfy relation (1), then there exists a common cause C for these events such that the fork ACB is conjunctive, that is satisfies (2)-(5)” (p. 163)



Sufficiency and Necessity



Not sufficient: (2)–(5) are not sufficient for an event C to be a common cause of the correlation between A and B.

Necessary?

Origin of the Common Cause Principle?

Russell: common causal ancester: ”When a group of complex events in more or less the same neighbourhood and ranged about a central event all have a common structure, it is probable that they have a common causal ancester.” (*Human Knowledge*, p. 483)

- ”A number of middle-aged ladies in different parts of the country, after marrying and insuring their lives in favour of their husbands, mysteriously died in the baths. The identity of structure between these different events led to the assumption of a common causal origin; this origin was found to be Mr. Smith, who was duly hanged.” (p. 482)

Explanatory Power

Explanatory power of the common cause:

- C screens the correlation between A and B off.
- C has (positive) statistical relevancy to both A and B.
- C entails (positive) correlation between A and B.

Reichenbach's Common Cause Principle

Reichenbach's Common Cause Principle (RCCP): If there is a correlation between two events A and B and a direct causal connection between the correlated events is excluded then there exists a (Reichenbachian) common cause of the correlation.

Question: What is the metaphysical status of the common cause?

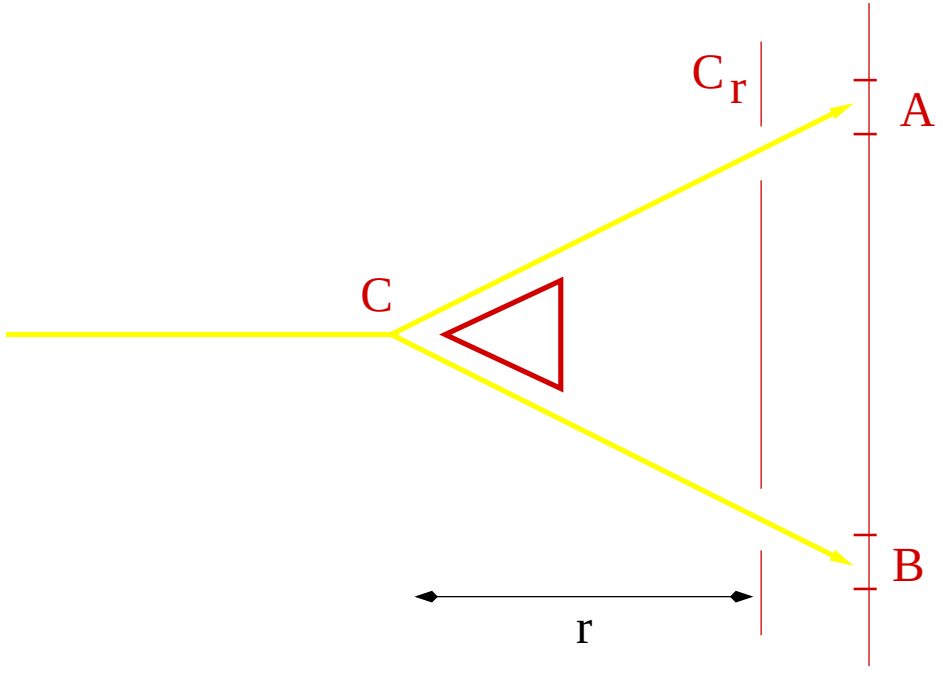
Four positions: Bas C. van Fraassen, Nancy Cartwright, Eliott Sober, Jeremy Butterfield

Van Fraassen

”My main objection to the common cause principle has been that it demands hidden variables of the deterministic sort, leaving little room for genuine, non-trivial indeterministic theories.” (Van Fraassen 1982)

Argument: perfect correlation + genuine indeterminism (no hidden variables) $\Rightarrow$ RCCP is not universal

The Lead Bullet and the Knife Edge

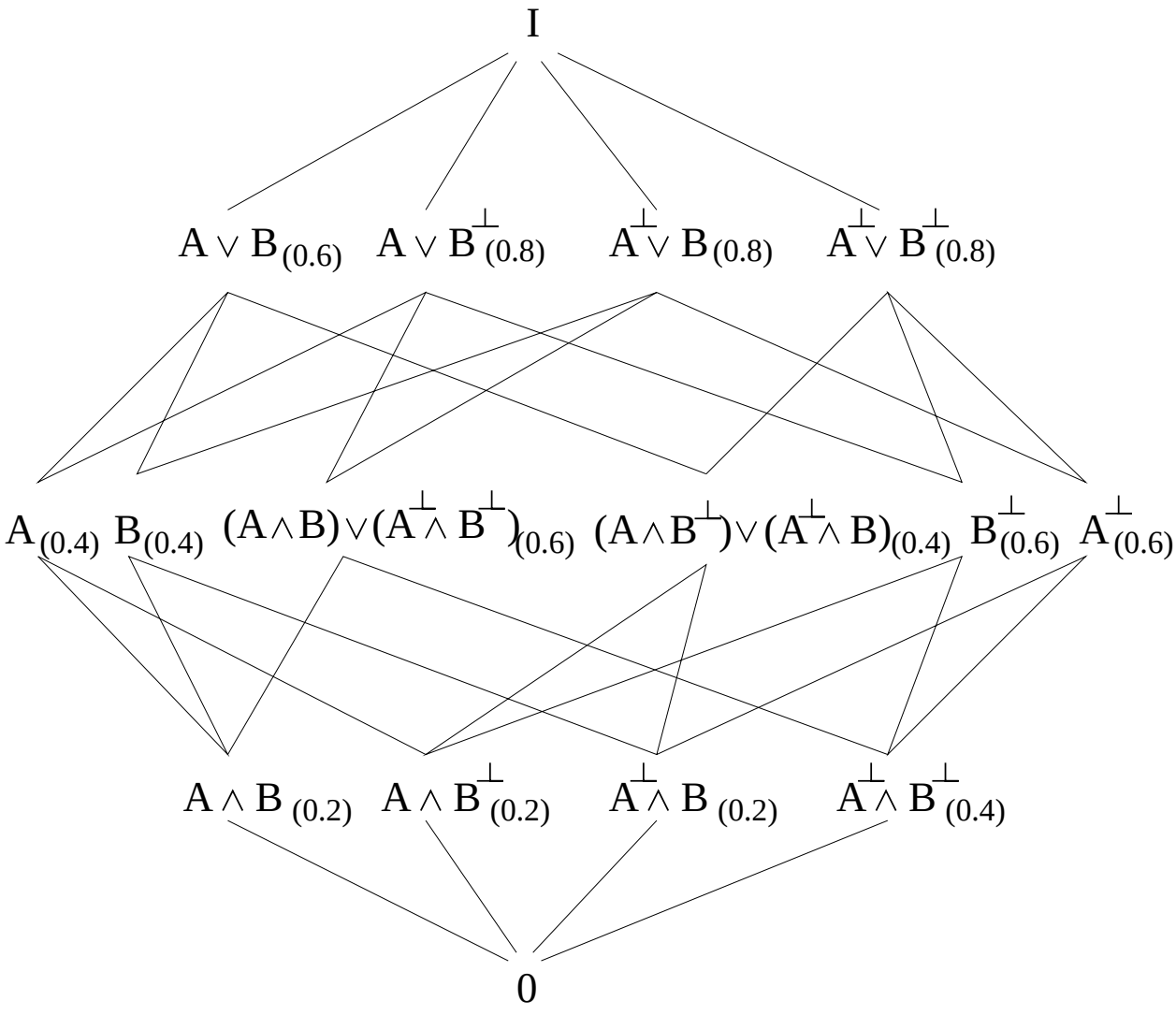


- Indeterministic scattering: $p(A) = p(B) = \frac{1}{4}$
- What is the common cause?
  - C_r: built-in correlation
  - C: does not screen off

Van Fraassen

Conclusion: RCCP is ”a *tactical maxim* of scientific inquiry and theory construction” (Van Fraassen 1982)

Remark: common cause incompleteness



Extendability

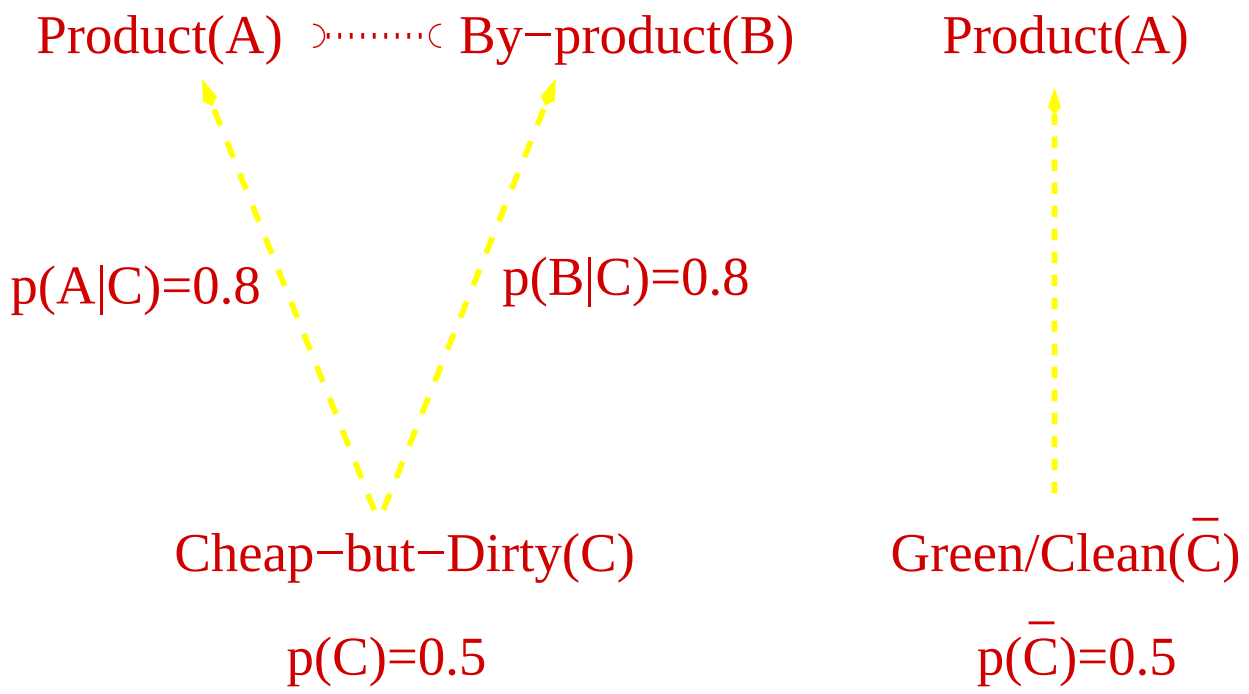
Extendability 1: Let (Ω, p) be a classical probability measure space and let (A, B) a correlating pair in Ω. Then there is a (Ω', p') extension of (Ω, p) such that for the correlation (A, B) there exists a Reichenbachian common cause C in (Ω', p'). (Hofer-Szabó, Rédei, Szabó, 1999)

Extendability 2: There exists an (Ω, p) classical probability measure space and two correlating pairs (A_1, B_1) and (A_2, B_2), respectively in Ω such that there is no (Ω', p') extension of (Ω, p) which contains a Reichenbachian *joint* common cause C in (Ω', p') for both correlations. (Hofer-Szabó, Rédei, Szabó, 2000)

Cartwright

”Van Fraassen style counterexamples do not show that there is anything fundamentally mistaken about the common cause idea, but rather that Salmon, following Reichenbach, has not been employing sufficiently general characterizations of it.” (Cartwright 1987)

The Cheap-but-Dirty Factory



Determinism: presence of the cause = operation of the cause

Indeterminism: presence of the cause $\neq$ operation of the cause

In indeterministic case any degree of overlap between the operations of the cause is possible.

Cartwright

Conclusion: ”The cause operates independently in producing each of its effects: whether one of the effects is produced or not has no bearing on whether the cause will produce the other.” (Cartwright 1987)

New nomenclature: ”not-very common-cause condition”

Sober

"Consider the fact that the sea level in Venice and that cost of the bread in Britain have both been on the rise in the past two centuries. Both, let us suppose, have monotonically increased. Imagine that we put this data in the form of a chronological list; for each date, we list the Venetian sea level and the going price of the British bread. Because both quantities have increased steadily with time, it is true that higher than average sea levels tend to be associated with higher than average bread prices. The two quantities are very strongly positively correlated." (Sober 1987)

Sober's counterexample

Year (t)	1	2	3	4	5	6	7	8
British Bread Prices	4	5	6	10	14	15	19	20
Venetian Sea Levels	22	23	24	25	28	29	30	31

A: higher than average British bread prices
B: higher than average Venetian sea level

Positive correlation: $\frac{1}{2} = p(AB) > p(A)p(B) = \frac{1}{4}$

A: British bread prices increase

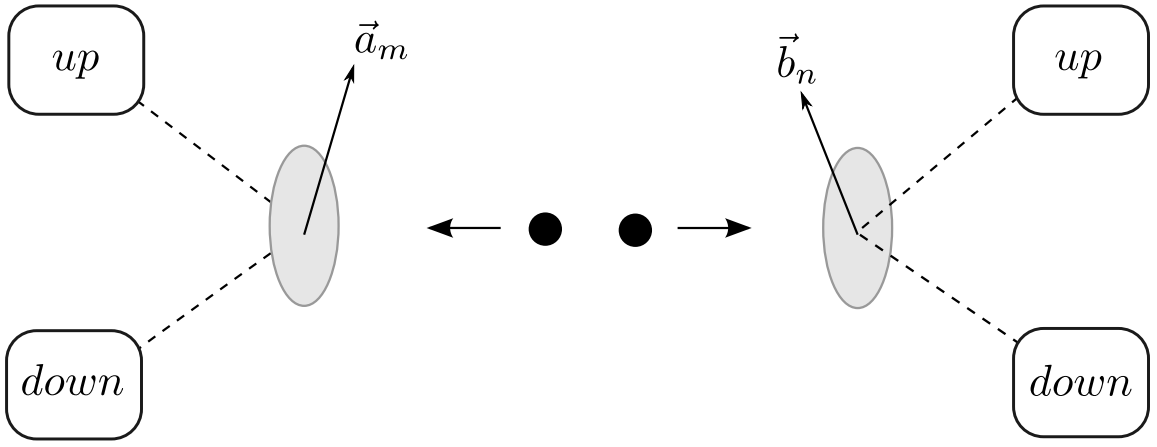
B: Venetian sea level increases

No correlation: $1 = p(AB) = p(A)p(B) = 1$

Butterfield

”. . . the statement that there is always a screener-off is false. But its falsity will not be a consequence of straightforward examples of van Fraassen’s; it will be a consequence of the Bell experiments’ results.” (Butterfield 1989)

EPR correlations



- Conditional correlations $(m, n = 1, 2)$:

$$p(A_m B_n | a_m b_n) \neq p(A_m | a_m)\, p(B_n | b_n)$$

where A_m, B_n are measurement *outcomes* and a_m, b_n are measurement *choices*.

Common causal explanation

Local, non-conspriratorial joint common causal explanation: a partition $\{C_k\}$ in Σ such that:

$$p(A_m B_n | a_m b_n C_k) = p(A_m | a_m b_n C_k)\, p(B_n | a_m b_n C_k) \qquad \text{(screening-off)}$$

$$p(A_m | a_m b_n C_k) = p(A_m | a_m C_k) \qquad \text{(locality)}$$

$$p(B_n | a_m b_n C_k) = p(B_n | b_n C_k) \qquad \text{(locality)}$$

$$p(a_m b_n C_k) = p(a_m b_n)\, p(C_k) \qquad \text{(no-conspiracy)}$$

Clauser–Horne inequality

Screening-off

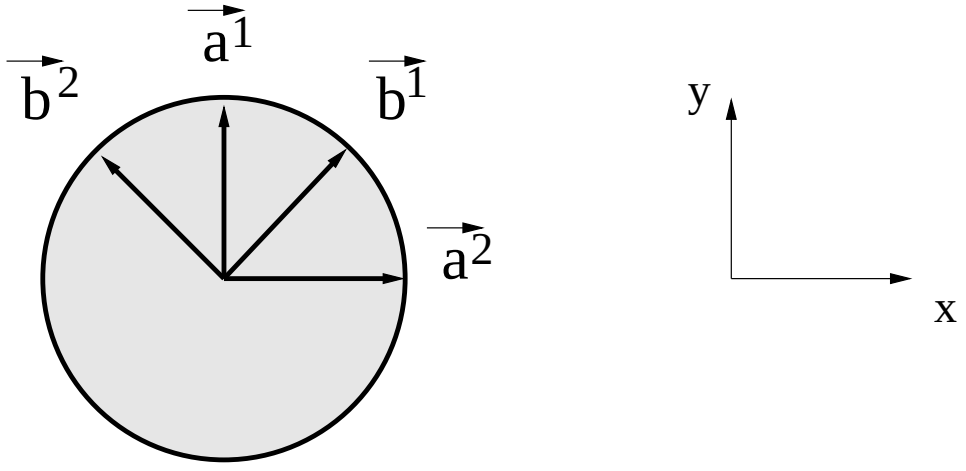
Locality $\Longrightarrow$ Bell inequality

No-conspiracy

$$-1 \leqslant p(A_1B_1|a_1b_1) + p(A_1B_2|a_1b_2) + p(A_2B_1|a_2b_1)$$
$$-p(A_2B_2|a_2b_2) - p(A_1|a_1) - p(B_1|b_1) \leqslant 0$$

Clauser–Horne inequality

... which is violated for the setting:



Conclusion: RCCP is not valid in QM.

Conclusions

”... assessing the status of the Principle of the Common Cause is a very subtle matter requiring a careful investigation of both the principle itself and the evidence for/against it provided by our best scientific theories.

Specifically, the arguments from the above mentioned counterexamples to the failure of the Common Cause Principle are too quick. What makes this perilous speed possible is in part the ambiguity and vagueness of the counterexamples in question: Almost invariably, the probabilistic framework in which the counterexamples would be well-defined is not specified explicitly; this has the consequence that the problem of validity and falsifiability of the Common Cause Principle does not get a conceptually and technically sharp formulation.” (Hofer-Szabó, Rédei, Szabó, 2012)

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Defusing Sober's counterexample

Note: RCCP refers only to physical correlations

Question: How are "higher than average sea levels" and "higher than average bread prices" physically realized?

A possible answer:

Year (t)	1	2	3	4	5	6	7	8
British Bread Prices	4	5	6	10	14	15	19	20
Venetian Sea Levels	22	23	24	25	28	29	30	31

Physical realization: Pick one year out of 8 randomly and check whether the value of sea level / bread price in that year is higher than the average

Claim: The picking is a Reichenbachian common cause (system)