Title: Making Sense of Relativistic Causality Conditions

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Making Sense of Relativistic Causality Conditions

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What makes a theory relativistic?

- Two sorts of considerations:
  - The theory's dynamical symmetries match the symmetries of Minkowski spacetime.
  - The theory respect the causal structure of Minkowski spacetime:
    1. The causes of an event lie in its past light-cone.
    2. No cause-effect relations between spacelike separated events.
  - These are logically independent.
    - In Axiomatic QFT, (1) is enforced by requiring Lorentz Covariance.
    - (2) requires, in addition, the Microcausality condition, which is a nontrivial constraint.

Causal modelling

- A popular way of dealing modelling causal relations: *interventionist*, or *manipulability* accounts.
- To understand the effects of a change in a variable X, consider an *intervention* on X.
- An *intervention* on a variable X sets its value, independently of any causal antecedent (that is, its value is treated as given exogenously, set by some process that we're not modelling within our theory).
- The effects on a variable Y of changing the variable X are seen by comparing what things are like for two (or more) values of X.

A problem

- If the theory is meant to be a comprehensive physical theory, we should be able (in principle, at least) to model our experimental apparatus within it.
- How to make sense of intervention?
- Judea Pearl: "If you wish to include the entire universe in the model, causality disappears because causal interventions disappear. . . ."
- If the dynamics of the theory are deterministic, two solutions that differ in the value of a parameter X differ also at all times to the past of the "setting" of X, including events to the causal past of Y.
- A state (quantum) or solution of the dynamical equations (classical) is global, specifying what happens for all space and time; does it make sense to talk about the value of one variable changing another?

Wrong answers

- *Exceptionalism*: There are some things (perhaps free-willed experimenters?) that are exempt from the laws of physics.
- *Eliminativism*: When the subject matter is fundamental physics, causal conceptions are out of place.
  - Ruetsche, again (*Interpreting Quantum Theories*)

    Soberly viewed all the special theory of relativity (STR) can be taken to demand of a theory set in Minkowski spacetime is that it exhibit Lorentz covariance. And this demand is met by QFTs in its scope, provided they satisfy the Covariance axiom—*even if they violate the Microcausality axiom*!

The way forward

- Note that there's nothing particularly quantum about the worry.
- Just as a state in QFT is a global state, a solution of the field equations of classical electromagnetism is a global solution.
- Nonetheless, part of the content of an undergraduate course in EM is how to create EM waves via an oscillating current.
- EM admits of a formulation in which sources (charges and currents) are treated exogenously.
- QFT can also be formulated with exogenous (c-number) fields.
- One can compare solutions with different values of these fields.

Principles of physical theorizing

- (Widely accepted in some quarters): It should be possible to model our experimental apparatus within physical theory (at least schematically). A comprehensive physical theory should be capable of describing everything; we should have to take measurement as primitive.
  - This has teeth: modelling the apparatus within a QFT, as coupling locally to the fields, does away with "impossible measurements."
- (I propose): A physical theory should also be capable of *not* describing everything; it should admit of a formulation with exogenous parameters. These give us a handle on which to hang causal talk.
- We should be able to switch back and forth between a *totalizing* perspective, in which everything relevant is modelled within the theory, and a *limited* perspective, in which variables such as experimental settings are treated as exogenous.

Do totalizing and limited perspectives conflict?

- Treating a parameter X as exogenous means treating its value as set independently of what has gone on before, or, at least, independently of past events that have an influence on the phenomenon being studied that doesn't go through X.

Thank you