

# Niels Bohr on Causal Explanation

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Bertrand Russell thought that causation is a folk [anthropomorphic] concept that has no place in a fundamental description of the world.

*The law of causality, I believe, like much that passes muster among philosophers, is a relic of a bygone age, surviving, like the monarchy, only because it is erroneously supposed to do no harm. (Russell, 1913, p 12)*

Niels Bohr thought that physics provides occasion to clarify and sharpen our most fundamental concepts.

*The significance of physical science for philosophy does not merely lie in the steady increase of our experience of inanimate matter, but above all in the opportunity of testing the foundation and scope of some of our most elementary concepts. (Bohr, 1958, p 308)*

## Philosophical background to Bohr's stance

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# Rationalism versus Empiricism

- The Law of Causality = The Principle of Sufficient Reason:  
Nothing happens without a cause
- Hume (1711–1776) argued that “ $C$  causes  $E$ ” cannot mean anything more than that events of type  $C$  have tended, in our experience, to be followed by events of type  $E$ .
- Kant (1724–1804) argued that the PSR is valid in the realm of experience.

## Harald Høffding on causality

- Hume is mistaken to assume that “thing” is unproblematic, while “cause” is problematic.

*The concept of a thing cannot be clear or valid, when the concept of cause is not. (Høffding, 1892, p 238)*

- It's impossible to prove or disprove the law of causality.

*Experience can never provide a full confirmation of the Law of Causality. (Høffding, 1892, p 241)*

- Methodological principle

*The Principle of the Conservation of Energy has the significance of a methodological principle which pushes us to look for equivalents for each quantum of matter or energy that seems to appear or disappear. (Høffding, 1892, p 36)*

- Our minds attempt to find continuity among events

*In every circumstance, we seek to conceive of that which happens as a continuous process, whose first and last elements we call cause and effect. The concept of causality is the expression for this striving. (Høffding, 1892, p 240)*

## Peculiarities of Bohr's views about causality

- Conservation laws

*A careful reading of Bohr's discussions of the notion of complementarity reveals that in this context he takes the applicability of a causal description to mean the applicability of the laws of conservation of energy and momentum. (Ben-Menahem, 1989, p 313)*

- Indispensable for the human experience of the world.

*All account of physical experience is, of course, ultimately based on common language, adapted to orientation in our surroundings and to tracing relationships between cause and effect. (Bohr, 1958, p 308)*



# The quantum challenge for causality

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## Bohr's doubts about causality

*The unrestricted applicability of the causal mode of description to physical phenomena has hardly been seriously questioned until Planck's discovery of the quantum of action. (Bohr, 1939b, p 11)*

*The interesting arguments brought forward more recently by Einstein ... rather than supporting the theory of light quanta will seem to bring the legitimacy of a direct application of the theorems of conservation of energy and momentum to the radiation process in doubt. (Bohr, 1921, p 413)*

## Bohr's doubts about causality

*As a result of the previous considerations, a general description of the phenomena, in which the laws of the conservation of energy and momentum retain in detail their validity in their classical formulation, cannot be carried through. (Bohr, 1924, p 40)*

- Bohr-Kramers-Slater theory
- Beta decay

# Complementarity as a generalization of the principle of causality

- Bohr: The discovery of QM settles (for now) the validity of the conservation principles.

*The establishment of rational methods of quantum mechanics and electrodynamics [has] proved the compatibility of the existence of the quantum of action with the strict validity of the conservation laws in all such phenomena as electron diffraction and Compton effect. (Bohr, 1936, p 25)*

- Several of Bohr's later articles focus on the concept of causality.

*With the foregoing analysis we have described the new point of view brought forward by the quantum theory. Sometimes one has described it as leaving aside the idea of causality. I think we should rather say that in the quantum theory we try to express some laws of nature which lie so deep that they cannot be visualised, or, which cannot be accounted for by the usual description in terms of motion. (Bohr, 1931)*

*Every application of conservation theorems, for instance to the energy balance in atomic reactions, involves an essential renunciation as regards the pursuance in space and time of the individual atomic particles. In other words, the use of the idea of stationary states stands in a mutually exclusive relationship to the applicability of space-time pictures. (Bohr, 1932, p 375)*

*Space time co-ordination and dynamical conservation laws may be considered as two complementary aspects of ordinary causality which in this field exclude one another to a certain extent, although neither of them has lost its intrinsic validity. (Bohr, 1932, p 376).*

## Causality as an idealization

No system is truly closed; no particle is truly free from all external forces.

*We are not acquainted with any absolutely isolated and closed totalities; and only for such is the Law of Conservation of Energy valid in the strictest sense. (Høffding, 1892, p 36)*

*The very nature of quantum theory thus forces us to regard the space-time coordination and the claim of causality . . . as complementary but exclusive features of the description, symbolizing the idealization of observation and definition respectively. (Bohr, 1927, p. 54)*












# Summary





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*Far from containing any mysticism contrary to the spirit of science, the view-point of 'complementarity' forms indeed a consistent generalization of the ideal of causality. (Bohr, 1939a, p 269)*

*... far from involving any arbitrary renunciation of the ideal of causality, the wider frame of complementarity directly expresses our position as regards the account of fundamental properties of matter presupposed in classical physical description, but outside its scope. (Bohr, 1958, p 314)*

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