Contextuality of Reason, Contextuality of Reality, and the Nature of Probabilities Involved

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The Global Order in Danger

- Another conference held in this building

  A Crisis in the Global Order?

  sounds like the global inconsistency paradigm of contextuality
  - Countries are locally consistent, but globally inconsistent. No global order to glue locally consistent countries together.
  - If countries are not locally consistent, you need the CbD theory.
- Is this a political contextuality?

The End of History

The present inconsistency in the global order would refute Francis Fukuyama's thesis of the End of History:

> *"What we may be witnessing is not just the end of the Cold War, or the passing of a particular period of postwar history, but the end of history as such; that is, the end point of mankind's ideological evolution and the universalization of Western liberal democracy as the final form of human government."* (The End of History and the Last Man)

I just wanted to quote this to move on to the Gödel's thesis of the "End of Theoretical Science", which sounds equally provocative.

The End of All Theoretical Science

Quantum physics even compelled Gödel to assert the "end of all theoretical science":

> *"[T]he development of philosophy since the Renaissance has by and large gone from right to left [...] Particularly in physics, this development has reached a peak in our own time, in that, to a large extent, the possibility of knowledge of the objectivisable states of affairs is denied, and it is asserted that we must be content to predict results of observations. This is really the end of all theoretical science in the usual sense" (*The modern development of the foundations of mathematics in the light of philosophy*)*

Quantum cognitive science has a similar impact on our conception of the world and ourselves therein?

What Quantum Cognition Tells Us at the End of the Day?

- How does quantum cognitive science impact our worldview as a whole?
  - It arguably elucidates the fundamental nature of human reason, such as rationality and contextuality.
  - I talked about this in Prague, so here will think of:
- Does it imply the end of something? End of some realism?

The Meaning of No-Go Results

- Bell-type No-Go results often exhibit obstructions to classical realism (e.g., local realism).
    - Apart from non-classical realism, did classical realism end in the quantum revolution? Does it compel us to eliminate classical elements from quantum physics?
- Do violations of Bell-type inequalities in cognitive experiments refute any realism?
    - More broadly, how do they affect the realist wordlview?
- What demarcates cognitive from quantum contextuality?
    - These are the questions I want to address in this talk.

1. **The Realism Debate and the Status of Classical Elements**

2. **Cognitive Contextuality versus Physical Contextuality**

1. The Realism Debate and the Status of Classical Elements

Bohr's classical-quantum dualism

- Let us first focus upon the (non-)end of classical realism in physics.
    - Although Bohr's philosophy is controversial, it is relevant here.
- Bohr mostly took strange features of quantum theory at face value, yet at the same time advocated the necessity of classical concepts in physics.
- His philosophy may be called the classical-quantum dualism; to him, classical concepts are indispensable in physics. Why?

Bohr's Indispensability Argument

Bohr argues as follows:

> *"[O]nly with the help of classical ideas is it possible to ascribe an unambiguous meaning to the results of observation" (*Atomic Theory and the Description of Nature*)*
>
> *"No more is it likely that the fundamental concepts of the classical theories will ever become superfluous for the description of physical experience. [...] It continues to be the application of these concepts alone that makes it possible to relate the symbolism of the quantum theory to the data of experience" (ibid.)*

Bohr's Indispensability Argument

- Bohr's philosophy was influenced by his Neo-Kantian teacher Harald Hoffding (Faye 1991; Beller 2001),
- Hoffding, in turn, built his philosophy upon Heinrich Hertz's, an influential Neo-Kantian at that time (Christiansen 2006).
    - Hertz and Helmholtz were well-known advocates of the so-called Back-to-Kant movement.
- Even the early Wittgenstein's picture theory was influenced by Hertz's picture theory (Kjaergaard 2002).

The Bohr-Hoffding-Hertz-Hilbert Link

- Hilbert was another thinker under the Neo-Kantian influence.
- "The axioms are, as Hertz would say, pictures or symbols in our mind" (Hilbert 1893-1894).
- "Hilbert became acquainted with Hertz's book on the foundations of mechanics [...] This book seems to have provided a final, significant catalyst for the wholehearted adoption of the axiomatic perspective" (Corry 2004).
    - Hertz might be the greatest influencer in modern science.
- Now I argue that there is an interesting Neo-Kantian parallelism between Bohr and Hilbert.

Bohr's Classicism and Hilbert's Finitism

- Bohr (1949): "[H]owever far the [quantum] phenomena transcend the scope of classical physical explanation, the account of all evidence must be expressed in classical terms."
  - Bohr thus aimed at the justification of the quantum by the classical.
- Hilbert (1926; 1928): However far the [infinitary] phonomena transcend the scope of finitistic explanation, the account of all justifications must be expressed in finitistic terms.
  - Hilbert aimed at the justification of the infinitary (ideal) by the finitary (real). This is the gist of his programme; conservativity of ideal (ZFC) over real (PRA) is equivalent to consistency.

Bohr's Classicisim and Hilbert's Finitism cont'd

- Hilbert: the source of meaning in mathematics is finitistic concepts (only finitistic statements have meaning on their own; Zach 2003).
- Bohr: the source of meaning in physics is classical concepts; "only with the help of classical ideas is it possible to ascribe an unambiguous meaning to the results of observation."
- Bohr is an instrumentalist about quantum theory (Faye 2002); Hilbert an instrumentalist about infinitary mathematics.

Bohr's Classicisim and Hilbert's Finitism cont'd

- Bohr's Neo-Kantian Philosophy: classical concepts give the condition of possibility of experimental verification, and so of empirical knowledge.
- Hilbert's Neo-Kantian Philosophy: finitism gives the condition of possibility of mathematical verification (esp. consistency proofs), and so of mathematical knowledge.
- Bohr's idea of classical concepts works like meta-theory, which is usually finitism in proof theory; e.g., you usually prove theorems about quantum logic over classical meta-theory.

The Infinity and Unsolvability Theses

Paul Erdös, who worked at Purdue, says:

> *In a way, mathematics is the only infinite human activity. It is conceivable that humanity could eventually learn everything in physics or biology. But humanity certainly won't ever be able to find out everything in mathematics, because the subject is infinite.*

Hilbert strongly argued every mathematical problem is solvable ("there is no *ignorabimus*"; if the formal system of mathematics is r.e. axiomatizable and complete, there is an algorithm to do this); it was a counterargument to Emil du Bois-Reymond, who listed the unsolvable Seven World Riddles including those on consciousness.

2. Cognitive Contextuality versus Physical Contextuality

Back to Quantum Cognition

- Let us come back to quantum cognitive science.
- Does it involve any sort of Quantum Brain Thesis?

No Quantum Brain

Tegmark (2000):

- "Based on a calculation of neural decoherence rates [...] the degrees of freedom of the human brain that relate to cognitive processes should be thought of as a classical rather than quantum system."
- "This conclusion disagrees with suggestions by Penrose and others that the brain acts as a quantum computer, and that quantum coherence is related to consciousness in a fundamental way."

If this is correct, there is no coherent quantum (effects on the) brain. Then, no problem on classical realism about the brain.

The Classical Brain Assumption

- I assume Tegmark is correct; the cognitive mechanism of the human brain is classical; human beings are classical macroscopic objects within the scope of classical realism.
  - We shall later use this Classical Brain Assumption.
  - This is comparable with Bohr's Classical Observer Thesis.
- To be fair, Penrose actually does not claim the brain is a quantum computer (Hameroff does).

Penrose on Quantum Computing

Penrose, "Consciousness Involves Noncomputable Ingredients", 1995:

- "When I argue that the action of the conscious brain is noncomputational, I'm not talking about quantum computers. Quantum computers are perfectly well-defined concepts, which don't involve any change in physics; they don't even perform noncomputational actions."
- "I don't think it can explain the way the brain works. That's another misunderstanding of my views."

Tegmark understood the brain, but did not understand Penrose's.

The Fundamental Limitation

- When things like the technological singularity thesis prevail in the society, it might be significant to recall Penrose's argument.
- Whether Penrose is correct or not, it is a mathematical fact that there is a fundamental limitation on the realm of computability.
- However powerful machine learning, quantum computation, and the like are, they still cannot go beyond the fundamental limitation either.

Quantum Cognition and Penrose's Thesis

- Is there any room for quantum effects in cognition?
- Functionalism: mental states are characterized by what they do rather than by what they are made of.
    - The essence of the mind is the cognitive function rather than the material substance; cf. Cassirer's *Substance and Function*.
- Different functions of the mind may be explained by different quantum-like models.
    - We call this the Quantum Mind Thesis as opposed to the Quantum Brain Thesis such as Penrose's.
- This functional Quantum Mind Thesis would be safer, and better explain the reality of quantum cognitive science.

Cognitive Contextuality versus Quantum Contextuality

- What demarcates cognitive contextuality from quantum contextuality?
- How does cognitive contextuality impact our conception of the world?
- We do not have a complete answer, but shall point out several relevant points.

Why Must the Cartesian Dualism Be a Dualism?

- Analyzing contextuality in physics and in cognition would tell us commonalities between the laws of Nature and the laws of Reason.
    - The Cartesian dualism may be resolved this way.
- Yet it would also tell us fundamental differences between the science of matter and the science of mind, or why the Cartesian dualism must be a dualism rather than a monism.
    - The Cartesian dualism may be reinforced that way.
- Understanding the relationships between cognitive and physical contextuality would contribute to this broader task of elucidating the Cartesian dualism.

The Fundamental Problem of Psychology

Like quantum systems, cognitive systems are sensitive to contexts of measurement.

- Unlike them, cognition is so embedded in contexts that contextual effects cannot adequately be controlled.
  - They are "beings-in-context" (cf. Dreyfus' situated AI).
  - "Life is warm, wet, and noisy."
  - Physical experiments are also subject to contextual noise, which can still mostly be controlled.
- Both internal and external noise, caused by uncontrollability on mental states and by uncontrollability on environments.

This, in particular, threatens reproducibility in cognitive and life sciences, and also lead to statistical violation of no-signalling.

Cognitive Holism versus Quantum Holism

Dzhafarov et al. have emphasized the violation of no-signalling / marginal selectivity / local consistency.

- Quantum Physics: wholes ($\otimes$) are not direct sums ($\times$) of parts.
- Psychology: parts are not direct restrictions of wholes.
- The relationships between parts and wholes are even more complex in psychology than in quantum physics.

This is a difference at the mathematical level; there would be more differences at different levels.

Origins of Probabilities

Where are origins of probabilities in quantum physics and in psychology?

- Physics: you get statistics by repeating an experiment on a single state (e.g., entangled state).
  - Probabilities come from the state per se.
- Psychology: you get statistics by repeating an experiment on different subjects in different mental states (e.g., someone on a university campus).
  - Probabilities do not come from any specific state.

To elucidate the difference, let us think of Laplace's demon.

The Experimental Demon

The theoretical Laplacian demon has the infinitary power of exact computation.

- The experimental Laplacian demon has the infinitary power of precise experimentation.
- In particular, the demon can fix every hidden parameter of an experiment in any noisy environment.
  - Let the demon perform the experiment as above.
- The demon repeats the experiment countless times. Yet he always gets the same result since he fixed every parameter.
  - The classical brain assumption is applied here.
- Hence no probabilities in the demon's psychology experiment.

To the demon, no indeterminacy or contextuality in cognition.

Quantum Contextuality Is Immune to the Demon

- What if the demon performs contextuality (or non-locality) experiments on quantum systems?
- The demon cannot erase contextuality by manipulating parameters since quantum contextuality is caused by the intrinsic properties of states and measurements.
- Rather the demon would obtain a more precise detection of contextuality in the system.

Put Another Way

- Probability models in quantum physics (such as Bell's) arise by measuring a single state in different contexts.
- Those in cognitive science (such as Cervantes-Dzhafarov's) arise by measuring different states in different contexts.

Intrinsic versus Extrinsic Probabilities

- At a mathematical level, cognitive and quantum contextuality have basically the same statistical structure.
- As to the nature of probabilities, quantum contextuality concerns intrinsic probabilities; probabilities come from the nature of a state measured.
- Cognitive contextuality concerns extrinsic probabilities; they come from the nature of different states collected together.

The Contextual Infinite Regress

- For excat prediction in cognitive science, you have to take into account all relevant hidden contexts.
- This leads to the same kind of infinite regress as in the frame problem. Impossible to consider all possible relevant contexts.
- The only demon can erase contextuality; the human being could not.
- If the demon conducts experiments on different states without fixing parameters, the demon may observe contextuality.

Concluding Remarks

Summing up:

- There is a conceptual parallelism b/w Bohr's classicism and Hilbert's finitism; Bohr's philosophy may be given a logical interpretation.
- The human mind is both classical and quantum: its hardware, the material brain, is classical / deterministic; its software, the cognitive function, can be quantum(-like) / indeterministic.

Concluding Remarks cont'd

What particularly demarcates cognitive from quantum contextuality would be the following:

- Physical Bell-type results refute classical realism about single state dynamics.
- Cognitive Bell-type results refute classical realism about collective state dynamics.
    - Each single state is classical in psychology as shown by the demon's thought-experiment.

Cognitive contextuality may lead to the infinite regress; it is impossible to explicate all relevant contexts.