A structural perspective on quantum cognition

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Outline

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Quantum Cognition

Quantum cognition is an emerging field; the literature on it has rapidly expanded in the last 10 or 15 years.

- Quantum cognition is interdisciplinary, involving psychology, linguistics, decision theory, behavioural economics, and so fourth.
  - N/B: Quantum cognition includes super-quantum one.
- Is it a “new kind of science”? Or a new kind of “fashionable nonsense”?
- I argue it is, at least, relevant to a new kind of philosophy.

Quantum cognition also allows us to shed new light on the fundamental nature of human reason, such as rationality and contextuality.

Typical Topics

Typical topics of quantum cognition include:

- The order effect in psychology.
  - Q_1 (resp. Q_2): Is Clinton (resp. Al Gore) honest and trustworthy. Q_1 and Q_2 are non-commutative.
- The conjunction effect in cognitive biases.
  - $Prob(\varphi \wedge \psi) \leq Prob(\psi)$ does not hold in the Linda experiment.
- The disjunction effect in the prisoners' dilemma.
  - Rational decision theory: a prisoner defects regardless of whether the other prisoner defects or not. But experimentally violated.
- Quantum cognition exploits quantum mechanical models (or GPTs) to account for such non-classical features of cognition.

Logically, these effects may be interpreted in terms of substructural logic.

My Background

- I have worked on categorical dualities. Also worked on logic and philosophy.
    - I have never worked on psychology, let alone quantum psychology.
- But I have published two articles in philosophy of mind:
    - M., "AI, Quantum Information, and External Semantic Realism", Synthese Library, 2016.
    - M., "The Frame Problem, Gödelian Incompleteness, and the Lucas-Penrose Argument", Springer SAPERE, 2018.
- Both link cognition with physics. AI is the computational theory of mind. Information Physics (IP for short) is the computational theory of the universe.
- I have elucidated their link, e.g., by a new distinction b/w weak and strong IP, and by arguments about their limits of computability.

Motivation

Quantum cognition is particularly interesting to me because:

- If there are structural mechanisms shared by both physics and cognition, it would pave the way for overcoming the Cartesian dualism of matter and mind.
  - Higher structural laws of information govern actual laws of matter and of cognition.
  - This would embody Chalmers' property dualism or double-aspect theory of information.
- If category theory is unified science, it has to give a stream-lined account of matter, life, and mind (while keeping pluralism / non-reductionism).

Also because the government gave me a nice grant under a recent scheme to promote quantum life sciences.

Remarks

- Roots of AI are in Czech.
- The term “robot” was coined by Karel Capek (based on “robota” in Czech).
- “Golem” in the Jewish myths is an even older form of the idea of robot, said to have an origin in Prague.

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Penrose's Argument for Material QMT

Roger Penrose (1989, 1994) argues:

- (i) AI or the computational theory of mind is misconceived in light of Gödelian incompleteness.
  - The (notorious) Lucas-Penrose argument; the capacity of human cognition is not bound by computability.
  - Gödel (1955): "the human mind (even within the realm of pure mathematics) infinitely surpasses the power of any finite machine" or "there exist absolutely unsolvable diophantine problems."
- (ii) The mind is materially quantum; consciousness emerges via material quantum processes in microtubules.
  - It is the Material Quantum Mind Thesis (Material QMT for short).

Approx. 200 pages of his *Shadows of the Mind* are devoted to replies to criticisms.

Interlude: Gödel's Philosophy of Physics

Gödel (born in Brno), *The modern development of the foundations of mathematics in the light of philosophy* (lecture never delivered):

> *"[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"*

Some equate Gödel's position with naïve realism, but he is not a simple realist. Indeed, he tries to reconcile the "right" ($\sim$ realism) and the "left" ($\sim$ antirealism).

I link this with philosophy of duality in my Dynamics of Duality paper (2017).

Chalmers against Penrose

David Chalmers (1999) argues against Penrose:

- "Why should quantum processes in microtubules give rise to consciousness, any more than computational processes should?"
- "[R]eader who is not convinced by Penrose's Gödelian arguments is left with little reason to accept his claims that physics is non-computable and that quantum processes are essential to cognition."

10 years later:

- Pothos-Busemeyer (2009): "the success of human cognition can be partly explained by its use of quantum principles."
- There is now some reason to accept Penrose's claim that "quantum processes are essential to cognition"? Not processes but principles.

Structural QMT

Fix Penrose's argument by replacing (i) computability by complexity, and (ii) the material QMT by the structural QMT:

- (i) Classical AI or the classical computational theory of mind is misconceived in light of the super-classical features and effectiveness of human cognition.
  - The mind cannot be a classical computer due to differences in complexity.
- (ii) The mind is structurally quantum; the structure of cognition is homomorphic to the structure of quantum information.
  - It is not that quantum processes are materially going on in the macroscopic physical brain; Tegmark (2000), e.g., computationally refutes Penrose's claim on microtubules.
  - The structure of economic systems is homomorphic to that of physical systems; this never means the nature of economy is materially physical.

The universe is a materially quantum computer; the mind a structurally quantum one.

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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-the-world" (cf. Dreyfus' embedded/situated AI).
  - A life scientist colleague told me a quote, "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, resp.

Contextual effects make state preparation difficult in psychology, in which it is unclear what kind of cognitive states is to be measured.

Super-Quantum Cognition

Especially, cognition violates no signalling (marginal selectivity) as noted by Dzhafarov et al.

- The relationships between parts and wholes are even more complex in psychology than in quantum physics.
  - Cf. Heisenberg, *Der Teil und das Ganze*, 1969.
- Quantum Physics: wholes ($\otimes$) are not direct sums ($\times$) of parts.
  - Analogous to Gestalt psychology. Generally called holism.
- Psychology: parts are not direct restrictions of wholes.
  - What is a general term for this?

They extend Bell-type inequalities to take such effects into account, and show proper contextuality in cognition.

Bell-type No-Go Results in Cognitive Science

Quantum cognition seems to share the same spirit as Bell-type thms. to a certain extent.

- Quantum Physics: classical models of physics do not hold any more.
    - Because there are non-local / contextual effects in fundamental reality.
- Psychology: classical models of cognition / decision do not hold any more.
    - Because there are contextual effects in human reason.
    - We need new models to take into account non-classical features of cognition.

Context influences cognition, whether directly or not (e.g., prisoner's).

Human Rationality Is Unselfish

Amartya Sen (1977):

> *[T]he puzzle from the point of view of rational behavior lies in the fact that in actual situations people often do not follow the selfish strategy. Real life examples of this type of behavior in complex circumstances are well known, but even in controlled experiments in laboratory conditions people playing the Prisoners' Dilemma frequently do the unselfish thing.*

Classical rationality is selfish, and human rationality sometimes unselfish, as Sen says. Quantum rationality can be unselfish.

Concluding Remarks

Summing up:

- I have discussed the conceptual significance of quantum cognition, reformulating Penrose's idea as the structural QMT.
- Contextuality in cognition does matter for two reasons: it explicates the nature of human rationality, and it elucidates the embeddedness or situatedness of Being (relevant in AI as well).

Remarks:

- Cervantes-Dzhafarov (2017) is interesting in many respects.
  - E.g., a probabilistic model discussed there indicates that global inconsistency does not ensure contextuality; it does in the framework of Abramsky et al. But logical Bell inequalities also can be extended so as to be applicable to signalling situations.