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What are the mechanics of quantum cognition?
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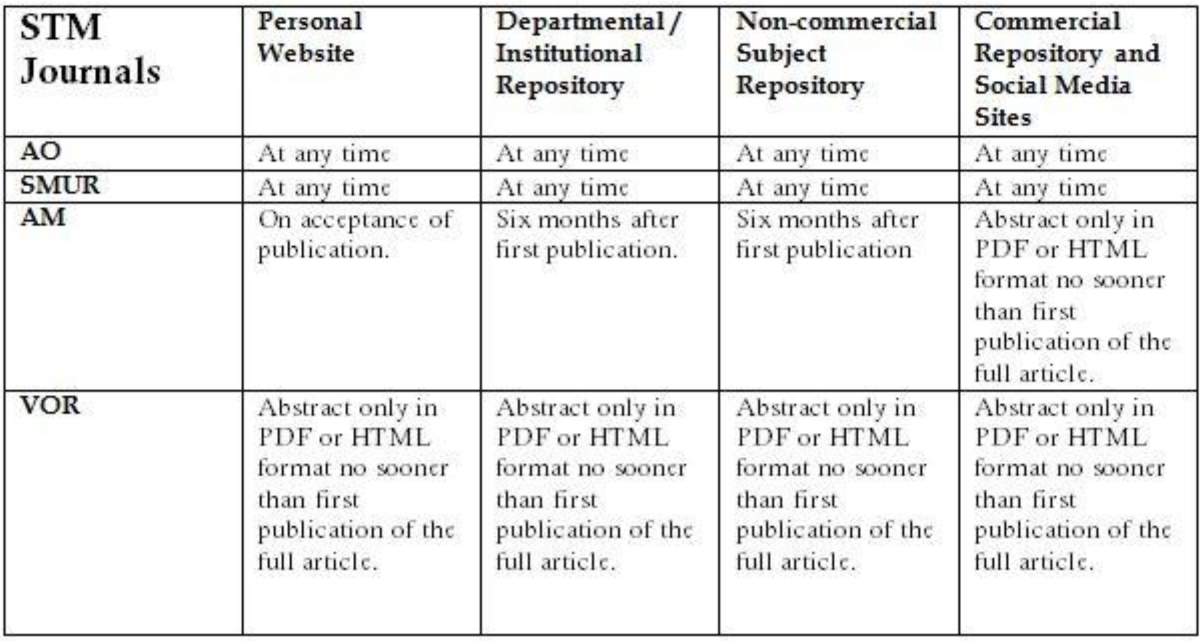

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Abstract:

Pothos and Busemeyer argue that quantum probability (QP) provides a descriptive model of behaviour and can also provide a rational analysis of a task. We discuss QP models using Marr's levels of analysis, arguing that they make most sense as algorithmic level theories. We also highlight the importance of having clear interpretations for basic mechanisms such as interference.

Main text:

What kind of explanation does a cognitive model offer? A standard way of approaching this question is to use Marr's (1982) three levels of explanation. A "computational analysis" provides an abstract description of the problem that the learner must solve, along with a normative account of how that problem should be solved. Bayesian models of cognition are usually computational level explanations. An "algorithmic level" explanation describes a mechanistic process that would produce human-like behaviour in some task. Most traditional information processing models and many connectionist models lie at this level of explanation. Finally, "implementation level" explanations propose a low level physical explanation of how the brain might perform the computations that are required. These are the kinds of models typically pursued in cognitive neuroscience.

Whereabouts in this classification scheme should we place the quantum probability (QP) framework? The implementation level is the simplest to consider. Pothos and Busemeyer explicitly disavow any implementation level interpretation of these models; making a clear distinction between their work on the formal modelling of cognition using a quantum formalism and those researchers (e.g., Hameroff 1988) who argue that neural function should be modelled as a quantum physical system. We agree with this distinction.

Should QP models be treated as computational level analyses? Although Pothos and Busemeyer make explicit comparisons to classical probability and to Bayesian models, we do not think it makes sense to treat QP models as computational level analyses. The critical characteristic of a computational analysis is to specify what problem the learner is solving, and to present a normative account of how that problem should be solved. Bayesian models work well as computational analyses because of the fact that classical probability provides good rules for probabilistic inference in everyday life. In discussing this issue, Pothos and Busemeyer point to problems associated with statistical decision theory (e.g., that Dutch books are possible in some cases), or to well known issues with the Kolmogorov axioms (e.g., sample spaces are hard to define in real world contexts). However, in our view their discussion misses the forest for the trees: showing that classical probability has limitations does not establish QP as a plausible alternative. There is a good reason why statistics is built on top of classical probability and not quantum probability: it is the right tool for the job of defining normative inferences in everyday data analysis. In contrast, although there are such things as "quantum t-tests" (e.g., Kumagai & Hayashi 2011), they have yet to find a natural role within everyday statistical analysis. It is possible that such usage may emerge in time, but we think this is unlikely, simply because the situations to which such tools are applicable (e.g., data follow a quantum Gaussian distribution) do not arise very often when analysing real data. Until statistical tools based on QP find a place in everyday data analysis, we remain unconvinced that QP makes sense as a normative account of everyday inference.

What about the algorithmic level? Here, we think that Pothos are Busemeyer are on more solid ground: there is some justification for thinking about QP models as mechanistic accounts. Consider the model used to account for Shafir and Tversky's (1992) data on the prisoner's dilemma. It relies on an interference effect to account for the fact that participants defect whenever the opponent's action is known but co-operate when it is unknown. This interference does not emerge as part of an optimal solution to the inference problem given to the decision maker, nor is it characterised at a neural level. It is clearly intended to refer to a psychological mechanism of some kind.

In view of this, a mechanistic view of QP seems to provide the right way forward, but at times it is difficult to understand what the mechanisms actually are. To take a simple example, why are some questions incompatible and others are compatible? Pothos and Busemeyer suggest that "[a] heuristic guide of whether some questions should be considered compatible or not is whether clarifying one is expected to interfere with the evaluation of the other". This seems sensible, but it begs the question. One is naturally led to ask why some psychological states interfere and others do not. This is difficult to answer because the QP formalism is silent on how its central constructs (e.g., interference) map onto psychological mechanisms. In our own work (Fuss & Navarro, under review) we have explored this issue in regards to the dynamic equations that describe how quantum states change over time. Specifically, we have sought to describe how these equations could arise from mechanistic processes, but our solution is specific to a particular class of models and we do not claim to have solved the problem in general. In our view, understanding how formalisms map onto mechanisms is one of the biggest open questions within the QP framework.

In short, we think that the potential in QP lies in developing sensible, interpretable psychological mechanisms that can account for the otherwise puzzling inconsistencies in human decision making. It might be that human cognition cannot be described using the standard provided by classical probability theory, but turns out to be more consistent with QP theory. That doesn't make QP a good tool for rational analysis, but it would make it an interesting psychological mechanism, particularly if it is possible to provide clear and consistent interpretations for its central constructs. Should events unfold in this way, then statistics would continue to rely on classical probability for its theoretical foundation, but cognitive modellers could use quantum probability in many instances. There is nothing incompatible about these two states.

References:

Fuss, I. & Navarro, D. J. (under review). Open parallel cooperative and competitive decision processes: A potential provenance for quantum probability decision models. Submitted to *Topics in Cognitive Science*.

Hammeroff, S. R. (1998). Quantum computation in brain microtubules? The Penrose-Hammeroff "orch-or" model of consciousness. *Philosophical Transactions of the Royal Society A, 356*, 1869-1896.

Marr, D. (1982). *Vision: a computational investigation into the human representation and processing of visual information.* San Francisco: W. H. Freeman.

Shafir, E. & Tversky, A. (1992). Thinking through uncertainty: nonconsequential reasoning and choice. *Cognitive Psychology, 24*, 449-474.

Kumagai, W. & Hayashi, M. (2011). Quantum hypothesis testing for quantum Gaussian states: Quantum analogues of chi-square, t and F tests. Available as arXiv preprint arXiv:1110.6255v1