Review of "Does Quantum Information Require Additional Structure?", by Ryszard Horodecki (*Foundations of Physics* 55:17, 2025)

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Philosophical study of the foundations of quantum information theory finds its apogee in the masterly book-length study of Timpson (2013). Among the many views and arguments considered and assessed in that book is the position of 'informational immaterialism', which begins with the thought that "perhaps information itself should be recognized as the fundamental constituent of the world, rather than those putative constituents provided by the more foundational story of a mechanics of particles and fields: the story of a mind-independent world of material things" (Timpson 2013, p. 70). I take this position to have been rebutted decisively by Timpson, who argues (quite famously) among other things that

> pieces of [information] are *abstracta*. To be realized they will need to be instantiated by some particular token or other; and what will such tokens be? Unless one is *already* committed to immaterialism for some reason (and let me not be coy: there can be no *good* reason why one would be), these tokens will be material physical things. So even if one's fundamental (quantum) theory makes a great deal of [information], it will not thereby dispense with the material world. One needs tokens along with the types. (Timpson 2013, p. 71)

Given the strength and prominence of these arguments—with which, for what it's worth, I concur entirely—it's perhaps surprising to find articles which continue to defend something like informational immaterialism in something like the above form; the article under review here is one such.[1] I take the central claims of this article to be the following:[2]

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[1]In this case, my guess would be that the reason is that the author—a prominent physicist—simply has not been exposed to philosophical works such as Timpson (2013), which of course can't be held against them.

[2]The article is somewhat marred by a number of grammatical and typographical errors, and—more significantly—a quite free-association approach to argumentation. I want to try to be helpful in this review, so I won't dwell further on any of this.

1. To emphasise the 'correspondence principle', which, as the author has it, is "the problem of the relationship between physical reality and mathematical models, including the role of universal constants" (p. 2).

2. To "propose an interpretation of the wave function as a mathematical representation of quantum information" (p. 2).

3. To revive a model of 'quantum relational continuum space' proposed by Chyliński (1985).

Let me take each of these in turn.

Ad (1), there are two points to make. The first is that the correspondence between mathematical models of physical theories on the one hand, and the physical world on the other, is one of the central questions in the literature on scientific representation (on which see e.g. Frigg and Nguyen (2021) for a primer); as such, the 'correspondence principle' of this article is not novel. The second point is that the nature of constants of nature is also a well-studied topic in the philosophical literature—see e.g. Jacobs (2022) and Johnson (1997). Going forward, I would invite the author, and others interested in these topics, to look into these works.

Ad (2): this position strikes me as being very akin to the informational immaterialist view introduced above. Unfortunately, the present article does not adduce new arguments for this position; as such, I take it that the criticisms from Timpson (2013) remain decisive against it. (The paper's project isn't aided by the fact that we are offered no clear definition of quantum information: the closest we get is that "*quantum information is what is carried by quantum systems*" (p. 6, emphasis in original), which is not particularly illuminating.) In any case, building upon these apparently informational immaterialist ideas, the article then (in §6) goes on to propose a 'quantum relational space hypothesis'. The idea here seems to be that, if the world is fundamentally comprised of (quantum) information, then there must be some sub-quantum and (because of informational immaterialism) non-spatiotemporal level of reality. The author associates with this more fundamental level of reality a configuration(-like?) space, $Q_{\rm rel}$, and writes (on p. 9) that "the space of quantum relations involves intrinsic quantum degrees of freedom such as spin, color, and smell" (smell?). The biggest problem with this picture as presented in the article is that the relations between these levels (quite apart from the information-theoretic constitution of the sub-quantum level) is not pinned down with any degree of precision. In addition (and to add to these problems), the paper is rather equivocal regarding whether the 'standard' quantum level is to be understood in terms (as I would have thought preferable) of an ontology of quantum states etc., or rather purely operationally (the author on occasion speaks of "clicks" and "measurements").

Ad (3): Whatever the merits of the work of Chyliński (1985), more would need to be said to link results of that work to the basic, quantum information-theoretic ontology which the author of the present piece seems to be after, since that work—as far as I can tell—does not in fact seem to have to do with such concepts.

All-in-all, then, my verdict is this. The achievements of the author of the present piece in the field of quantum information can hardly be overstated (see e.g. Horodecki et al. (2009)). But the challenges for a quantum information-theoretic approach to the fundamental ontology of quantum mechanics remain legion, and it's not obvious (to me, at least) that this article makes much progress in meeting those challenges. That being said, I hope that what I've said here might still be helpful, insofar as I've tried to direct foundations-curious physicists (always a laudable trait) in the direction of the existing philosophical literature and challenges on these topics.

Acknowledgments

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