Shared Reality in
Epistemic Interpretations of QM

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1 Introduction

The Frauchiger-Renner thought experiment [1], an extension of the famous *Wigner's friend paradox*, has evoked a lot of discussion in the quantum mechanics (QM) community in recent years, especially concerning interpretations of QM. The authors showed that three prima facie plausible assumptions are inconsistent, so that any correct interpretation of QM needs to reject at least one of them (or point out and reject a 'hidden' assumption underlying the derivation of the inconsistency). The three assumptions are:

- (Q): any agent[1] can use QM to reason about any system around him (including macroscopic ones, possibly encompassing other agents) and make predictions about measurement outcomes;
- (C): agents can reason *as if* from the point of view of another agent, i.e. upon establishing 'some other agent must be certain of fact p', they can conclude fact p for themselves;
- (S): from the perspective of any agent, measurement outcomes have unique outcomes.

The authors go on to discuss interpretations that reject each of the assumptions. For assumption (S), they name many-world interpretations. However, Nurgalieva and Renner [2] point out that, as long as one does not allow for one single agent, after performing a measurement of e.g. the spin of an electron in some direction, to say 'I observed spin up *and* spin down' (but instead, as most many-world theories do, claims that there are now two distinct agents, both continuous with the agent before performing the measurement, one saying 'I observed spin up' and one saying 'I observed spin down'), then assumption (S) is not violated. Hence, the space of rejectable assumptions is reduced by one (unless one admits agents making such contradictory claims). In this paper, I want to discuss interpretations that assertively deny assumption (C).

Specifically, the interpretations I want to consider are *QBism* and *relational quantum mechanics* (RQM), which are sometimes referred to as epistemic interpretations.[2] In section 2, I examine the motivations for epistemic interpretations in general and outline the two interpretations in detail, highlighting their view of observers, the role of QM in general, and the status they assign to quantum states and probability. As both interpretations focus on the perspectives of observers, the notion of a shared reality between observers becomes non-obvious and, indeed, both theories are often accused of being solipsistic. In section 3, I want to consider possible ontologies of a reality that is shared between perspectives. Lastly, in section 4, I compare the proposed ontologies and discuss possible future developments thereof.

[1] The authors mostly use the term 'agent'rather than 'observer'. I use both terms interchangeably.
[2] My understanding of QBism and RQM, as presented in this paper, is based predominantly on [3–8].

2 Epistemic interpretations of quantum mechanics

Many interpretations of QM assume that the quantum state of some system describes the system in a way that is identical for all observers of the system, and that there is a uniquely correct quantum state for any system at any given time; hence the state describes an inherent property of the system 'by itself'. Furthermore, a measurement performed on a quantum system affects the system directly and produces a definite result; e.g. after measuring the spin of an electron in some direction that was previously in a superposition, the electron then 'really has' whatever spin was observed.

Most saliently, this is the case for the *conventional Copenhagen* interpretation, as espoused i.a. by Bohr and Heisenberg, where observers are treated as classical systems and the wave function of some observed quantum system collapses (or in more modern terms: the state vector assumes an eigenstate of the respective observable) when the quantum system is observed by some observer; the question of what exactly counts as an observer and whether to treat a measurement apparatus as a classical extension of the observer or itself as a quantum system is left unspecified has been the subject of numerous debates. Less obviously, traditional *many-worlds* interpretations, like that by Everett, also presuppose an observer-independent status of quantum states: upon the occurrence a quantum event with multiple possible outcomes, the universe, in its objective entirety, *branches*, such that there are then multiple equally real universes, one for each outcome. But crucially, to the observers of each particular branch, the quantum states of the systems around them are still definite and unique.[3]

To illustrate the problems of the observer-independent view of quantum states and measurement outcomes, consider the famous *Wigner's friend* paradox (in the 'friend-in-a-box' version from [2, §3]; see there for a more detailed description): a quantum system R is in a lab with Wigner's friend F, while Wigner himself, W, is waiting outside the lab; by thought-experimental idealisation, we assume that the lab containing R and F is 'perfectly isolated'. For concreteness, let us take R to be an electron whose spin is to be measured in some fixed direction by F at an agreed-upon time; we initialise R to be in the state $\sqrt{\frac{1}{2}}\big(|up\rangle_R + |down\rangle_R\big)$ and assume that both F and W know this. Then, after performing the measurement, from the perspective of F, the state of R is either $|up\rangle_R$ or $|down\rangle_R$. From the perspective of W, however, if he treats the lab as a composite quantum system $R + F$ and hence models the measurement as a unitary evolution (at the agreed-upon time),[4] the lab will be in a superposition $\sqrt{\frac{1}{2}}\big(|up\rangle_R \otimes |\text{'}\mathit{I\ observed\ spin\text{-}up}\text{'}\rangle_F + |down\rangle_R \otimes |\text{'}\mathit{I\ observed\ spin\text{-}down}\text{'}\rangle_F\big)$. Furthermore, by 'tracing out' F, we get that from the perspective of W, the system R is still in the original superposition. This clearly contradicts the view that the quantum state assigned to a system describes the system in an observer-independent way (when accepting assumption (Q)), since F and W simultaneously assign differing state vectors to R.

An alternative is to view the quantum state as encoding information about the system relative to an observer; this is the general approach taken by QBism as well as by RQM. Both are in a class that Pienaar [6][5] calls 'Copenhagenish' interpretations (adopting the term from Matt Leifer), in that they agree on four general principles: (i) a measurement does not entail a branching of the world (no many-worlds), (ii) the status of quantum states is 'broadly epistemic', i.e. it encodes information, (iii) QM can be applied to all physical systems (corresponding to assumption (Q)), (iv) QM is a complete theory without hidden variables. For the purpose of the present discussion, point (ii) is most relevant, motivating their labelling as 'epistemic interpretations' in this paper. In the following subsections, a brief overview of each interpretation is presented.

Beforehand, we shall briefly consider the distinction between epistemic and ontic quantum states, which has been discussed by Harrigan and Spekkens [9]. To them, an *epistemic state* of a system

[3]For the brief overview of interpretations in this paragraph, I am indebted to [2].

[4]When rejecting assumption (Q), as in the conventional Copenhagen interpretation, where systems involving other observers are not quantum systems, this step is invalid.

[5]Di Biagio and Rovelli refer to [6] as 'an excellent comparison between RQM and QBism' [8, p. 12], while Pienaar is a QBist himself, which is why I view it as authoritative for both interpretations.

relative to some observer encodes the (complete) knowledge of that observer about the system in the form of a probability distribution. (This definition is general enough to encompass both what Pienaar, in reference to the same paper by Harrigan and Spekkens, calls 'epistemic in the narrow sense' and 'broadly epistemic' [6, p. 3].) An *ontic state*, on the other hand, is a 'complete specification of the properties of a system' [9, p. 2]; this is generally understood as referring the system in a necessarily observer-independent way (i.e. not just a complete specification 'as seen' by some observer).

2.1 QBism

QBism originally was an abbreviation of *Quantum-Bayesianism*, but has since been adopted as the stand-alone name of the interpretation; its most well-known proponents are Fuchs, Mermin, and Schack (see e.g. their paper [10]). The main tenet of QBism is its view of quantum states as describing not physical reality, but the epistemic views about a system *of an agent*. Agents, which are taken to be necessarily conscious observers, hence play a central role in the QBist interpretation: they can perform (measurement) actions on the systems around them and the quantum state of a system encodes merely the probabilities (as given by a modified version of the Born rule) they should assign to the possible outcomes of the measurement as experienced by that agent; more generally, QM informs agents about the experiences they should expect to have (i.e. the *degrees of belief* they should assign) upon acting on the world. In this, QBists view QM as a *normative* rather than a descriptive theory. Agents, along with their actions and experiences, are taken as primitives and are not further defined.

QBists have a subjective view of probability. To illustrate, consider a coin toss: after the toss, the side that the coin landed on was completely determined by the precise conditions of the toss (initial position, force and direction of the toss, height, etc.) and the laws of classical mechanics, so the 50-50 probability is not a property of that toss (let alone the coin) itself, but just describes the uncertainty of an observer regarding which side the coin landed on. QBists adopt this position for quantum outcomes as well, by denying that the probabilities assigned by the quantum formalism describe any objective indeterminism inherent in quantum systems. This is not to say that they belief that the outcomes of quantum measurements are actually deterministic. Rather, they belief that '[t]here are no laws that determine objective probabilities for measurement outcomes. The world does not evolve according to a mechanism' [11] ([3]).

Above, I wrote that QM, as a normative theory, informs agents about the probabilities they should assign. This again would require an underlying *ontic state* that would determine which epistemic state is 'correct'. However, QBists reject that there is a single correct quantum state, even from the perspective of a single agent; instead, they accept that the quantum state encompasses also 'the agent's general worldview, temperament, etc.' [6, p. 4]. The quantum formalism tells the agent merely, in Bayesian fashion, how they should update their beliefs based on new information, and gives them quantum states to 'manage' their beliefs.

2.2 Relational quantum mechanics

Relational quantum mechanics (RQM) is an interpretation of QM originated by Rovelli [12]. In contrast to the consciously perceiving and action-taking agents in QBism, any physical system can take on the role of the observer of any other system in RQM. The central notion of RQM is that of *relative facts*: upon the interaction of two systems, an observable (the RQM literature prefers the more neutral term 'variable') of the observed system takes on a value relative to the observing system, and this is then a relative fact for the observing system. Crucially, variables take on valuations only at the moments of interaction and only relative to the observing system. Any physical interaction, then, counts as a measurement.

This relativity is often likened to relativity in other areas of physics. For example, the speed of an object is only defined relative to a fixed reference, and the notion of simultaneity is only defined with respect to a reference system in special relativity. However, while two (stationary) observers may agree upon the speed of an object relative to some reference, and every observer can determine the notion of simultaneity as seen from another reference frame using a Lorentz transform, such a comparison of viewpoints is not as straight-forward in RQM. Relative facts *can* be compared between systems, but only, again, through a physical interaction between systems. Crucially, there is no 'view from nowhere' that provides a full description of reality independent from any observer. In the case of Wigner and his friend at the point in time after performing the measurement but before opening the door, F has relative facts about R, but W does not; after opening the door, W has relative facts about F, including their report about the measurement of R. (The fact that W can use this to draw conclusions about R is because the relative fact of F about R is a *stable fact* for W due to decoherence effects. I will not explain this further and direct the interested reader to [7].)

Although it is convenient to use traditional thought experiments involving conscious agents, it is important to note that RQM does not require them. In particular, the conclusions about the above scenario would hold equally were the three systems replaced by any other type of physical system, where the term 'measurement' should then be replaced by the more neutral 'interaction', and 'report about the measurement' by 'an indicator variable in F corresponding to its interaction with R'. Macroscopic agents, equally, are just seen as physical systems, their knowledge being nothing more than (variables corresponding to) the configuration of their neurons and communication between agents nothing more than complex physical interactions.

Based on the relative facts of an observing system about an observed system, the former assigns a quantum state to the latter. As the perspective of an observer is (roughly speaking) identified with all its relative facts stemming from past interactions, the quantum state it assigns to systems is uniquely determined, i.e. from the perspective of one (observing) system, there is only one correct quantum state to be assigned to each observed system. This is another important difference to QBism, where we saw that this is not the case. In this sense, although quantum states are not 'given' in reality but are just seen as a tool for calculating probabilities, the obtained probabilities must be descriptive of an underlying reality, they must have a 'certain kind of ontological significance' [6, p. 4]. The implications of this will be explored in the next section.

3 Ontology of a shared reality

As we have seen, both QBism and RQM put an emphasis on the world from the perspective of observers and reject that quantum states represent something that is an inherent property of a system by itself. This corresponds to the principles (ii) and (iv) of 'Copenhagenish' interpretations, as presented above. There is an apparent tension between these principles, though, in that it seems natural to say that if the quantum state encodes information, then there must be some underlying state, i.e. a hidden variable, that this information is about. This is the case for what Harrigan and Spekkens [9] call the ψ-epistemic view of quantum states, where the quantum state merely codes incomplete information about some definite and observer-independent *ontic state* of the system. The PBR theorem [13] shows that such a view of quantum states is untenable. QBism and RQM differ in the degree of 'ontic significance' they assign to quantum states, but they agree that the information encoded by a quantum state is about 'something other than hidden variables', namely 'an observer's probability assignments for the outcomes of possible future measurements' [6, p. 3]. There remains the question, then, what *grounds* these probability assignments.

Put differently, in order to account for the consistency between perspectives, in the absence of hidden variables and branching worlds, both interpretations must posit some underlying determinant of measurement outcomes. To make this point more clearly, consider again Wigner and his friend after F measured R but before W opened the door: both interpretations accept that, to W, R still is in a superposition. However, (a) the 'measurement' by opening the door cannot be truly indeterministic, since there is only one outcome that is in agreement with F's perspective, (b) the outcome cannot have been predetermined, as that would require hidden variables, (c) nor is one allowed to say that both outcomes happen, since many-worlds approaches are excluded. This has implications for the ontology of a shared reality in which systems interact, which is what I want to consider in this section.

To be clear, both interpretations are committed to such a shared reality in which systems (including agents) exist and interact. What both reject, as we have seen, is the view that properties of systems and measurement outcomes are defined in an observer-independent way in this shared reality. To some extent, this resembles (and succeeds) the ontological adjustments consequent upon Einstein's relativity theory: since it was no longer possible to speak of the simultaneity of events independent of any reference frame, the notion of time as fixed and global had to be given up in favour of an ontology of spacetime. Crucially though, there it is still possible to 'assume' the view of any other reference frame by using the theory, which is generally regarded as not possible by both QBism and RQM. Hence, one has to ask what other aspects of our shared reality have to be given up and what must remain to allow for interaction between systems. In the following subsections, I discuss ontologies suggested by the proponents of each interpretation.

3.1 QBism

As described above, in QBism, quantum states and the associated probabilities encode merely the subjective beliefs of agents and offer no description of the system they are associated with (by an agent). An assignment of probability 1 to some anticipated event, then, does not guarantee that event; it just corresponds to the agent's conviction, which might end up being incorrect. Furthermore, the update of an assigned quantum state in light of new information (due to measurements) represents no change of the system itself, but merely a change of the information the agent has about the system.

Nevertheless, QBists belief in an external reality in which systems and agents exist and interact, and even see it as the aim of science to describe that reality. However, they belief that QM can contribute to that description only indirectly, Pienaar [6] drawing the metaphor of QM as a saw, in the examination of which one might learn something about the material it is used to cut. Fundamentally, though, a central tenet of QBism is that 'the world does not evolve according to a mechanism' [11] ([3]). Concretely, this can be illustrated on the example of the Born rule, which is not seen as a law of nature, in that it does not describe objective probabilities of systems behaving in certain ways; nevertheless 'the Born Rule correlates with something that one might want to call "real," as justified only [...] by the way we might use it to "better find our way in the world"' [14, p. 6]. Although Fuchs insists on the normative status of QM, this points to a grounding of this normative rule in a description of the structure of reality (as experienced by an agent). In a footnote to the quoted passage, Fuchs points out the resemblance to *structural realism*, but adds the qualifier '*in this respect*' and does not commit to a structural-realist ontology.

To some extent, QBism can be interpreted as being agnostic about an underlying ontology and as being purely *instrumentalist* about QM, i.e. viewing it as a tool to make predictions rather than statements that can be true or false. Generally speaking, however, many proponents belief that QBism does have ontological implications (though there is no commonly agreed-upon, spelled-out view). Mermin writes: '[M]y science has a subject (me) as well as an object (my world). Your science has a subject (you) as well as an object (your world)' [15] ([3]). This seems to suggest a kind of subjective idealism in the spirit of Berkeley. However, he goes on to add: 'While each of us constructs a different world, the world of science is our joint construction' [15] ([3]), and similar talk of a *constructed* common reality (sometimes called a 'public world' in contrast with each agent's 'private world') can be found elsewhere in the QBist literature, with the emphasis being that this shared reality is constructed through *communication*. However, this suggests that the subjective worlds of agents are ontologically prior to the shared reality between agents, which begs the question of an *underlying* shared reality in which agents communicate. Perhaps it has to be understood in a hierarchical fashion, in that there is an underlying external reality in which agents and systems exist and communicate, out of which agents construct their private worlds, about which agents communicate and thereby construct a public world. Even then, what remains unclear is the ontological status of the underlying reality and whether agents can really be said to *share* a public world if it is embedded in each private world.

Alternatively, the private world of each agent and their public world may be understood as equal in status, in that both are equally constructed out of the experiences, and communications thereabout, of agents, so that there is one public world which is 'extended' in parts by the private worlds of agents. This would be in line with Fuchs's *participatory realism*, which may be incompletely compressed into the assertion that 'reality is more than any third-person perspective can capture' [14, p. 1]. Still, there seems to be a dualism between an underlying, external, and 'material' reality, on top of which agents *construct* their phenomenal (private and public) world of experience. To come back to the point I made above in reference to the Wigner's-friend thought experiment, quantum theory would then be applicable only to the constructed world of experience, while the underlying reality plays the role of what I called the 'underlying determinant of measurement outcomes'.[6]

Now, I am not sure if QBists would generally accept this analysis, since I have not found an examination of this 'double role' of our shared reality (as medium of interaction and as constructed world) in the limited amount of literature on QBism I have consulted. Fuchs, however, does speculate about a more *neutral* (i.e. neither materialistic nor phenomenal) ontology; he writes [16, pp. 32–33]:

> [T]he ontological abstracta of our decision-theoretic conception of quantum theory is neither the agent, nor the object, but something that can be polarized in one direction or the other depending upon the attending analysis one gives it. [...] These normative constraints [given by QM] cannot be independent of the character of the underlying primal stuff. The task before QBism then is to reverse engineer–to distill and make explicit why these normative constraints (not some others) are imposed on us in the first place.

So in summary, although QBism understands quantum theory in purely subjective terms, it does keep the door open to finding a description of the objective nature of our shared reality aided by our understanding of QM. What this description looks like, however, is still a matter of speculation and ongoing research at this point. Whether the resultant ontology will be able to give a satisfactory explanation of the reliability of predictions made using QM remains to be seen.

3.2 Relational Quantum Mechanics

Information, as given by relative facts, is a central notion in RQM. In contrast to QBism, it is removed from any mental connotations and expresses simply the configuration of a physical system relative to another (observing) system. In particular, since conscious observers have no special role in RQM and are just seen as physical systems, for the purposes of understanding QM, our knowledge is nothing more than the configuration of the neurons in our brains. A relative fact, then, is a correlation between an (observable) variable of one system and a ('pointer') variable of the observing system.[7]

However, information is not itself a primitive notion, since it must be 'embodied' as the configuration of a physical system (relative to another one). Hence, the ontology of RQM is committed to the existence of physical systems (in themselves) as well as a reality in which they can interact. This is also evident in Di Biagio and Rovelli writing that 'RQM takes the notions of physical system and quantum events happening between systems as primary' [8, p. 10]. The reader might wonder why I even point out such an uncontroversial statement; I do because it is juxtaposed with the same authors saying that RQM '[bases] its ontology on relative facts' [7, p. 7]. Moreover, they write of 'reality relative to one system'[8] and identify it with 'the collections of facts relative to that system' [8, p. 6]. In this setting, the ontological status of relations (i.e. relative facts) and their relata (i.e. physical systems) is in need of disambiguation.

[6]There seems to me to be a connection here to Kant's *transcendental idealism* with its inaccessible *things-in-themselves*, though I do not know enough about it to make more of it than this passing remark.

[7]It might be questioned whether a notion of information that is completely removed from any mental aspects is tenable, since any definition of information ultimately relies on the assignment of some syntax, e.g. to ask how much information is stored on some medium, one must define what the ones and zeros are, so to speak – as Searle points out, 'syntax is not intrinsic to physics' [17, p. 26]. However, since the user of QM must pick out relevant variables in any case, this point might well be irrelevant.

[8]Note the resemblance to the private worlds as encountered in the above discussion of QBism.

The above suggests a kind of 'doubly founded' ontology, where both individual physical systems as well as the relations between systems are taken as primary/primitive. However, the physical systems do not have any properties that are irrespective of a particular perspective. To illustrate, consider again how in special relativity, any observer (with sufficient knowledge and computing power) can infer the speed of some system relative to any other observer; in contrast, in RQM, for an observer that has not interacted with a system, the properties of that system are not defined and, more strongly, *not part of (their) reality*. It then seems reasonable (to some philosophically inclined individuals at least) to take systems themselves not as primitives, but as derived from relations. Taking relations, or structures, as fundamental is the starting point of the metaphysical position known as *ontic structural realism* (cf. [18]) and has been considered as an ontological framework for RQM (see e.g. [4, §3.2]).

Another insightful formulation of the ontology of RQM can also be read in [4, §3.1]:

> [T]he description of the way distinct physical systems affect each other when they interact (and not the way physical systems 'are') exhausts all that can be said about the physical world. The physical world must be described as a net of interacting components, where there is no meaning to 'the state of an isolated system', or the value of the variables of an isolated system. The state of a physical system is the net of the relations it entertains with the surrounding systems. The physical structure of the world is identified as this net of relationships.

This passage in particular is reminiscent of the *conscious agents* model by Hoffman et al. [19], which takes reality to be entirely constituted of interacting conscious agents (although the focus on consciousness seems to be more in line with QBism). In the quoted passage as well as in the conscious agents model, however, the particular network of systems/agents seems to me to have an observer-independent character that departs and subtracts from the aspired reduction of reality to relations and interactions. Towards a resolution, the quoted passage, at least, might be compatible with deriving systems from relations rather than seeing them as primitive in that one might deny any (intensional) identity of systems and instead identify them by their (extensional) net of relations.

As for quantum states, they too cannot be seen as properties of systems themselves. What they do describe is the informational result of a momentary interaction between to systems. The RQM literature refers to quantum states as computational tools which one may use to make predictions about future interactions. As we already remarked above, however, there is only one *correct* quantum state to be assigned by one system to another system after an interaction, so that in this sense, QM is descriptive (and not just normative) of reality; Pienaar concludes that 'on RQM's account, quantum theory amounts to a theory of the natural laws of information exchange obeyed by all physical systems' [6, p. 8]. The sense in which quantum states are epistemic then differs drastically from that in QBism, because there quantum states represent the 'mental' beliefs of an agent, whereas in RQM, the information they represent is embedded in the physical relations between systems. In the relative-fact–centred ontology of RQM, there is no place for an ontic state of a system, in the sense of describing the system observer-independently; however, the state is an exhaustive description of (the represented variables of) a system at the moment of interaction *as seen from the perspective of some observing system*. In this sense, the state has a certain 'relative-ontic' quality.

Lastly, we consider how the outlined ontology can resolve the conceptual problems of the Wigner's-friend thought experiment identified above: F measures R and observes some outcome, while to W, F and R are still in an entangled proper superposition. When F and W then interact, since this interaction is symmetrical, there is only one pair of facts (describing the interaction from both perspectives) that is consistent with the previously established relative facts of both perspectives; i.e.: W observes F telling him of the measurement outcome concerning R that F did, in fact, observe.

In summary, the central tenet of the ontology of RQM is that there can be no 'view from nowhere', no 'God's-eye view' of the universe, and that reality can only be seen *from within* through a certain perspective. In this, it is very close to Fuchs's [14] point that 'reality is more than any third-person perspective can capture.'

4 Outlook

We have seen that (the proponents of) both QBism and RQM agree that an ontology of reality that is consistent with QM must reject a notion of a fixed external reality in which systems exist and have well-defined and observer-independent properties. They differ, though, in the ontologies they suggest. QBists' focus on subjective experience along with their commitment to the existence of an external reality leads them to ontologies of neutral monism that can unite objective and subjective aspects of reality. Proponents of RQM focus on the relations that QM informs us about on speculate towards relativistic and structural ontologies. (With their focus on facts, however, they forgo ambitions to account for conscious experience, though, in that it evidently is phenomenologically incorrect to say that our experienced worlds are collections of facts.)

The proposed ontologies I discussed above, to the extent that I read about them, are not yet worked-out and rather speculative. Interestingly, both Fuchs and Rovelli appeal to earlier ideas that might be seen as rather obscure by the modern scientific community: Fuchs [14] sees in William James's *pure experiences* a possible basis for an ontological foundation of QBism, while Rovelli [20][9] refers to the Buddhist philosopher Nagarjuna's treatments of *emptiness* and *interconnectedness* as providing insight into the nature of reality.

Another way to characterise the agreement of both approaches is this: they can be read as stating that QM does not explain an external world, but only the consistencies within our experience. Because of this, both are often accused of solipsism, which they are quick to deny in pointing out that their experiences lead to them to conclude that other people in their perception have a conscious experience as well. This in itself, however, does not require the existence of an external reality, as one might instead interpret this conclusion as 'there exist conscious experiences associated with what I perceive to be another person's point of view'. Such an interpretation would be in line with what I belief to be a defensible account of solipsism, e.g. as proposed by Caspar Hare [21].

Without *any* notion of an external reality, there would be nothing that could play the role of what above I called the 'underlying determinant of measurement outcomes'. Hence, one would have to adopt either a hidden-variable interpretation or accept that all possible outcomes are equally observed, the latter leading to a many-minds/many-lives interpretation.

Remaining agnostic about the existence of an external reality and 'branching minds' for now, I still belief that a focus on subjective experiences, which to each of us is *everything*, is a fruitful starting point for an ontology; such an ontology would take *perspectives* as primitive. However, these perspectives are clearly *structured*, enabling a structural analysis.[10] Hence, both ontological approaches that I discussed above might be usefully integrated into one theory. This theory would not only provide an ontological basis for an interpretation of QM, but might also (dis)solve the *hard problem of consciousness* (cf. [23]). Granted, this seems rather ambitious and perhaps even far-fetched, but this line of thought is one that I would like to pursue more deeply in the future.

[9] For an excerpt, see contemplativeinquiry.blog/2021/11/08/exploring-emptiness-carlo-rovelli-and-nagarjuna.

[10] In particular, the *structure* of an experience ('subjective world') might be identified with the set of the relative facts of that experiential perspective. This identification of set of facts with worlds is common custom in logic, suggesting a logical modelling approach. Given the quantum setting and the focus on epistemic aspects, (a version of) *quantum dynamic logic* as proposed by Baltag and Smets [22] might be well-suited for this endeavour.

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