Perspectival Objectivity

or: How I Learned to Stop Worrying and Love Observer-Dependent Reality

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Abstract

Brukner (2018) proposes a no-go theorem for observer-independent facts. A possible consequence of the theorem is that there can be no absolute facts about the world, only facts relative to an observer. However, admitting such observer dependency runs the risk of licensing pernicious anthropocentrism in our account of reality, thereby precluding the possibility of objectivity in scientific inquiry, which would surely count as a mark against taking Brukner's result too seriously at face value. In this paper I argue that, properly understood, observer-dependent reality does not preclude objectivity, and I claim that this idea has philosophical pedigree, too. Working through the examples of colour perception and causality, I identify a perfectly reasonable notion of 'perspectival objectivity'. I argue that such a view would not be out of place in Bohr's philosophy of quantum theory, and claim that this notion of perspectival objectivity can be appropriated as part of an understanding of quantum phenomena to take the sting out of the possibility of observer-dependent reality, and permitting the objectivity required for scientific inquiry.

1 Introduction

Employing a pair of Wigner's friend scenarios that share an entangled bipartite quantum system, Brukner (2018) constructs a Bell-style no-go theorem for observer-independent facts by deriving a formal inequality from basic assumptions that is violated by the quantum mechanical formalism. More precisely, the no-go theorem demonstrates that the following assumptions are incompatible: quantum theory is universal, in the sense that quantum predictions hold at any scale; the choice of the measurement settings of one observer has no influence on the outcomes of the other distant observers ('locality'); the choice of measurement settings is statistically independent from the rest of the experiment (sometimes known as 'free choice'); one can jointly assign truth values to the propositions about observed outcomes of different observers (the truth values form a Boolean algebra) (Brukner, 2018, p.5). Thus if one accepts the universality of

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quantum mechanics (which excludes the class of quantum models known as 'collapse models'), and also accepts locality and free choice (arguments against which can be motivated by other more famous no-go theorems (Bell, 1964, 1966)), then the violation of Brukner's Bell-type inequality by observed quantum systems (which has already been demonstrated (Proietti *et al.*, 2019)) implies that Brukner's no-go theorem rules out the possibility of jointly assigning truth values to the propositions about observed outcomes of different observers; that is, the theorem rules out observer-independent "facts".

A possible consequence of this theorem is that there can be no absolute facts about the world – that is, no absolute third-person description of reality – only facts relative to each observer. However, admitting such observer dependency runs the risk of licensing pernicious anthropocentrism in our account of reality: observer dependency might preclude the possibility that observers agree about any facts of reality, thereby precluding the possibility of objective scientific inquiry. This sort of observer dependency would surely count as a mark against taking Brukner's result too seriously at face value.

As Brukner (2018, p.7) points out, the result that facts of reality are observer dependent has precedent in relational quantum mechanics, quantum Bayesianism, and the (neo)-Copenhagen interpretation(s). What is less commonly known is that, properly understood, the notion that worldly facts are observer dependent has philosophical pedigree also. In particular, one can find examples wherein some feature of the world is in part a function of the agent perspective while at the same time, given such a perspective that is inescapably shared between similar agents, there is an objective fact of the matter concerning that feature. I call this position perspectival objectivity. I argue that this notion is precisely the notion required to make sense of the consequences of Brukner's no-go theorem and, moreover, that such a view would not be out of place in Bohr's philosophy of quantum theory.

This notion of perspectival objectivity is not out of place amongst a cluster of views in the philosophy of science concerned with scientific perspectivism, in particular perspectival realism (Giere, 2006; Massimi, 2012, 2018a). Such views set out to carve a middle path between considerations of the historical and cultural situatedness of scientific knowledge, on the one hand, and a commitment to the existence of a mind-independent, or context-free, reality, on the other. The perspectival notion I espouse in this work is not so concerned with the existence of a mind-independent reality—although this is an obvious task for future research on this theme. The perspectival notion for which I argue here is purely directed towards the objectivity of scientific knowledge, bracketing to one side considerations for the nature of reality. To this end, I take the situatedness at the heart of this perspectival notion to be an inescapable condition of worldly-directed human agency.

The paper proceeds as follows. In §2 I consider two examples that motivate the idea of perspectival objectivity: first, in §2.1, the relatively straightforward case of colour perception; and secondly, in §2.2, the more nuanced case of causal perspectivalism. In §3, I consider Bohr's quantum picture and claim that perspectival objectivity, when understood in the sense espoused in §2, is not out of place as an interpretation of his approach. In §4 I briefly explore a hierarchy of different types of perspectivalism, in order of increasing inescapability to human agents, to argue that the perspectivalism that is best for understanding observer dependency in quantum mechanics is indeed inescapable to human agents, and thus a shared perspective across human agents ensures the objectivity of scientific inquiry. In this way, the notion of perspectival objectivity in quantum mechanics takes the sting out of observer-dependent reality, and thus Brukner's no-go theorem.

2 Two case studies

Let us now consider two case studies that will help motivate the notion of perspectival objectivity. We begin with the objectivity of colour perception.

2.1 Is there colour when nobody looks?

Imagine you are standing on a deserted beach looking westward on a warm Summer's evening. As the sun descends towards the horizon, the sky and clouds above you begin to glow with vibrant oranges, pinks, and reds. Now imagine a similar westward facing beach on a warm Summer's evening with a similar sunset in process, but this time the beach is properly deserted, in the sense that there is no embodied human agent that is the subject of any experience of the aforementioned sunset—perhaps this moment exists somewhere on Earth 500 million years ago. Do the sky and clouds in this moment glow with the same vibrant oranges, pinks, and reds? Are the colours really there? This is a well-known example, so I will not labour the point. But the answer to whether the colours are really there depends on what we mean by 'really there'. A quick detour through the human optical system and colour perception will illuminate the issue.

The human optical system consists of three different types of specialised retinal cells at the back of the eye, called cones, that are sensitive to three different spectral ranges, which gives rise to trichromatic vision in humans. When stimulated by incoming light to the eye, the cones, through a chain of chemical events, emit an electrical signal that is sent to the visual cortex via the optic nerve, and (to cut the long story short) this is then processed by the brain as a visual experience. The combination of the three cones provides a response to the stimulus that is dependent upon the frequency profile of the light, but this dependence is not one-to-one, rather it is many-to-one. That is, many quite different frequency profiles can produce the same signal in the optic nerve that is then processed in the brain to a single colour experience. Thus two ordinary objects that are an identical shade of yellow to the human eye—say, a banana and a tea cup—might very well have completely different surface spectral reflectance profiles, despite being identified as identical shades according to the human optical system. In fact, the frequency profiles that arise from the surface spectral reflectance properties of all the identically shaded yellow objects that can be observed might only have in common that the human optical system identifies them as the same shade of yellow (Hubel, 1988, p.165).

We can see then that the answer to the question concerning the reality of the colours of the prehistoric sunset. What is really there at some point on the beach where we would imagine ourselves to be standing is a frequency profile that is a function of, say, the surface spectral reflectance of the clouds. But that this is orange or red is purely a function of the human optical response to that particular frequency profile. So in part we would like to say that there is some objective feature of the world 'out there', the particular frequency profile, but in part the ascription of colour to that profile is a subjective feature of human agents. It is certainly not the case that this subjectivity is of the sort that a human agent might in some sense decide the nature of the colour experience in response to the stimulus. There is a fact of the matter in the world that, given a human optical system and some particular frequency profile, some particular colour experience will be had. There is a term employed in probability theory to describe probabilities that are a function of both the worldly circumstances and an agent's knowledge of those circumstances: an 'objective epistemic' probability is epistemic since it is a measure of an agent's degree of reasonableness of belief, and it is objective because it is independent of the beliefs of any particular agent (Achinstein, 2001, p.170). We can borrow the sentiment of this term and apply it in the current case. The colour ascription is epistemic since it relies crucially on the capabilities of the agent—in particular, the agential 'perspective'—and it is objective because there is a fact of the matter about what colour will be experienced from that perspective, given a particular stimulus, independently of any particular agent. It is our shared optical system as human agents that ensures this objectivity. I call this type of objectivity 'perspectival objectivity'.[1]

To get a better grip on the utility of this notion, let us consider a second illustrative case study: the debate over objectivity of causality at the intersection of agency and interventionist accounts.

2.2 Causal perspectivalism and objectivity

It is no coincidence that this example is related to the last. Menzies and Price (1993) argue that causation should be understood as a secondary quality much the same as colour, where our "ordinary notions of cause and effect have a direct and essential connection with our ability to intervene in the world as agents" (Menzies and Price, 1993, p.187). The idea is that, just as the account of the nature of colour above made crucial reference to the capabilities of the agent, so too should an account of the nature of causation be understood in reference to the capabilities of the agent. This view is known as the agency account of causation, and is a type of manipulability or interventionist account. A traditional criticism of the agency account (one that Menzies and Price (1993, p.198–201) address) is that the account is too anthropocentric, in the sense that, if there were no human agents, then there would be no causal relations.

Woodward (2003) criticises the agency account (with further criticism in Woodward (2007, 2009)) for this very reason: "it leads us toward an undesirable kind of anthropomorphism or subjectivism regarding causation" (Woodward, 2003, p.123). In contrast, Woodward develops an interventionist account of causation with a view to establishing causation as an objective relation. Let us briefly consider here the basic details of Woodward's interventionist account to get to the heart of the contention over the objectivity of causal relations. The interventionist account (like all manipulability accounts) defines the relation between two variables X and Y as causal if and only if there exists a possible intervention on X that changes the probability distribution of the possible values of Y, holding fixed all other variables relevant to the system.

[1] Giere (2006, Ch.2) also addresses colour vision in humans in the context of perspectivism, as part of his arguments in favour of perspectival realism.

Such a relation is established by way of an intervention variable I that satisfies a series of conditions that constrain the nature of the probabilistic relation between I, X and Y, and any other relevant variables which we take to be causally related to X and Y (Woodward, 2003, p.98):

(i) I causes X;

(ii) I breaks the relation between X and the rest of its causes;

(iii) I is not (directly or indirectly) causally related to Y except (if at all) through X;

(iv) I is statistically independent of any variable that is both a cause of Y and is part of a causal chain that does not include X.

The essential idea behind these conditions is to place I in total control of the value of X and eliminate any correlations between X and Y that are not a function of the intervention on X.

According to the interventionist account, a causal relation is 'invariant' when the functional relation between X and Y, $Y = f(X)$, that establishes the causal relation holds for at least some range of possible interventions, $X = x_1 \dots x_n$. In addition, a causal relation is 'stable' when there is at least some range of background conditions under which the relation between X and Y is causal. Both the notions of invariance and stability are relative notions: there might exist a causal relation between X and Y under a certain range of possible interventions and background conditions that breaks down under other possible interventions and background conditions. Only under the appropriate domains for both interventions and background conditions where the functional relation can be established can we claim that X causes Y; this is because it is only within these domains that we can think of manipulating X as an appropriate means for manipulating Y.

Moreover, the variables upon which one might intervene must be chosen such that they are sufficiently distinct from each other: an intervention must be 'surgical' so as to ensure that the variable upon which the intervention is being made is the only variable influenced by the intervention. An intervention is 'fat-handed' or confounding when it either directly affects Y, or indirectly affects Y by affecting other variables that are not on the $I - X - Y$ path, in addition to affecting Y through X. In a similar vein, for a given set of functional relations between a set of variables to correctly represent the causal facts concerning some system, the interventionist account requires that the functional relations are 'modular'; that is, an intervention I on some variable X does not alter the functional relation between the putative effect Y and any of its causes that are not on a directed path from X to Y (Hausman and Woodward, 1999, p.543). Modularity requires that some functional relation is invariant and stable over some range of interventions and background conditions (and thus is also a relative notion), and any other functional relations in the system remain unchanged when an intervention is carried out. This notion captures the idea of a system being constituted by distinct causal mechanisms.

Significantly, the invariance, stability, and modularity of a set of functional relations relative to a range of interventions and background conditions is connected to the idea that the level of detail or generality of the variables that we take to characterise these functional relations—the ‘level of grain’—in a sense needs to be stipulated. So long as we stipulate a level of grain for the variables and relations of a system such that (i) we are able to intervene on the system as per the above criteria, (ii) the functional relations between the variables are sufficiently modular, and (iii) there are appropriate ranges of invariance and stability under which the functional relations hold, then we can take the model to represent causal relations. Variables and functional relations with these properties may manifest themselves at finer or coarser grains. The appropriate level of grain at which to model a system is dependent upon the sort of causal information one wishes to obtain by way of intervention. Likewise, whether a system can be characterised at all as being constituted by causal relations will itself depend upon the particular coarse-graining that is chosen. Ultimately, though, the causal relations, according to Woodward, are objective: “Relative to a specification of system and a level of description or graining for it...once one fixes the variables one is talking about, it is [an] ‘objective’ matter whether and how [the variables] are causally related” (Woodward, 2007, p.90). The core of the “objectivist position regarding the connection between causality and agency” that Woodward (2003, p.125) endorses is that “quite independently of our experience or perspective as agents, there is a certain kind of relationship with intrinsic features that we exploit or make use of when we bring about B by bringing about A”.

At least part of Woodward’s criticism of the agency account of Menzies and Price concerns the fact that they “are not very forthcoming about just what is meant by their claims that causation is [a secondary quality]” (Woodward, 2003, p.118). Price (2007) goes some way to addressing this criticism by outlining a position called ‘causal perspectivalism’, in which a more nuanced account of the role of the agent in an interventionist account is developed (and where Price (2007, p.279) claims that interventions themselves become a Trojan Horse for causal objectivists). Causal perspectivalism claims that it is the distinction between cause and effect on an interventionist account that can be reduced to an agent’s perspective: “the strong temporal asymmetry of the notion of intervention—and hence, apparently, of our causal thinking in general—stems not merely from the fact that we are agents, but also from a further contingency concerning our temporal circumstances: above all, the strong temporal bias of our epistemic access to our environment” (Price, 2007, p.280). Thus, when we approach, as human agents, a system on which we wish to intervene, the causal relations that are exploitable by us are constrained by our particular epistemic perspective. Given this constraint, however, there is subsequently a fact of the matter—characterised in the detail of Woodward’s interventionist account—concerning which relations are causal and which are not. In this way, Woodward is correct to point out the objective nature of causal relations, but this objectivity is dependent upon a particular perspective; one that happens to be stable across human agents.

With this position in hand, Price (2014) goes on to argue that the supposed ‘objectivity’ of Woodward’s version of interventionism and the supposed ‘subjectivity’ of agency accounts that consider causation to be a secondary quality are really not such different accounts. Moreover, the dependency of interventions on the agent perspective is not limited to the temporal bias of our epistemic access to our environment. This is evident most prominently in the relativity of invariance, stability, and modularity, and their connection to a choice of grain, which are all perspectival, agent-dependent systematisations of the manipulable parts of the world. Relative to a specification into system and environment, and a level of description or grain, there is a fact of the matter concerning what causes what. But this specification and level of grain are agent-centric features of the causal model of some system.

Ismael (2016) sharpens this debate (and provides a capstone of sorts) employing the notion of 'frame-dependency' in our causal ascriptions on the world. The idea is that some aspects of our causal ascriptions are frame-dependent, or perspectival, in the same way that, say, temporal durations are frame-dependent according to relativity theory. However, and this is part of Ismael's rapprochement between the subjective and objective flavours of interventionism, once we identify and discount any frame-dependency, we expect there to be some invariant fundamental structure in the world that is independent of any perspective. This 'modal substructure', as Ismael (2016, p.258) calls it, comprises the objective relations that we exploit when we intervene on the world; we partition the invariant structure into cause and effect based on our idiosyncratic epistemic constraints and limitations concerning that structure. It is thus perfectly reasonable to refer to some causal relation as objective, so long as we understand such a claim in a deflationary, epistemic sense: there is a fact of the matter about whether the relation is causal, but only given a separation of the system containing the causal relation into system and environment and a level of grain of description that enables a series of conditions that characterise causation to be met. Both the delineation into system and environment and the level of grain of description are agent-centric specifications and are a function of a particular epistemic perspective on the world. It is, as human agents, our shared temporal direction and shared physical capabilities as manipulators of the world that provide our shared idiosyncratic epistemic constraints, and so ensures the objectivity of our causal claims. Much like the perspectival objectivity of colour, we have here perspectival objectivity of causality.

Armed with this notion of perspectival objectivity, let us now turn our attention to its application to quantum theory and consider Bohr's quantum picture.

3 Bohr's quantum picture

Recall that the task at hand is to attempt to provide a philosophical foundation for the claim that arises from Brukner's no-go theorem that seems to rule out the possibility of observer-independent facts. In the previous section I developed the idea of perspectival objectivity, whereby some feature of the world is in part a function of the agent perspective while at the same time, given such a shared perspective between similar agents, there is an objective fact of the matter concerning that feature. In this section I consider the applicability of this notion to quantum theory; in particular, I claim that perspectival objectivity as understood here is not an unnatural interpretation of Bohr's approach to quantum theory. By way of contrast, first with Heisenberg, then with Einstein, I show that Bohr's picture is simultaneously ontically indeterminate, realist, and complementary, and argue that Bohr's picture ensures the objectivity of quantum phenomena.[2]

[2] I follow here the analysis of Barad (2007), who uses these considerations of Bohr's quantum picture to develop her own so-called 'onto-epistemological' position: agential realism. There are notable similarities between agential realism and perspectival objectivity, not least the incorporation of agent-centric elements to ontology and objectivity, respectively. One key difference, however, is that agential realism rejects the anthropocentrism

3.1 Ontic indeterminacy

Heisenberg developed the uncertainty principle that bears his name in 1926 while working at Bohr's institute in Copenhagen. The principle places a finite limit on the precision with which conjugate variables can be simultaneously measured. While Heisenberg preferred an epistemic understanding of the principle, Bohr developed his own understanding, preferring to refer to it as the indeterminacy relation. Bohr's indeterminacy relation is to be understood ontically, in the sense that it is the world itself that is indeterminate, not merely our knowledge of it. As Bohr (1928, p.582) argues:

> The essence of [the indeterminacy relation] is the inevitability of the quantum postulate in the estimation of the possibilities of measurement. A closer investigation of the possibilities of definition would still seem necessary in order to bring out the general complementary character of the description. Indeed, a discontinuous change of energy and momentum during observation could not prevent us from ascribing accurate values to the space-time co-ordinates, as well as to the momentum-energy components before and after the process. The reciprocal uncertainty which always affects the values of these quantities is. . . essentially an outcome of the limited accuracy with which changes in energy and momentum can be defined. . .

The take-home message of this passage is that Bohr, in noting that an epistemic understanding of the uncertainty principle "could not prevent us from ascribing" precise values for both position and momentum for some quantum system, prefers to understand the reciprocal uncertainty as arising as "an outcome of the limited accuracy with which changes in energy and momentum can be defined" (where a property is 'defined' when it has physical reality (Barad, 2007, p.128)). That is, it is the measurement conditions that define the ontic values of dynamical variables, and these values are indeterminate without specification of the measurement conditions.

3.2 Physical reality

That Bohr's quantum philosophy is realist is demonstrated by his response to the argument of Einstein, Podolsky and Rosen (1935) (EPR) regarding the criterion of physical reality (Bohr, 1935, p.700):

> From our point of view we now see that the wording of the above-mentioned criterion of physical reality proposed by Einstein, Podolsky and Rosen contains an ambiguity as regards the meaning of the expression "without in any way disturbing a system." Of course there is in a case like that just considered no question of a mechanical disturbance of the system under investigation during the last critical stage of the measuring procedure. But even at this stage there is essentially the question of *an influence on the very conditions which define the possible types of predictions regarding the future behavior of the system*. Since these conditions constitute an inherent element of the description of any phenomenon to which the term "physical reality" can be properly attached, we see that the argumentation of the mentioned authors does not justify their conclusion that quantum-mechanical description is essentially incomplete.

of Bohr's quantum philosophy. Perspectival objectivity differs in emphasising the human agent. Whereas Barad (2007) distances her view from the anthropocentric features of Bohr's view, I take these to be expressions of perspectival objectivity.

While Bohr grants that a lack of mechanical disturbance of the system ensures the physical reality of the system in the EPR argument, and so suggests that the quantum mechanical description is incomplete, the completeness of the quantum mechanical description does not necessarily imply a lack of physical reality of the systems. Bohr takes "the very conditions which define the possible types of predictions"—that is, the experimental conditions under which the particular phenomena arise—as influencing the physical reality of the system under investigation without countenancing a mechanical disturbance. Thus Bohr grants the same 'physical reality' to quantum systems as does EPR whilst still maintaining that the quantum mechanical description is complete. What is important for Bohr is that, since the experimental conditions are an inherent element in defining the ontic values of dynamical variables, physical reality is likewise conditionally defined.

3.3 Separability, complementarity, and objectivity

As a result of the debate between Bohr and Einstein subsequent to the EPR argument and the concerns about physical reality, Einstein expressed dismay that abandoning 'separability'—"the real in part of space A should (in theory) somehow 'exist' independently of what is thought of as real in space B" (Einstein *et al.*, 1971, p.164, 31 March, 1948)—would be tantamount to abandoning any possibility of objectivity. Here is Einstein recounting this sentiment in his correspondence with Born in 1948 (Einstein *et al.*, 1971, p.164, 31 March):

> However, if one abandons the assumption that what exists in different parts of space has its own, independent, real existence, then I simply cannot see what it is that physics is meant to describe. For what is thought to be a 'system' is, after all, just a convention, and I cannot see how one could divide the world objectively in such a way that one could make statements about parts of it.

This is important for Einstein since if one were not able to secure objectivity, then one could not secure the possibility of scientific inquiry. Barad (2007, p.317–321) argues that the relationship between separability and objectivity is at the core of the debate between Bohr and Einstein concerning the EPR argument. According to Barad, Bohr can indeed secure objectivity in his quantum philosophy while simultaneously rejecting separability in favour of an ontology of phenomena. These phenomena, constituted by coupled pairs of objects and measurement conditions, "are the objective referent of measured properties. *Complementarity is an ontic (not merely an epistemic) principle*" Barad (2007, p.309). Here is Bohr (1949, p.217) commenting on his debate with Einstein on this topic:

> This point is of great logical consequence, since it is only the circumstance that we are presented with a choice of *either* tracing the path of a particle *or* observing interference effects, which allows us to escape from the paradoxical necessity of concluding that the behaviour of an electron or a photon should depend on the presence of a slit in the diaphragm through which it could be proved not to pass. We have here to do with a typical example of how the complementary phenomena appear under mutually exclusive experimental arrangements and we are just faced with the impossibility, in the analysis of quantum effects, of drawing any sharp separation between an independent behaviour of atomic objects and their interaction with the measuring instruments which serve to define the conditions under which the phenomena occur.

Thus, complementarity can secure objectivity: given some sufficiently defined measurement conditions (or experimental arrangement), there is an objective fact of the matter concerning the *phenomena* associated with those conditions. But rejecting separability raises a slightly different concern for Bohr. As Barad (2007, p.320) puts it:

> Einstein wants to know, if we give up on separability, what we should understand physics as describing. Bohr had already answered: *phenomena* are what physics describes, not some presumably independently existing object (which the failure of separability denies). Einstein wants to know how the "observer" can then be differentiated from the "observed" such that this individuation is made in an objective fashion.

For Bohr, all that is required for a differentiation between the measured object and measurement device is a clear and reproducible record, determined by the experimental arrangement, of the measurement device having acted upon ('measured') the object. Thus, there is a "measurement of one part of the phenomenon by another part" (Barad, 2007, p.320). So long as the record is clearly reproducible, in the sense that the same combination of system and measurement conditions would share the same set of resulting phenomena, this record secures the objectivity of the phenomena.

4 Perspectival objectivity in quantum mechanics

I claim that Bohr's characterisation of objectivity is a kind of perspectival objectivity. The parallels between the account of perspectival objectivity described in §2 and Bohr's characterisation of objectivity in his quantum picture are stark. Both characterisations portray a kind of conditional objectivity: given certain conditions, there is an objective fact of the matter about some feature of the world. In the former case, the conditions consist in a particular agential perspective on the world, and in the latter, the conditions consist in a particular experimental arrangement. In so far as we can take an experimental arrangement to provide a particular (albeit non-agential) perspective on some physical system (that may or may not exhibit complementary phenomena), then we can take the objectivity of Bohr's picture to be a kind of perspectival objectivity.

Despite the fact that the kind of perspectival objectivity found in Bohr's quantum picture is non-agential, it would be wrong to think that it were not anthropocentric (*contra* Barad (2007)). Indeed, what is an experimental arrangement in Bohr's picture if not anthropocentric? If a phenomenon is an agent experience of a system comprised of a 'measuring' part and a 'measured' part, then surely the measuring part—the experimental arrangement—is specifically devised by the agent to bring about the phenomenon in accordance with the idiosyncratic experiential faculties of that agent. For human agents, the relevant phenomena consist of visible indicators and audible clicks in accordance with our idiosyncratic optical and aural faculties. In this sense, then, the 'perspective' of the experimental arrangement is anthropocentric in origin (Giere, 2006, Ch.3).[3] (Of course, quite trivially, we could not successfully arrange for a phenomenon to arise beyond our experiential faculties, not least because it would be in principle

[3] I take this to be what Barad (2007, p.339) is getting at with the notion of 'agential separability', whereby separability of some phenomenon into object and measuring device is relative to the specific phenomenon.

unexperienceable.) Bohr was cognisant of this agent-centric feature of a measuring apparatus, as shown in his example of a blind man using a cane to explore a room (Bohr, 1929, p.485): the cane can be the object of sensation (when explored itself by hand), or the mediator of sensation (when held tightly and extended towards another body) where it serves as an extension of the agent's experiential faculties.

To get to grips with the objectivity of this agent-centric perspective on the world, it will be informative here to consider different types of perspectivalism, organised hierarchically in order of increasing inescapability to human agents. In so far as the nature of the agential perspective that is best for understanding observer dependency in quantum mechanics is indeed inescapable to human agents, the fact that this perspective is shared across human agents ensures the objectivity of scientific inquiry. Consider the following sources of perspectivalism in science:

(i) Spatiotemporal epistemic vantage point

(ii) System/environment split – level of grain/scale

(iii) Instrument construction/implementation

(iv) Proclivity of scientific agent

(v) Personal idiosyncrasy

Source 1 refers to our highly temporally constrained epistemic vantage point from which we have knowledge of the past, but no knowledge of the future. This constraint is uncontroversially shared by all human agents. Considering the perspectival nature of this constraint could lead one, for instance, to the view that the arrow of time is perspectival (Rovelli, 2017), or that the direction of time, as distinct from space, is perspectival (Baron and Evans, in press). In both cases, the shared nature of this constraint would ensure that the relevant temporal phenomena, given this perspective, are objective.

Source 2 refers to the constrained way in which we model physical systems as distinct from their environments, and at a level of coarse graining that is suitable for our interventionist tendencies (as discussed in §2.2 above). The system/environment split is largely a pragmatic decision made by scientific agents during the modelling process that is dependent upon the utility that this split might serve for scientific purposes (prediction or information gathering). Some of these pragmatic decisions are inescapable, and some are not.[4] The pragmatic decisions that are inescapable are those related to our idiosyncratic physical capacities for interacting with the world: the dynamical variables we have the capacity to model are chosen *de facto* by our physical constitution (our eyes, ears, and hands); likewise, we coarse grain as part of the modelling process *just so* dynamical variables with the right sort of functional interrelationships can be objectified for our practical purposes. These idiosyncratic physical capacities are shared amongst human agents. Taking into account the perspectival nature of these constraints leads

[4]The pragmatic decisions that are not necessary include those that are a function of particular theoretical or paradigmatic considerations (Massimi, 2018b). While there is a sense that some of these considerations might be shared by large numbers of scientific agents, they need not be.

to the causal perspectivalist view outlined in §2.2. As we saw there, the shared nature of these constraints ensures that the relevant causal ascriptions, given this perspective, are objective.

Source 3 can be seen as an extension of these considerations concerning our idiosyncratic physical capacities. As we have just considered, our scientific instruments are specifically devised by us to allow us to interact with the world in accordance with our experiential faculties, thus our instruments operate via visible indicators and audible clicks. As above, this constraint is shared amongst human agents. Taking the perspectival nature of this constraint into account might lead one to argue that the conditions of measurement are an inherent part of the phenomena that arises from measuring some physical system, just as we saw in §3 that Bohr argued as part of his quantum picture. Just as I argued in §3.3, the shared nature of this constraint ensures that the relevant quantum phenomena, given this perspective, are objective.

For the remaining two sources of perspectivalism in science (4 and 5), as well as in a certain sense source 3, are not necessary constraints for scientific agents, although in some instances these sources of perspectivalism may be shared by very many agents. For source 3, we can imagine that the process of instrument construction and implementation is a function of particular theoretical or paradigmatic considerations: scientific agents are interested in measuring particular dynamical variables because these are the dynamical variables of interest within some scientific paradigm. These interests are not necessarily shared amongst all scientific agents, and this source of perspectivalism cannot ensure the objectivity of scientific inquiry. Likewise for sources 4 and 5: the regular theoretical and paradigmatic practices of a scientific agent provide a framework within which physical phenomena can be modelled and interpreted, or particular personal idiosyncrasies may also provide such an interpretational framework, but these sources of perspectivalism in science are not necessarily shared amongst scientific agents.

In so far as the first three sources of perspectivalism science are created by constraints that are inescapable to human agents, any scientific inquiry undertaken from within these perspectives is 'objective' in the sense I have been elucidating in this work – that is, perspectival objectivity – despite being anthropocentric in origin. It is this shared perspective across human agents that ensures the objectivity of scientific inquiry. And as I have argued in §3, Bohr's quantum picture incorporates a type of perspectivalism along the lines of source 3 (properly understood) and so ensures the objectivity of scientific inquiry (and I take this to be an integral part of Bohr's lifelong defence of his quantum picture). And this 'perspectival objectivity', as I have called it, in quantum mechanics is of a piece with the parallel frameworks for understanding the 'objectivity' of colour perception and causality.

5 Final thoughts

It is this picture of perspectival objectivity in quantum mechanics that I take to be a panacea for any apprehension generated by observer-dependent reality. The phenomena might very well be observer-dependent, but that does not preclude the possibility of objectivity, and so does not preclude the possibility of reasonable scientific inquiry: given a system subject to an experimental arrangement, there is an objective fact of the matter concerning the subsequent possible phenomena. The important point to which this work is alluding, though, is that the idea of perspectival objectivity has philosophical pedigree—causal perspectivalism is a well-established position in the philosophy of causality. The task remains, then, to flesh out perspectival objectivity in quantum mechanics in parallel to causal perspectivalism to provide a more robust philosophical foundation for observer-dependent reality.

There are challenges and opportunities that lie ahead for this analysis of the consequences of Brukner's no-go theorem. Perhaps the biggest challenge relates to understanding what perspectival objectivity means for a third-person description of the Bell-style pair of Wigner's friend scenarios. While I have argued that the objectivity of scientific inquiry can be ensured on such a view, I have not attempted to provide an ontological description of the experiment, realist or otherwise. It may be that such a task might lead one to a kind of neo-Carnapian pragmatist approach to quantum ontology (not unlike the perspectival normative realism of Glick (2018), developed from an analysis of the realist credentials of quantum Bayesianism). Either way, this challenge requires further attention.

On a note of optimism, however, for the foundations of perspectival objectivity in quantum mechanics, Karakostas and Zafiris (2018) set out a formal framework for understanding the interrelation between the global structure of the set of phenomena associated with some quantum system (the so-called quantum event algebra) and the set of local Boolean probing frames that each arise as a result of a particular measurement perspective on the system. They argue, in category theoretic terms, that this interrelation is underpinned by a bidirectional relation whereby the multilevel structure of interconnected local Boolean frames encodes the global informational content of the quantum event algebra, and the quantum event algebra formally decomposes via the action of Boolean probing frames into local perspectives for the measurement of observables. Formally, then, a 'perspective' is a complete Boolean algebra of commuting projection operators generated by a set of mutually compatible physical quantities (Karakostas and Zafiris, 2018, p.4). Their formalism captures very nicely the suggestion I made above that a perspective arises from a particular experimental arrangement applied to some quantum system.

A further promising connection that could be made as a result of the above analysis concerns the environment-induced selection of stable preferred-basis states as part of the decoherence program. A foundational problem arises from "the fact that the quantum-mechanical measurement scheme... does not uniquely define the expansion of the postmeasurement state and thereby leaves open the question of which observable can be considered as having been measured by the apparatus" (Schlosshauer, 2005, p.1278). According to the environment-induced selection account, preferred sets of quantum states are selected as a function of the interaction between system and environment as a preferred measurement basis, due to the stability of the states in the face of interaction with the very many degrees of freedom in the environment. This account relies on the fact that the decomposition of any state into system, apparatus, and environment is always unique.[5] But the uniqueness of decomposition does not by itself specify preferred basis states will, thus the account requires additional criteria to do so. I submit that the sort of benign anthropocentrism that I have outlined in this work might provide grounds for

[5]This is called the tridecompositional uniqueness theorem. See (Schlosshauer, 2005, p.1278) and references therein for further details.

justifying the decomposition of system, apparatus, and environment from agent-centric principles, and also how our quantum descriptions select dynamical variables of a sort that might be useful for classical agents such as ourselves. Exploring this connection looks fruitful.

Finally, and perhaps most promisingly, it seems an interesting task to explore how perspectival objectivity could provide a philosophical foundation for relational quantum mechanics (Rovelli, 1996) (and perhaps also its relation to 'participatory realism' in the context of quantum Bayesianism (Fuchs, 2017)). Relational quantum mechanics is explicitly observer dependent, where an 'observer' is taken to be any physical system interacting with the system of interest. By incorporating the sort of perspectivalism I espouse in this work, one can ensure the objectivity of relational quantum states.

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