Perspectival Objectivity

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

Peter W. Evans*

School of Historical and Philosophical Inquiry, University of Queensland

Abstract

Building on self-professed perspectival approaches to both scientific knowledge and causation, I explore the potentially radical suggestion that perspectivalism can be extended to account for a type of objectivity in science. Motivated by recent claims from quantum foundations that quantum mechanics must admit the possibility of observer-dependent facts, I develop the notion of 'perspectival objectivity', and suggest that an easier pill to swallow, philosophically speaking, than observer-dependency is perspective-dependency, allowing for a notion of observer-independence indexed to an agent perspective. Working through the case studies of colour perception and causal perspectivalism, I identify two places within which I claim perspectival objectivity is already employed, and make the connection to quantum mechanics through Bohr's philosophy of quantum theory. I contend that perspectival objectivity can ensure, despite the possibility of perspective-dependent scientific facts, the objectivity of scientific inquiry.

1 Introduction

In his book "Scientific Perspectivism", Giere (2006) argues in favour of a view he calls 'perspectival realism'. According to this view, both the claim that science delivers objectively true representations of reality, and the counterclaim that scientific reality is constructed—and ultimately constituted—by the fruits of human scientific activity, are rejected. Instead, Giere explicates his position as one that accepts both that there are mind-independent elements to physical reality and that scientific knowledge is historically and culturally situated in scientific practice: it is only in the context of some specific (usually highly confirmed) physical theory that reality appears to be a particular way. This position is considered 'perspectival' on account of this 'situatedness'—in the parlance of sociological approaches to the philosophy of science, the concept of situatedness recognises that agents (knowers) are necessarily embedded within a social context or environment (Anderson, 2019). This view thus recognises the fundamental fact

*email: p.evans@uq.edu.au

that scientific knowledge is always mediated through the lens of a scientific theory, while avoiding the inherent relativism that often follows from some sociological approaches to science. As Massimi (2018a, p.343) puts it, a scientific perspective refers "to the actual... scientific practice of any real scientific community at any given historical time" (where a scientific practice is understood to be constituted by scientific knowledge claims, and the scientific resources to ensure those claims are reliable and justified). Thus, over time, as the scientific practice of particular scientific communities evolves, so too does the scientific perspective of those communities, and so too their scientific claims about reality.

In the edited collection "Causation, Physics, and the Constitution of Reality" (Price and Corry, 2007), Price (2007) (with later developments by Ismael (2016)) develops a view he calls 'causal perspectivalism'. According to this view, the temporal asymmetry of cause and effect is reduced to the temporal bias of an agent's epistemic access to its environment; or, as Price (2007, p.263) puts it, it is reduced to the "agent's perspective". The use of the term 'perspectival' in this context is again tied to the situatedness of agents, in the sense that it is the embedding of an agent in a particular context that gives rise to the possibility of alternative perspectives. Although, according to causal perspectivalism, it is the epistemic consequences of the fact that agents are embedded within a (necessarily inescapable) environment with a particular temporal direction that is significant here, rather than the epistemic consequences of a particular social or cultural embedding, as above.

In addition to these two examples of this use of the label perspectival, the term has been employed with increasing frequency in recent years especially (with a few earlier examples). As Creţu (in press) points out, perspectivalism "has been advocated in connection to... explanation (Craver, 2013; Dewhurst, 2018; Kästner, 2018; Winning, 2018), time (Rovelli, 2017; Torrengo, 2017; Baron and Evans, in press), meta-ethics (Schafer, 2014), peer disagreement (Kvanvig, 2013), justification (Sosa, 1991; Rosenberg, 2002), [and] contextualism and relativism in philosophy of language (Bach, 2011)". My interest in this work is to explore the possibility of the potentially radical suggestion that perspectivalism can be extended to account for a type of objectivity, a type of observer-independence, in science, but where facts about scientifically modelled objects are nonetheless indexed to an observer perspective. My motivation is a recent set of claims from quantum foundations that quantum mechanics rules out the possibility of "observer-independent facts".

1.1 No-go theorems for observer-independent facts

Following the argument of Frauchiger and Renner (2018), that claims an incompatibility between the universal validity of quantum theory and the assumption that particular sets of measurements have jointly definite outcomes, Brukner (2018) argues that observer-independent facts are in fact inconsistent with the universal validity of quantum theory. Subsequent work due to Bong *et al.* (2019), following Healey's (2018) review of both Brukner (2018) and Frauchiger and Renner (2018), criticises the strength of Brukner's assumptions and proves a stronger theorem containing a weaker set of assumptions than Brukner's theorem. Their theorem establishes that observer-independent facts are incompatible with the widely accepted assumptions of 'locality' (the choice of the measurement settings of one observer has no influence on the outcomes of the other distant observers) and 'free choice' (the choice of measurement settings is statistically independent from the rest of the experiment), without relying on assumptions specific to quantum theory, and so independently of the universality of quantum mechanics.[1] Specific details of this debate aside, the central claim emanating from this body of research is that accepting the assumptions of locality and free choice (arguments against which can be motivated by other more famous no-go theorems (Bell, 1964, 1966)), there is a very real possibility of observer-dependent facts. That is, in certain scenarios there is no possibility of jointly assigning truth values to the propositions about observed outcomes of different observers.

I contend that this claim requires increased attention. To begin with, none of Frauchiger and Renner (2018), Brukner (2018), nor Bong *et al.* (2019) attempt to explain in any great detail what exactly is meant by observer-dependent facts. While there is discussion in each work regarding various interpretations of quantum theory, and a mention that relational quantum mechanics, quantum Bayesianism, and neo-Copenhagen interpretations to varying degrees already reject observer-independent facts, there is no accompanying discussion concerning what this is supposed to mean philosophically. Subsequently, one might take the admission of observer dependency as licensing pernicious anthropocentrism in our account of reality: pernicious, since observer dependency might preclude the possibility that observers agree about some facts of reality, thereby precluding the possibility of objective scientific inquiry. In this context, Healey (2018, p.1585), in the final words of his critique of Brukner (2018) and Frauchiger and Renner (2018), diagnoses the consequences for objectivity as a possible place to focus philosophical attention when he concludes:

> This result prompts further reflection on how to understand quantum theory... The arguments considered in this paper give us no reason to doubt the sincerity or truth of experimenters' reports of definite, physical outcomes. But I think [they] should make us reconsider the extent and nature of their objectivity.

The present work is a response to this prescription for further critique: it contains an examination of one possible, albeit radical, way to consider the nature of the objectivity of the claims made by experimenters when observing quantum systems. Appropriating the notion of perspective from the 'scientific perspectivism' and 'causal perspectivalism' research programmes, I set out to develop a position that I call 'perspectival objectivity'. In short, I suggest that these no-go theorems, rather than demonstrating the possibility of observer-dependent facts, would be better understood as demonstrating the possibility of perspective-dependent facts, leaving untouched the notion of observer-independence—that is, objectivity—indexed to a perspective.

1.2 Main claims and outline of the paper

As mentioned above, a perspective refers to the practical, epistemological, and/or theoretical constraints placed by a context or environment on an agent embedded within that context

[1] Bong *et al.* propose an experimental arrangement to test their theorem, wherein "a photon's path is deemed an observer", and this experiment has been completed, and Bong *et al.*'s result verified, by Proietti *et al.* (2019). However, it is controversial whether a photon can be deemed an observer is such a way. This issue is beyond the scope of the present work.

or environment. According to scientific perspectivism, in the context of a particular scientific tradition, the way the world appears to be is constrained by the historical and cultural environment in which that scientific tradition is situated. According to causal perspectivalism, given that we are agents embedded in an environment with a particular temporal direction, the causal direction between causally related events is constrained by the temporally directed epistemic environment (that is, that we have knowledge of the past but not of the future) in which we are situated. It is worth emphasising that the interactive nature of the agent-embedded-in-an-environment is significant to this notion of perspective, in contrast to a common metaphorical understanding of perspective as simply a passive point of view, or window on the world. To this end, any time that an embedded agent delineates an object (a system/environment split), or the subsequent interaction between the agent and the object (system/apparatus/environment split), this necessarily characterises a perspective.[2] Thus, according to these traditions, observation cannot be detached from a perspective.

Relatedly, and a point on which I wish to expand below, Giere (2006, p.14) argues that scientific instruments are perspectival, in two senses:

> First. . . instruments are sensitive only to a particular kind of input. They are, so to speak, blind to everything else. Second, no instrument is perfectly transparent. That is, the output is a function of both the input and the internal constitution of the instrument.

In the first sense, Giere identifies that instruments take as input only some subset of variables, or perhaps a limited range of values for some subset of variables, that we take to characterise some system, and are silent concerning the remaining complete set of variables. In the second sense, Giere recognises that instruments to some extent 'process' the input to the instrument, such that the output of the application of an instrument is typical to that instrument. In the background of these considerations for Giere is the fact that instruments are theory-laden, and so are perspectival in a broader scientific sense, also.

I wish to push this idea that scientific instruments are perspectival to a more extreme position, taking a cue from causal perspectivalism. When an embedded agent delineates system and environment, part of this delineation is an identification of the variables that are taken to characterise the system, with other variables redundant to that characterisation relegated to the environment. But the variables of interest to an embedded agent for characterising a system are a function of the capabilities of that agent to interact with the system. For the same reason that Giere claims to make instruments perspectival—that instruments are sensitive to only some subset of variables that might characterise a system—so too does it seem that our own interaction with a system is equally perspectival: we are sensitive to only a certain set of variables, namely, ones that can be detected by sight, sound, touch, smell, and taste.[3] We are blind to all other variables that could characterise the system. To some extent this is a trivial observation, in the sense that we cannot model undetectable properties or behaviour of

[2]Often, this sort of delineation is largely a pragmatic decision made by scientific agents during the modelling process that is dependent upon the utility it might serve for scientific purposes (that is, prediction or information gathering).

[3]And these variables within a limited range of values, too: only a limited range of frequencies of electromagnetic radiation; a limited range of frequencies of pressure waves in the air; a limited range of pressures on our skin; and a limited set of molecular compounds on the membranes and receptors in our nose and tongue.

a system in terms of undetectable variables, but this consideration also brings to light a deeper perspective from which we model reality. Just like the historically and culturally situated scientific practice defines a perspective, and our epistemic access to our temporally directed environment defines a perspective, so too does our constrained idiosyncratic capabilities to interact with, and model, reality define a perspective.

While it is certainly true that we can extend the range of values for each of the variables in the set to which we are sensitive using advanced scientific instruments, since the output of our instruments is useless unless it is itself detectable by us, the usefulness of scientific instruments is likewise limited to processing any input to output into the same set of variables circumscribed by the human agent perspective. As Giere (2006, p.126) notes, "an observer, whether a human or an instrument, can interact with an object only from the observer's own particular perspective". Again, it is trivial to consider that we cannot model properties or behaviour of a system in terms of undetectable outputs from the interaction of an instrument with the system.

Furthermore, just like our epistemic access to our temporally directed environment is inescapable for embedded agents such as ourselves, so too is our constrained interaction capabilities. According to causal perspectivalism, the fact that all human agents are embedded in the same temporally directed environment permits intersubjective agreement between human agents concerning the attribution of directed causal relations between events. Since this temporally embedded perspective is inescapable, this intersubjectivity lends itself to a kind of objectivity or observer-independence, albeit an 'intersubjective objectivity' (Giere, 2006, p.13); that is, since every possible observer is equally temporally embedded, each observer attributes the same directed causal relations between events, with this attribution indexed to the perspective of the temporally embedded agent. I take the term perspectival objectivity to refer to this kind of intersubjective objectivity indexed to a particular agent perspective. That is, perspectival objectivity refers to a scenario in which 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 (intersubjectively) objective fact of the matter concerning that feature.[4] I argue that colour perception (§2.1) and causal perspectivalism (§2.2) can be understood as examples of perspectival objectivity. One of the main claims of this paper is that the perspective characterised by our constrained interaction capabilities—an inescapable condition of worldly-directed human agency—is also an example of perspectival objectivity, and that this can underpin the possibility of objective scientific inquiry in the face of the prospect of observer-dependent facts.[5]

[4]There is a term employed in probability theory to describe probabilities that are a function of both the worldly circumstances and a (potentially hypothetical) 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). An objective epistemic probability is thus agent-independent indexed to an epistemic perspective. I take such probabilities to express a similar sentiment to perspectival objectivity.

[5]There are other types of perspectives that do not support necessary intersubjective agreement across observers. For instance, the regular theoretical and paradigmatic practices of a scientific agent provide a framework within which physical phenomena can be modelled and interpreted (Massimi, 2018b), or particular personal proclivities may also provide such an interpretational framework, but these sources of perspectivalism in science are not necessarily shared intersubjectively amongst scientific agents.

To be sure, perspectival objectivity is highly incongruous with the conception of metaphysical objectivity in, say, realist approaches to scientific ontology. I make no pretence to be contributing to any debate regarding objectivity in this strong metaphysical sense. If anything, perspectival objectivity is a strongly qualified and attenuated sense of objectivity that I claim is sufficient, given that our scientific practice is a purely intersubjective affair, to ensure the objectivity of scientific inquiry; that is, to ensure that scientific inquiry is observer-independent indexed to a perspective. What is more, I contend that this notion is thus also sufficient to make sense of the consequences of the no-go theorems above, preferring them to be showing the possibility of perspective-dependent facts, rather than observer-dependent facts, and I make this case by connecting perspectival objectivity to Bohr's philosophy of quantum theory in §3. While this may not be the only, or indeed a necessary, reading of Bohr, the reader should keep in mind the main motivation for this work: to put forward an albeit unorthodox interpretational stance to attempt to make sense of the possibility presented by the no-go theorems for observer-dependent facts in quantum theory. To this end, I am marshalling a range of philosophical and physical positions in support. After I explore in more depth the concept of perspectival objectivity in §4, I finish in §5 with one such supporting position that is an interesting example of the kind of perspectivalism I propose for quantum theory: a recent proposal by Karakostas and Zafiris (2018) of a formal framework for a quantum perspective. At the very least, I take this range of arguments to establish that this unorthodox proposal is not implausible.

2 Two case studies

Let us now consider two case studies that I take to illustrate the notion of perspectival objectivity. Both the scientific perspectivism and causal perspectivalism programmes can count this first example, colour perception (§2.1), as a foundational example. Giere (2006, Ch.2) considers colour perception to be a "prototype for a scientific perspectivism", and the precursor for Price's work on causal perspectivalism ("Causation as a Secondary Quality" (Menzies and Price, 1993)) takes the 'objectivity' of colour perception to be a parallel case to the 'objectivity' of causal relations, which will comprise our second example (§2.2). Let us here rehearse the general outline of these accounts.

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 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).

It is from these considerations that we can begin to answer 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 function of the particular perceptual capabilities of a human agent. 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.

It should be clear that the perceptual capabilities of a human agent comprise a perspective in the sense explicated above. The human optical system practically constrains the access that human agents have to the environment. But it should also be clear that a crucial part of colour perception is that there will be intersubjective agreement between agents that share perceptual capabilities, such as human agents sharing an optical system. Thus, the colour of the prehistoric sunset is observer-independent, and so objective, in the sense that colour ascription is independent of any particular human agent (all human agents will ascribe to it the same colour); but it is also observer-dependent in the sense that agents with different perceptual capabilities may well disagree about its colour (or whether it has colour at all), and so, given that we are taking the perceptual capabilities of an agent to comprise a perspective, we can describe the colour of the prehistoric sunset as perspective-dependent. Thus, colour perception can be characterised as objective indexed to a particular agent perspective, and so constitutes an example of perspectival objectivity.

This then rehearses the case of colour perception as outlined in Giere (2006, Ch.2) and (Menzies and Price, 1993), explicated in terms of the notion of perspectival objectivity I have introduced above. It is important to note, both here and below, that this notion of perspectival objectivity detaches from human agents to a much broader notion of agency. *Any* type of agent (or perhaps even universality class of agents), with any idiosyncratic perceptual capabilities, defines a perspective, to which some observer-independent (for observers within the class of agents) phenomena can be indexed (although it is contingent whether any such phenomenon corresponds to, say, colour). Whether we could welcome any such class of agents into our epistemic community will depend upon the possibility of (natural or manufactured) overlap between our respective sensory contingencies. This notion of perspectival objectivity also extends naturally to scientific instruments, where the nature of the interaction between instrument and system characterises a kind of 'capability' for the instrument, and so defines a perspective (in the way discussed above in §1.2) to which objective phenomena can be indexed. Needless to say, we design and engineer scientific instruments to mesh with our perceptual capabilities; I will say more about instruments in this context in §4 below.

The case of colour perception is relatively straightforward. As a second, more nuanced, illustrative case study, let us now consider the debate over the objectivity of causality at the intersection of agency and interventionist accounts.

2.2 Causal perspectivalism and objectivity

It is no coincidence that causal perspectivalism is related to the previous case of colour perception. 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 perceptual capabilities of human agents play a crucial role in defining colour perception, so too do the intervention capabilities of human agents play a crucial role in defining causal relations and, in particular, the asymmetry of causation. 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. 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, $X = x_1 \ldots x_n$. 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, and 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. 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) develops the notion of causal perspectivalism to address this criticism, 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 (we have knowledge of the past, but not of the future). 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. We can see in Price's diagnosis of the objectivity of interventionist causation the hallmark of perspectival objectivity: the objectivity of causal relations is indexed to a perspective defined by the temporal embedding of the intervening agent, as well as other agent-centric pragmatic constraints (like the specification of a level-of-grain).

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 supposed '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 orientation and shared physical capabilities as manipulators of the world that provide our shared idiosyncratic epistemic constraints, and so ensures the intersubjective objectivity of our causal claims. This provides us with the the perspectival objectivity of causality.

Armed with a more complete 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 suggest a possible philosophical foundation for the claims that arise from the no-go theorems of §1.1 ruling out the possibility of observer-independent facts. The tool that I develop in this work to address this is perspectival objectivity, whereby some shared constraint amongst agents ensures the possibility of intersubjective objectivity indexed to the agent perspective. My contention here is that this notion is sufficient to make sense of observer-dependency by recasting it in terms of perspective-dependency, maintaining objectivity—observer-independence—within a perspective. In this section I extend the discussion to quantum theory, connecting perspectival objectivity to Bohr's approach to quantum theory. By way of contrast, first with Heisenberg, then with Einstein, I explore Bohr's conception of objectivity through his thoughts on ontic indeterminacy, physical reality, and complementarity, and argue that Bohr's picture ensures the objectivity of quantum phenomena.[6] In the next section, I relate Bohr's conception of objectivity with my notion of perspectival objectivity.

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.127)). 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. We can think of these measurement conditions as themselves defined by, in the first instance, scientific instruments, but also naturally extend this to encompass any external system interacting with the quantum system of interest.

3.2 Physical reality

We can explore Bohr's views on the nature of 'physical reality' through his response to the argument of Einstein, Podolsky and Rosen (1935) (EPR) regarding their 'criterion of physical reality' (Bohr, 1935, p.700):

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

> 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.

In the last sentence of this passage, Bohr takes the term 'physical reality' to apply unambiguously ('properly') only to a phenomenon (Barad, 2007, p.274). For Bohr, a phenomenon in quantum theory refers exclusively to observations obtained under specific experimental circumstances, where the interaction between the system and apparatus is an inseparable part of the phenomenon (see, for instance, Bohr (1949, p.238) and Bohr (1958, p.4)). Thus, Bohr is able to grant to Einstein *et al.* that, according to their argument, a lack of mechanical disturbance of the system ensures the physical reality of the definite-valued measured properties, which for Bohr are the 'phenomena'. But for Bohr the completeness of the quantum mechanical description does not necessarily imply a lack of physical reality of the phenomena. Since Bohr takes "the very conditions which define the possible types of predictions"—that is, the experimental conditions under which the particular phenomena arise—as an inseparable part of the phenomena, the physical reality of the definite-valued measured properties can be influenced without countenancing a mechanical disturbance, simply by changing the experimental conditions. Thus Bohr grants the same 'physical reality' to the phenomena as do EPR while 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—that is, the phenomena—then the phenomena, and thereby physical reality, are likewise conditionally defined by the experimental apparatus.

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 above 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. But, as argued in §1.2, instruments, and, by extension, experimental arrangements, can also be understood as perspectival. Recall that we can understand the nature of the interaction between instrument and system as characterising a kind of 'capability' for the instrument, and so it constrains the subset of variables to which the measured system can respond, and thereby defines a perspective to which objective phenomena (given the experimental arrangement) can be indexed. Thus, 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, where phenomena are objective indexed to an experimental arrangement (observer-independent, but instrument-dependent, we might say).

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 if not anthropocentric? I have argued throughout this work that, just like scientific instruments define a perspective, so too does our constrained idiosyncratic capabilities to interact with, and model, reality define a perspective. In this context, the interaction between an instrument and a system characterises a kind of 'capability' for the instrument by constraining the subset of variables to which the measured system can respond. But we design and engineer scientific instruments to mesh with our perceptual capabilities, thus we manufacture overlap between the 'capabilities' of our scientific instruments and our idiosyncratic sensory contingencies. So in the quantum context, if a phenomenon for Bohr is comprised of a 'measuring' part—that is, the experimental arrangement—and a 'measured' part, then, given these considerations, the experimental arrangement is specifically devised by the agent to bring about the phenomenon in accordance with the idiosyncratic experiential faculties of that agent. (Recall the Giere quote from above: "an observer, whether a human or an instrument, can interact with an object only from the observer's own particular perspective".)

This does not raise some novel quantum problem associated with observation, but is a simple recognition that our observations are constrained to a set of variables matching our perceptual capabilities, and our scientific instruments necessarily mediate our observations. For human agents, the relevant phenomena consist mostly 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.[7] (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 unexperienceable. Some other class of agents outside out own might very well be capable of interacting with and measuring quantum systems, but any information they might gather is only useful *to us* in so far as it can be translated into a form detectable by our idiosyncratic sensory contingencies.) 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.

Thus, I have argued that the perspective characterised by our constrained interaction capabilities is an inescapable condition of worldly-directed human agency, and also underpins the

[7]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.

design and implementation of our scientific instruments. The inescapability of the perspective ensures intersubjective agreement between agents that share the perspective, and so there is a perfectly reasonable sense of objectivity—that I have called perspectival objectivity—that is available to underpin the possibility of objective scientific inquiry. In this and the previous section I have mounted a case that Bohr's quantum picture incorporates a type of perspectivalism, and a type of perspectival objectivity, 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). But my motivation all along has been to attempt to accommodate the recent claims from quantum foundations that quantum mechanics rules out the possibility of "observer-independent facts". By extending the notion of perspectivalism to generate a strongly qualified sense of observer-independence, whereby facts about scientifically modelled objects are indexed to an observer perspective, I suggest that these no-go theorems, rather than demonstrating the possibility of observer-dependent facts, would be better understood as demonstrating the possibility of perspective-dependent facts, which is a much easier pill to swallow, allowing for a notion of observer-independence indexed to an agent perspective. Thus perspectival objectivity can ensure, despite the possibility of perspective-dependent scientific facts, the objectivity of scientific inquiry. The task remains, then, to flesh out perspectival objectivity in quantum mechanics to provide a more robust philosophical foundation for a perspective-dependent reality.

5 Future directions

There are challenges and opportunities that lie ahead for this analysis of the consequences of the no-go theorems. Perhaps the biggest challenge relates to understanding what perspectival objectivity means for a third-person description of the Wigner's friend scenarios therein (or if such a description remains possible at all). 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 ('categorical adjunction') 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 'quantum 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).

There are similarities between this formal framework and categorical approaches such as Isham and Butterfield (1998); Döring and Isham (2011); Abramsky and Brandenburger (2011) and especially the 'Bohrification' programme of Heunen *et al.* (2011). The express difference between these approaches and Karakostas and Zafiris is that Karakostas and Zafiris derive a categorical adjunction to relate the local Boolean and global quantum structural level, which conceptually and technically differentiates the approaches. Nevertheless, one might wonder about the strength of the support that the formal framework of Karakostas and Zafiris lends to perspectivalism given that these other categorical approaches seem able to formalise the interrelation between the non-commutative global structure of a quantum system and the commuting sub-algebras of events that are measurable in experiments without recourse to the conceptual machinery of perspectivalism. This, however, gets the strength of the claim I make in this work wrong. I am not arguing for the necessity of perspectival objectivity in understanding and interpreting measurement in quantum theory, nor do I take Karakostas and Zafiris (2018) to have outlined a necessary interpretation of their categorical formalism. The intention in this work is to suggest an albeit unorthodox proposal that is developed from an existing tradition of perspectivalism in science and plausibly provides a way to understand the observer-dependent facts of recent no-go theorems rather in terms of perspective-dependent facts, while maintaining the observer-independence of scientific claims within the perspective. It is reason to be optimistic for this proposal that the framework of Karakostas and Zafiris (2018) formally and independently captures that a perspective arises from a particular experimental arrangement applied to some quantum system. It remains to be seen how far this programmatic approach can be pushed.

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 here 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, sets of quantum states are selected as a preferred measurement basis as a function of the interaction between system and environment, 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.[8] But the uniqueness of decomposition does not by itself specify preferred basis states, 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 justifying the decomposition of system, apparatus, and environment pragmatically from agent-centric principles, and moreover 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.

[8]This is called the tridecompositional uniqueness theorem. See (Schlosshauer, 2005, p.1278) and references therein for further details. Although, see Donald (2004) for dissenting voice on the application of this theorem in this context.

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 observer-independence of relational quantum states.

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