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A loose and separate certainty: Caves, Fuchs and Schack on quantum probability one

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ABSTRACT

Carlton Caves, Fuchs, and Schack (2002) have recently appealed to an argument of mine (Stairs, 1983) to address a problem for their subjective Bayesian account of quantum probability. The difficulty is that on the face of it, quantum mechanical probabilities of one appear to be objective, but in that case, the Born Rule would yield a continuum of probabilities between zero and one. If so, we end up with objective probabilities strictly between zero and one. The authors claim that objective probabilities of one leads to a dilemma: give up locality or fall into contradiction. I argue that this conclusion depends on an overly strong interpretation of objectivism about quantum probabilities.

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1. Introduction

Carlton Caves, Christopher Fuchs and Rüdiger Schack (henceforth CFS) have long defended a subjective Bayesian account of quantum mechanical probability. This may seem implausible for probabilities of one, but that case is important for their view. Assigning probability one to a quantum proposition typically generates a continuum of probabilities between zero and one *via* the Born rule. If probability one is objective, it would presumably follow that these other probabilities are as well. Consequently the viability of CFS's program requires them to deny that quantum probability is objective even for probability one. They write:

> The statement that the measurement outcome is 1 with certainty is… not a proposition that is true or false of the system, but an agent's belief – and another agent might make a different prediction. (Caves et al., 2002, p. 267)

In order to make their case, CFS appeal to a paper of mine from some years ago (Stairs, 1983). Though I am flattered by the attention to my work, I do not think their argument goes through. The appearance that it does rests on an overly strong reading of what objectivism calls for.

What follows is not intended as a full defense of objectivism about quantum probability (henceforth we will just say "objectivism.") CFS try to show that if probability one is objective, we face a dilemma: embrace non-locality or fall into contradiction. The main goal of this paper is to show that there is no such dilemma. As for quantum probabilities strictly between 0 and 1, the argument would not be that they must be treated objectively, but rather that nothing CFS say rules this out. I will sketch what I take to be a promising strategy for objectivism about quantum probabilities, but working out that strategy – or any other – goes beyond this paper.

CFS's case breaks into three parts: general arguments on behalf of subjective Bayesianism, a brief against an objective view of state preparation, and an argument that if we treat quantum certainty as objective but accept locality, we wind up in contradiction. I will urge that the general considerations are not compelling, that the case against the objective view of state preparation does not succeed, and that the argument about quantum certainty can be turned aside by some careful reflection on the connection between probabilities, properties and counterfactuals.

2. General considerations

According to CFS, propositions and probabilities lie on opposite sides of a category divide. Probability has an objective

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component: events or facts, which agents can settle unambiguously, and the rules of probability, including the Born rule. However, probabilities themselves are degrees of belief, and are neither true nor false. Probabilities do not follow from facts, and unlike physical parameters, they cannot be determined unambiguously—not even approximately. And though David Lewis's Principal Principle (Lewis, 1986a, 1986b) attempts to bridge the gap between degrees of belief and objective chances, the Principle is off the mark at least in the case of supposedly deterministic examples such as coin tosses. Or so we are told.

We will not spend much time on the category issue. It would be pointless to try to get by without subjective probability, and we can agree that degrees of belief are not facts. Nonetheless, CFS do not show that there could not be objective probabilities, nor that "objective probability" amounts to a category mistake. They are right that probability claims – subjective *or* objective – do not follow from non-probabilistic facts. However, this does not tell us anything about the objectivity of probabilities. The fact that the stuff in the shaker is mostly sodium chloride does not follow from the fact that it is table salt, even though table salt *is*, mostly, sodium chloride; the fact that Mary is thinking of Vienna does not follow from any non-psychological description of her, but this does not threaten physicalism about the mind. Moral claims do not follow from non-moral claims, but moral facts could still supervene on non-moral facts. For all CFS have said, objective probabilities might supervene on physical symmetries, for example, even though the symmetry claims do not *entail* the probability statements.

2.1. The Principal Principle and Humean chance

Accounts of what objective probability might be are not hard to find. Maudlin (2007) provides a lucid discussion of three possible analyses, and one would be hard-pressed to argue that one of them must be uniquely right or clearly wrong. CFS devote some attention to David Lewis's views, and in particular to the Principal Principle as a way of making sense of objective chance. Though they do not say a lot, it will be worth our while to say more.

Roughly, the Principal Principle (PP) holds that our degree of belief in a proposition ought to agree with the objective chance, if there is one and if we know it. More precisely, let A be a proposition. Let X say that the chance of A is x. And let E be any other "admissible" proposition, where "admissible" means, roughly, "does not provide any credence-relevant information about A beyond what knowledge of chances provides." Then PP says that a rational credence function Cr satisfies

$$Cr(A|XE) = x$$

This constraint is silent on the metaphysics of chance. In particular, it does not require that chances be intrinsic dispositions. On Lewis's account, however, nothing that violates PP could reasonably count as chance. Our credences guide our actions, and "chances" that could not be action-guiding even if we knew them are not worthy of the name.

So far, all this says is that *if* anything is worthy of being called chance, it must satisfy PP. That's consistent with there being no such thing. CFS maintain that in at least one case, non-trivial chances cannot exist: deterministic setups such as we usually suppose coin-tossing arrangements to be. The problem is that a fully precise specification of any such chance set-up will fix the outcome, leaving us with chances of 0 and 1.

The immediate reply is that Lewis would agree. He held that in a deterministic world, there are no chances (1986b, 117–121.) If determinism fails, Lewis provides his own account of chance: an extension of what he says about laws of nature. According to Lewis, a law of nature is a theorem of the "best system" of generalizations for describing the totality of events—the so-called "Humean Mosaic." "Best" includes the dimensions of simplicity, strength and fit. On Lewis's view, whether something is a law of nature is a fact about the world itself—about the arrangement of the mosaic. The idea can be extended to chance. We can broaden the range of law-like generalizations to include ones that describe statistical patterns. A candidate probabilistic law will earn its keep in the same way that strict laws do: by being part of the Best System. Such laws would be objective; they would reflect features of the world itself.

Lewis rejects the idea that there can be chances in a deterministic world, but not everyone agrees. Roman Frigg and Carl Hoefer (Frigg and Hoefer, 2010; Hoefer, 2007) argue that objective chances are real even if fundamental laws are deterministic. Our interest is not in the question of whether there can be objective probabilities in a deterministic world, but in the general character of Frigg and Hoefer's scheme, which is closely related to Lewis's.

The phrase "objective chance" suggests a dispositional or propensity account, but Frigg and Hoefer are no friends of hidden propensities. Their point is that when we describe things at the level of lotteries, coin tosses and so on, the world exhibits stable statistical patterns. Chance as described by Frigg and Hoefer is called "Humean Objective Chance" or HOC, and they use the metaphor of "Lewis's Demon" to convey the idea. We imagine a being who knows all the details of the Humean Mosaic of events (HM):

> The demon now formulates all possible systems of probability rules concerning events in HM… The rules in these systems assign numbers to events. These numbers have to satisfy the axioms of probability… but nothing over and above this is required at this stage. Then the demon is asked to choose the best among these systems, where the best system is the one that strikes the best balance between simplicity, strength and fit. The probability rules of the system that comes out of this competition as the best system then, by definition, become 'chance rules'… [T]he chances for certain types of events to occur… simply are what probabilistic laws of the best system say they are. (Frigg and Hoefer, 2010)

These chances are not epistemic. If we knew the mosaic whole and could juggle the details with godlike ease, we would have no use for probability—objective or subjective. But the patterns, if they exist, are part of the world. One way to see the point is to pretend for a moment that frequency is all that matters: to say that among situations fitting a certain macroscopic description, 30% exhibit feature F is to say something about events in the world itself and not our knowledge of it.

Of course, frequency is not all there is to the story, though Frigg and Hoefer describe their view as "a (major) sophistication of finite frequentism." We can get a sense of what the view means for quantum probability by extending Frigg and Hoefer's metaphor. Suppose the demon discovers that the pattern in the mosaic provides not just excellent confirmation for quantum theory, but better than for any rival theory. For this to be true, the actual frequencies could not depart wildly and systematically from the ones we expect based on quantum mechanics. If they did, quantum theory would fall down badly on the dimension of fit. If quantum mechanics is the best fit for the pattern in the mosaic, then quantum probabilities correspond straightforwardly to objective chances: to HOCs.

This is not the only way one could reasonably think about objective probability in quantum mechanics, but it is worthy of being taken seriously not least because of its minimalism; objectivism need not carry large metaphysical commitments.