Philosophy of Quantum Mechanics: Week 6

Two Breeds of Probability

Credences: *Subjective* probabilities—express our degree of belief.

Chances: *Objective* probabilities—express facts about the world.

If we're looking for a realist account of quantum mechanics, it seems reasonable that quantum probabilities should behave like chances, not credences.

Goal: Try to understand what objective probabilities could be.

Subjective Probabilities

There's nothing stopping us from having some very odd degrees of belief, but there are plausibly some rules:

- Degrees of belief should fall between 0 and 1.
- And if we'd like to be *rational*, then they'll be a whole lot more constrained.

Dutch Books

If we're to be *rational*, our degrees of belief must satisfy the *Kolmogorov probability axioms*:

1. Probabilities must lie between 0 and 1.
2. If an event p is certain to occur, its probability is 1.
3. Incompatible events satisfy $\Pr(p \text{ or } q) = \Pr(p) + \Pr(p)$.

An agent whose credences don't satisfy the Kolmogorov probability axioms can fall foul of a *Dutch book argument*—someone else's betting strategy that is bound to always win.

- If my credence in p is 0.6, then I should be willing to bet 60p on p for a chance of winning £1.
- Suppose my credence in p is 0.6, and my credence in not-p is also 0.6. In this case my credences violate the third axiom.
- Then I ought to be willing to bet 60p on p and 60p on not-p.
- If I place both bets, then I will always lose money: whatever happens, I'll pay out £1.20 and win £1.

The Principal Principle

The connection between chance and credence is typically taken to proceed via the *principal principle*, due to David Lewis. Here's how Saunders puts it: (*Many Worlds?*, intro.)

PP: Let S be the statement that the objective probability of event E at time t is P, and suppose our background knowledge K is 'admissible' (i.e. it excludes information as to whether or not E happened): then our subjective probability of E, conditional on S and K, should be P.

Put simply, **PP** states that one should set one's subjective probabilities equal to whatever one has the best evidence to believe are the objective probabilities in nature.

Some think that **PP** gives a kind of functional *definition* of chance—chances are those structures in the world to which rational agents *should* strive to match their credences.

Objective Probabilities

Frequentism

Frequentism identifies chances with relative frequencies—"Thus, we might identify the probability of heads on a certain coin with the frequency of heads in a suitable sequence of tosses of the coin, divided by the total number of tosses." (SEP)

Finite frequentism: The probability of an attribute A in a finite reference class B is the relative frequency of actual occurrences of A within B.

Problems for finite frequentism:

- "[J]ust as we want to allow that our thermometers could be ill-calibrated, and could thus give misleading measurements of temperature, so we want to allow that our measurements of probabilities via frequencies could be misleading, as when a fair coin lands heads 9 out of 10 times." (SEP)
- "[A]ccording to the finite frequentist, a coin that is never tossed, and that thus yields no actual outcomes whatsoever, lacks a probability for heads altogether ... a coin that is tossed exactly once yields a relative frequency of heads of either 0 or 1, whatever its bias." (SEP)

Infinite frequentism: Identify probabilities with *limiting* relative frequencies, in the limit in which the size of the reference class goes to infinity.

Problems for infinite frequentism:

- "But what if the actual world does not provide an infinite sequence of trials of a given experiment? ... In that case, we are to identify probability with a hypothetical or counterfactual limiting relative frequency. We are to imagine hypothetical infinite extensions of an actual sequence of trials; probabilities are then what the limiting relative frequencies would be if the sequence were so extended. ... Note that at this point we have left empiricism behind." (SEP)

- “Consider an infinite sequence of the results of tossing a coin, as it might be H, T, H, H, H, T, H, T, T, Suppose for definiteness that the corresponding relative frequency sequence for heads, which begins 1/1, 1/2, 2/3, 3/4, 4/5, 4/6, 5/7, 5/8, 5/9, , converges to 1/2. By suitably reordering these results, we can make the sequence converge to any value in [0, 1] that we like. (If this is not obvious, consider how the relative frequency of even numbers among positive integers, which intuitively should converge to 1/2, can instead be made to converge to 1/4 by reordering the integers with the even numbers in every fourth place, as follows: 1, 3, 5, 2, 7, 9, 11, 4, 13, 15, 17, 6,)” (SEP)

- “It is well known that the relative frequency of sixes on an (indestructible!) fair die is not *certain* to tend towards $1/6$ as the number of throws tends to infinity. The best that can be proven is that the *probability* of the relative frequency diverging by any given amount from 1/6 tends to zero as the number of throws tends to infinity. (This is one form of the Law of Large Numbers ..) ... If we are using relative frequencies to *measure* probability, this is reassuring: the more repetitions of the experiment that we perform, the less likely it is that the probabilities are not accurately measured by the relative frequencies. If we are using relative frequency to *define* probability, on the other hand, it is disastrous: if probability *is* limiting frequency, what can it possibly mean to say that the long-run relative frequency approaches the probability with high frequency?” (Wallace, *The Emergent Multiverse*, p. 123.)

Propensity Interpretations

On the *propensity view*, objective chance is thought of as a physical propensity/disposition/tendency of a given physical situation to yield an outcome of a certain kind.

- “But as Hitchcock (2002) points out, “calling this property a ‘propensity’ of a certain strength does little to indicate just what this property is.” Said another way, propensity accounts are accused of giving empty accounts of probability, à la Molière’s ‘dormative virtue’ (Sober 2000, 64).” (SEP)