Does Quantum Mechanics Require a New Concept of Probability?

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In the 1951 Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability, the Noble Prize winning physicist Richard Feynman used Young's double-slit experiment to claim that classical probability is unable to describe the behavior of a single particle, like an electron or a photon. He then proposed an alternate calculus for combining probabilities based on Born's Rule (as is invoked in Schrodinger's Equation). This in turn gave an added impetus to quantum probability, and quantum probability is a foundation for quantum communication and quantum computing. Many computer scientists claim that quantum computing is the answer to the problems and challenges of "big data."

Thrown in the above mix is Heisenberg's principle of uncertainty, which according to some calls for a fundamental change in the very foundations of probability theory. In particular, they claim that it is inappropriate to make probability assignments on the conjunction of events in a sigma-algebra of events. Because of Feynman's impeccable reputation as a physicist of the highest caliber, challenges to his claim of inadequacy have been minimal. An exception is the work of Koopman, Suppes, and Varadarajan.

In this expository talk, I will describe the double slit experiment, and show how the phenomenon observed by Feynman can also be described via the classical probability calculus via random mixtures two distributions. My interest in the probabilistic foundations of quantum mechanics was spawned by some recent and very fascinating work done by QBists. These are quantum physicists who claim that several paradoxes of quantum mechanics, such as the collapse of the wave function, entanglement, and non-locality, can be explained by adopting a *subjective* (Bayesian) view of probability.