# Humeanism and the Measurement Problem

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**Abstract**

It has been recently argued that the measurement problem of standard quantum mechanics (SQM) dissolves if we accept Humeanism about laws of nature. In this paper, I argue that this new analysis of the measurement problem is seriously flawed, and a more complete analysis does not support the conclusion.

The measurement problem is a well-known problem of standard quantum mechanics (SQM). The theory postulates two distinct dynamics: one is the linear and deterministic Schrödinger equation, and the other is the nonlinear and indeterministic wave-function collapse. When a quantum system is not measured, its wave function evolves over time according to the Schrödinger equation, while when the system is measured, its wave function will collapse to the state that corresponds to the result of the measurement according to the collapse postulate. It has been widely argued that SQM is plagued by the measurement problem (Bell, 1990; Albert, 1992; Lewis, 2016; Ismael, 2021). The main reason is that SQM does not give a precise definition of measurement, such as what physical process is a measurement and what physical system is qualified as a measuring system, and thus the laws of SQM, namely the above two dynamics, is not precise and even empty in most cases; if it is unknown whether a certain interaction is a measurement, then SQM cannot tell us how the wave function of a quantum system evolves over time under the interaction.

In a recent paper, Dorst concludes that the measurement problem of SQM dissolves if we accept Humeanism about laws of nature (Dorst, 2021). He observes that the arguments for the existence of the measurement problem presuppose an anti-Humean metaphysics of laws, according to which the laws are principles that govern the behavior of physical systems. He then argues that if we adopt a Humean view of laws, according to which the laws are some sort of description of the behavior of physical systems, then the measurement problem no longer arises, and the Schrödinger equation and the collapse postulate together can comprise the fundamental laws of nature. This is a surprising result indeed.

In this paper, I will examine Dorst's arguments. I will not analyze whether all arguments for the existence of the measurement problem presuppose an anti-Humean metaphysics of laws. Nor I will analyze the validity of property opportunism, or whether laws can reference derivative properties besides the fundamental properties, such as the property of being measured. I assume that these analyses of Dorst are correct. I will only examine his analysis of the so-called nomological gaps, which is the key step to reach his conclusion that Humeanism dissolves the measurement problem. If this step fails, then Dorst's whole project will not succeed.

According to Dorst, a nomological gap is a situation that the laws say is physically possible, but for which they give no predictions. The nomological gaps of SQM result from the lack of a precise definition of measurement. Due to this imprecision, SQM does not state precisely where the Schrödinger dynamics gives way to the collapse postulate, which further means that SQM cannot make predictions in certain situations where a more precise theory can. This will result in reduction in strength of the systematization of the Humean mosaic by SQM. The question is whether the nomological gaps and the resulting reduction in strength are so great that SQM cannot be qualified to be the best system.

Consider Dorst's example of Schrödinger's cat. In the experiment, there is a measuring device $M_1$ inside the box which measures the cat's heartbeat to see if it is alive. Due to the lack of a precise definition of measurement, there will be some imprecision concerning exactly when the $M_1$ measurement has occurred. In other words, SQM will not tell us exactly when the wave function of the composite system has collapsed; it will only give us an interval in which the collapse occurred.

Suppose that there is a second measuring device $M_2$ outside the box, which can measure the interference between the two branches of the wave function of the composite system and which performs its measurement faster than $M_1$ within the interval. Then the statistical distribution of the results of $M_2$ (for an ensemble of identically prepared composite systems) will differ depending on whether the collapse of the wave function of the composite system has occurred by the time $M_2$ makes its measurement. This means that the vagueness concerning exactly when the $M_1$ measurement occurs will further infect the result of the $M_2$ measurement: SQM makes no predictions about that measurement result. Dorst calls this a nomological gap: "a situation that the laws say is physically possible, but for which they license no predictions."

Now it comes to Dorst's key step to reach his conclusion that Humeanism dissolves the measurement problem. Dorst thinks that the nomological gaps of SQM are potentially worrisome, but they are not a dealbreaker for the Humean. His reason is as follows. According to Humeanism about laws of nature, these nomological gaps will be accounted for in the balance of simplicity, strength, and tractability. The main place they seem to be problematic is with respect to strength: since the laws of SQM don't tell us what happens in these gaps, they are less informative than we hope. However, the amount of lost information or the reduction in strength by positing such gaps depends on how many of those gaps happen to obtain in the Humean mosaic. Since measurements like $M_2$ are extremely difficult to realize, these nomological gaps of SQM will be quite rare or even nonexistent. Then, from the Humean perspective, the fact that SQM has such nomological gaps in some exceedingly rare situations should not count as a major strike against it and further disqualify it to be the best system.

In the following, I will examine Dorst's analysis. First of all, it is worth pointing out that the realization of measurements like $M_2$ is not prohibited by SQM or other fundamental principles. Moreover, with rapid developments in quantum technologies such as quantum computation, we should be more and more optimistic, not pessimistic, about the possibility of realizing such measurements in the near future.

Next, even if this kind of measurements will never be technologically feasible, we have other non-interferometric methods to measure the collapse of the wave function, which are more feasible with current technologies (for a recent review see Bassi, 2021). One method is to detect the energy increase or spontaneous heating of the composite system during a measurement or measurement-like process. It has been shown that the collapse postulate of SQM violates the conservation of energy and momentum and leads to energy increase during a measurement (Pearle, 2000). Several experimental tests using this method have also been proposed to detect the existence of the collapse of the wave function (Diosi, 2015; Vinante et al, 2017). Thus, even if the nomological gaps of SQM are rare or even nonexistent for measurements like $M_2$, they are not rare for other non-interferometric measurements.

Thirdly, and more importantly, failing to predict the results of measurements is only a small and derived part of the nomological gaps of SQM. Since Humeanism about laws of nature is a realist view, the predictions of SQM, from the Humean perspective, should be essentially about the state of the world or the Humean mosaic, while the predictions about the results of measurements are derived from the predictions about the state of the world. Insisting that the predictions of quantum mechanics are only about the results of measurements is a legacy of the Copenhagen view, not the Humean interpretation of quantum mechanics, as also admitted by Dorst (2021). Then, in the above example of Schrödinger's cat, the imprecision concerning exactly when the $M_1$ measurement has occurred will lead to more general nomological gaps; SQM gives no predictions about the state of the world after the $M_1$ measurement starts. Such nomological gaps of SQM are independent of whether or not the collapse of the wave function can be detected; they are not rare or nonexistent but always existent.

In fact, SQM has more nomological gaps when considering the imprecision of defining a measuring system. Dorst's analysis supposes that $M_1$ is a genuine measuring device, and thus the imprecision is confined only within a very short interval, namly the measuring time. However, in SQM we don't know if a physical system is a geniune measuring device. As Bell famously wrote,

> "What exactly qualifies some physical systems to play the role of "measurer"? Was the wavefunction of the world waiting to jump for thousands of millions of years until a single-celled living creature appeared? Or did it have to wait a a little longer, for some better qualified system ... with a Ph.D.? " (Bell, 1990)

Then, the imprecision concerning exactly when a measurement has occurred is not confined within a very short interval; rather, it may last for an infinitely long time. For example, in the case of Schrödinger's cat, if we open the box soon, then the imprecision concerning exactly when the superposed state of Schrödinger's cat collapses is confined only within a short interval between the sealing and the opening of the box. But if we never open the box, then the imprecision will last for an infinitely long time.

Finally, it is worth noting that the collapse postulate in SQM is ill-defined for measurements of continuous observables such as position. The ill-definedness is independent of the above imprecision. For instance, according to the collapse postulate, if we do a position measurement, the wave function will collapse to a position eigenstate, which is unnormalizable and hence not a valid physical state. Moreover, as Wallace (2019) has argued, the collapse postulate also fails correctly to account for repeated, continuous and unsharp measurements.

To sum up, I have argued that Dorst's analysis of the nomological gaps of SQM is seriously flawed. Contrary to his conclusion, the nomological gaps of SQM, which results from the imprecision of the collapse postulate, are not rare or even nonexistent but common and great, and thus it is hard to see that the theory can be qualified to be the best system. More convincing arguments are needed to support the conclusion that there is no measurement problem for Humeans.

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