## Interpretation or Existence

Let us set *a* = .5 (which is indicative of a maximally entangled state) in order to examine the impact of our development, and assume the devices are 100% efficient. Assume in the Hypothesis $H_0$ in Hypothesis Test 3.1, that all systems evolve via Schrödinger's equation. After the initial Schrödinger unitary evolution of photon and devices, the subsequent operation of Step 3 is performed while assuming $H_0$ also proceeds unitarily. Now we know that the unitary prediction is to entangle the two-qubits, and hence Step 3 of the UMDT will result in a CHSH sum $2\sqrt{2}$ under $H_0$.

On the other hand, suppose that Device 1 is a system that we *know* is a bona fide efficient measurement device. In Schrödinger unitary theory the state after Step 1 is given in Equation (3.9)

$$|\psi_{\text{fin}}\rangle = |0\rangle \otimes (\sqrt{a}\,|\psi^1\rangle_1 \otimes |\psi^0\rangle_2 + \sqrt{1-a}|\psi^0\rangle_1 \otimes |\psi^1\rangle_2).$$

The state is predicted via Schrödinger's equation to be in a superposition of two terms. The first is that Device 1 absorbed the photon in Path *B* and evolved to a new readout state $|\psi^1\rangle_1$ while Device 1 evolved to state $|\psi^0\rangle_2$ indicative of no absorption. The second term is that Device 2 absorbed the photon in Path *C* and evolved to a new readout state $|\psi^1\rangle_2$ while Device 1 evolved to state $|\psi^0\rangle_1$ indicative of no absorption. On the other hand, we know that if a photon is sent via only Path *B* that the only unitary possibility, as the devices are assumed 100% efficient, is to evolve to $|\psi^1\rangle_1 \otimes |\psi^0\rangle_2$, and we know that if a photon is sent via only Path *C* that the final state that is predicted unitarily is $|\psi^0\rangle_1 \otimes |\psi^1\rangle_2$. Hence, we know the final states of the devices under Hypothesis $H_0$ when no superposition occurs. If one assumes that unitary evolution suffices to explain all processes including measurement, and that when a measurement occurs the final state exists in a definite pointer state of either $|\psi^1\rangle_1 \otimes |\psi^0\rangle_2$ or $|\psi^0\rangle_1 \otimes |\psi^1\rangle_2$ then one needs to examine whether there are any observational consequences if indeed the final state of the two devices ends up after Step 1 in the Schrödinger unitarily predicted state of Equation (3.9) or ends up in either $|\psi^1\rangle_1 \otimes |\psi^0\rangle_2$ or $|\psi^0\rangle_1 \otimes |\psi^1\rangle_2$.

The case when both Device 1 and Device 2 are in a state that corresponds to what would have been the case if the photon took either the upper or lower path results in a tensor product state of devices $|\psi^1\rangle_1 \otimes |\psi^0\rangle_2$ or $|\psi^0\rangle_1 \otimes |\psi^1\rangle_2$. One finds the UMDT CHSH sum corresponds to taking a 2-qubit state that is in a tensor product, and results in $\sqrt{2}$ as seen in the dotted curve in Figure 3.16. On the other hand, under $H_0$ the CHSH sum can be computed as $\sqrt{2}(1+\mathbb{C})$.

An important issue is whether or not the CHSH sum changes if one increases the number of particles in the device. Note that we first generally developed theory that generates the Step 1 and 2 operations for an arbitrary Hamiltonian. Suppose that one changes the Hamiltonian from the two-particle example to three particles and computes the results. The results are the same, $\sqrt{2}(1+\mathbb{C})$ for Schrödinger unitary and $\sqrt{2}$ for the case when the final state is a definite device pointer state of either $|\psi^1\rangle_1 \otimes$

$|\psi^0\rangle_2$ or $|\psi^0\rangle_1 \otimes |\psi^1\rangle_2$. Suppose one changes the Hamiltonian to 100000 particles. It would take a long time to simulate on a computer, but one would obtain the same result.

The UMDT CHSH sum is independent of the number of particles. The result is independent of the operators: for example, one can include creation and annihilation operators common in quantum optics. The result is independent of the local time-like environment surrounding the detector that could possibly be directly affected by the interaction. The result is also independent of the type of particles that compose the device as they can be either bosons or fermions or composite particles. And the result is independent of local interactions between the particles composing the device; these can be completely arbitrary.

One might take exception to the fact that the initial states of the device were always pure states, and in fact there is the possibility of mixed state initial states. How are we assured that the same results will occur for such mixed initial states? This is a valid objection; the theory will be extended to mixed states shortly and shown that the same result occurs for initially mixed device states.

In this manner, the UMDT operations specified are indeed capable of resolving Hypothesis Test 3.1. Theoretically our construction shows that Hypothesis $H_0$ is false and $H_1$ is correct; given our assumptions, one *must* include an evolution process that diverges from Schrödinger's equation if one expects to be consistent with the experimental facts that measurements do occur and are statistically correlated with the degree of superposition $a$.

Now if it were the case that the substitution of either of these states were such that it did not provide any observational differences in this setup or others, the problem can rightly be deemed to be strictly interpretational and a matter that could be argued is best left as philosophy. However, as there does appear that there are observational differences, then the problem cannot be assumed *a priori* to be a strictly interpretational issue.

Let us now turn to Hypothesis Test 3.2 which examines whether or not Schrödinger unitary evolution is a valid description for Born's bifurcation rule. Born's rule predicts that when a measurement occurs in one of the two devices, there is a probabilistic bifurcation of the quantum state. In the case that we are considering, Born's rule predicts that the photon is found with probability $a$ in Path B and $(1 - a)$ in Path C. This is consistent with either the state $|\psi^1\rangle_1 \otimes |\psi^0\rangle_2$ whereby Device 1 is in a final readout state and the Device 2 is in a final state indicating no measurement, or whereby the state is $|\psi^0\rangle_1 \otimes |\psi^1\rangle_2$ whereby Device 1 indicates no measurement and Device 2 is in a final state indicating a measurement. But either case results in the CHSH sum of $\sqrt{2}$. Now if one assumes only Schrödinger unitary evolution under $H_0$ if Hypothesis Test 3.2 and then applies Step 1 and Step 2, the result is predicted to be $\sqrt{2}(1 + \mathbb{C})$. As these predictions are the same for all numbers of particles that compose the device, it *cannot* be that Schrödinger's equation is a valid description of the physics as the number of particles of the device increases: Hypothesis $H_0$ of Hypothesis Test 3.2 is false.