On the Many-Worlds Interpretation of Quantum Mechanics and their Worlds Being a Subset of Lewisian Modal Realism[1]

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The Everett Interpretation (henceforth EI) is one of the interpretations on the table in Quantum Mechanics for attempting to deal with the measurement problem. (Everett, 1957) Assuming that the EI is true, and that there is no collapse during measurement, EI sticks to the mathematics of the Schrodinger equation and says that every value obtains on a "branch" (henceforth referred to as a "world") within a set of possibilities. In addition to ignoring the question of whether EI is true, this essay also tables questions surrounding why *you* find yourself on a particular branch instead of another. We will be merely concerned with i) how many worlds are there under EI and ii) in what sense are the worlds real.

Modal Realism, as put forth by David Lewis (1986), is a doctrine of metaphysics that is grounded within a semantic theory on the nature of propositional content within natural language. For Modal Realists, possibilities put forth within statements, if they fulfil the requirement of being genuine *possibilia*, obtain in some "world" that is distinct from the actual world. We are concerned with i) how many possible worlds are there under Modal Realism and ii) in what sense are the worlds real. Each of these sets of worlds from EI and Modal Realism get the name of their founder, but neither of them

[1] Thanks to both Tiziana Vistarini and Graham Greeve who helped me understand concepts I still feel I may not have the license to speak about.

hang on whether or not the positions of Everett or Lewis is adequately captured by either of the sets.

The essay proceeds in three sections. The first section details the way in which both Lewisian Worlds (LWs) and Everettian Worlds (EWs) are real, in that they are maximally consistent, spatio-temporally isolated, and contain every physical system and everyone of its states. The second section argues that EWs are a subset of LWs, irrespective of whatever their sizes may turn out to be. The third section discusses the size of LWs and EWs, and discusses the reasons for why the infinite of each set is undecidable.

What is "real" here?

Both the LWs and EWs consider worlds to be real, but in what sense? In this section, I will give a gloss to help understand how LWs and EWs are both metaphysically *real*, which I will then suggest makes LWs and EWs compatible in virtue of having i) identical conceptions of being real and ii) overlap with regards to how these worlds related to one another despite being causally independent from one another.

To start, I will use some formalism from Quantum Mechanics (QM) in order to describe entities at the quantum level.

|Ψ›OBJECT is the quantum state of an object in a definite state and position. That object could be any macroscopic phenomena. A short list could include things like a table, a cat, or the planet Neptune. Each of these macroscopic phenomena can have

their physical makeups discussed at a quantum level, which is to say that all physical objects are made up of quantum entities.

In each world where the macroscopic entities are made up of quantum entities, there is a list of objects within those worlds as follows:

$\Psi\text{WORLD}\rangle = |\Psi\rangle\text{OBJECT 1}\ |\Psi\rangle\text{OBJECT 2} \ldots |\Psi\rangle\text{OBJECT } N\ |\Phi\rangle$[2]

Stated simply, each world taken on the quantum level contains n many objects in Φ states at any given time.

Whereas EWs are a result of interpreting data from a quantum experiment, LWs are a result of understanding the semantics behind interpreting various propositions. Propositions include things like 1) statements, such as “The sun is the center of the solar system”; 2) counterfactuals, such as “If the New York Mets had not lost game 7, they would have won the world series,” or 3) statements with modal content, like possibilities, such as “Milan might have been the capital of Italy.” Each of these statements gaven be assessed as true or false given some world *w* in which they were uttered. For example, ‘Milan might have been the capital of italy’ is true iff there is a world *w* in which Milan is the capital of Italy.

In this essay, we are concerned with the set of *possibilia* within LWs that contain the *possibilia* within EWs. A point on disambiguating some terminology. LWs are real, in that they are instantiated possibilities, and EWs are real, in that they are instantiated possibilities. Possibilities, however, under this account are misleadingly so-called unless there is a disclaimer concerning why our world is actual and other worlds are

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[2] This notation is taken directly from Lev Vaidman’s Stanford Encyclopedia entry.

merely possible. A world is a possible world only in relation to worlds in which observers privilege their world as the *actual* world. As a corollary, our world is a possible world to statement makers discussing events that obtain in our world in another possible world.

Some worlds will be off limits to both LWs and EWs. As a result of both sets being maximally consistent, some fact α about world *w* makes either α true at that world and or ¬α true at that world, and not both. Thus, rules of logic like the law of excluded middle will be upheld at both LWs and EWs, for reasons of non-classical logic being uninstantiable in LWs and eliminating superposition as a genuine physical state brings back classical logic for EWs.[3]

If a world is *isolated*, then it is not in a spatio-temporal relationship within other worlds. That is, there is no boundary between a possible world w_1 and w_2 where something could pass between the two worlds. In other words, it is impossible to communicate within other worlds, despite our being aware of them.

EWs are a subset of LWs

One of these sets is a proper subset the other if and only if all the worlds contained set Δ are also members of set Γ and Γ contains members that are not in Δ. I argue that EWs are a subset of LWs, and that it's not *prima facie* clear why that should be the case. After all, they both are large sets. So large, in fact, that they are both

[3] Contrast with other interpretation of QM that do not allow for maximal consistency, such as the Copenhagen Interpretation.

infinite. EWs are infinite because for any arbitrary placement of a particle, there are infinitely many alternative positions which could have obtain. Take any Hilbert space defined with natural numbers and it is not hard to see why. EWs capture changes in physical objects. EWs are worlds where we could have microscopic properties and processes obtain different outcomes and still possess the same nomological laws. In other words, changing facts about quantum states does not entail that we must change facts about the physical laws across worlds where those laws obtain. We can think about it in the following formula:

For some world *w*, the physical law(s)[4] **ϕ** obtain and properties about physical entities Ψ, where Ψ's change without necessarily impacting **ϕ**.

This is roughly the same formulation we had using more quantum mechanically identifiable language in the previous section. The EI stipulates that all the possible states described in the Schrodinger equation obtained at various branches. That means that electrons are composing physical entities that resemble (or do not) the ones in our world, but have variations in certain properties.

There is a problem with identities between worlds with EI, but, briefly, I think counterpart theory within modal realism may account for a legitimate worry. Whichever world in which a macroscopic entity exists, there are nearby possible worlds where those macroscopic entities exist, perhaps without any noticeable variations. The privilege of saying that we are in the *actual* world is in virtue of how our indexicals are pointing out objects in our world, such as the pronoun "I" points out exactly the entity of

[4] I do not claim that there need be multiples laws; it might be the case that the entire universe supervenes on the actualization of one, totalizing physical law

the utterer in which that entity refers to itself in the world it occupies. For you and me, we refer to ourselves in the actual world, but your counterpart is justified in calling their world actual, too.

EWs are alternative physical possibilities to instantiated in a set of possible worlds. They are causally isolated and complete, in that the events of one world do not impact the events of another world, and the there is no piece of information missing from each world, i.e. if some fact *x* is true at that world then *x* is a member of the list of information about that world.

To that degree, LWs counterfactuals capture the meaning of the descending branches of EWs. Thus, LWs are, at a minimum, containing equal members.This creates a kind of ballooning affect, in that whatever worlds EWs postulate, LWs pick them up by extension.

Next, I will demonstrate that there are worlds missing within the set of EWs from the set of LWs. It might be the case that the size of EWs and LWs are equivalent. If that were true, for ever world we could have in EWs could be a world that LWs point to, and *vice versa*. That is, whatever could be said about postulating the existence of some world *w*, the two sets are equal if and only if EW can account for the existence of world *w* and LW can account for the existence of world *w*. If we can find one world that is within LWs and not within EWs, our job is done.

I aim to suggest that there are metaphysically possible worlds in LWs that are missing from EWs for the following reason. If LWs are a set containing what is *physically* possible, then there is no way to infer from LWs that *metaphysical* facts about those worlds must obtain as well. Paradigmatic examples of metaphysical facts that are not entailed from physical facts include: features of consciousness, e.g. sensation, issues within identity, e.g. is the essence of water being H_2O, and moral laws, e.g. worlds where moral laws do not obtain. From QM's, we might say that the collapse[5] obtains as a cause to retrieve information from a quantum system within LWs but, in virtue of stipulation within the theory, not within EWs. You can take any example you like (or all of them). If this is too much to stomach, in that you may disagree that there are metaphysical facts that do not supervene on physical reality, or, to formulate it differently, all metaphysical assumptions are derivable from physical reality, then the rest of the essay will not be any more pleasant. Instead, it is safe to say that the buck stops here in regards to understanding the property of *plentitude* that LWs obtain and that EWs do not, that is, LWs contain *every* possible, whereas EWs contain only *some* possibilities.

The next section will address how large each of the sets actually are.

What is the size of each of the sets?

Were we to list out every possibility conceivable under the sun, we might be here for a while. Because the amount of possibilities allowed by the constraints of Lewis is more lenient regarding membership, the question will be what are the size of the sets?

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[5] This suggestion is from Vistarini.

There are five possibilities:

1) Both sets are finite, and LW contain more members, thus LW > EW
2) LW is an infinite set, whereas EWs are finite, thus LW > EW
3) LW is an infinite set and EW is an infinite set, but EW is a subset of LW, similarly to the set of even numbers is a subset of natural numbers, thus LW ≥ EW
4) LW is a *infinite set and EW is an infinite set, where *infinite is the cardinality of the set of rational numbers, or 1א, and infinite is the cardinality of the set of natural numbers, or 0א , thus LW > EW
5) LW is a *infinite set and EW is a *infinite set, thus LW ≥ EW

First, if we establish that EWs are an infinite set, then we can at least disregard possibilites in 1 and 2. Second, if we establish that LWs are *infinite, then we can disregard possibility 3. Finally, we will see if EWs are also *infinite, asserting 5 and rejecting 4.

In the first section, we discussed how the variation in position in some world *w* made it the case that LW contains infinitely many worlds, namely through the inference that if particle *p* is in some 3dimensional coordinate position <x,y,z>, or Hilbert Space, then we can change the values of x, y, or z within the range of rational numbers. Therefore, there are infinite variations in position for particles in each world. Therefore, there are infinitely many worlds where each of the positions is realized.

LWs are *infinite iff there is no way to capture the amount of worlds in LWs using the cardinality of natural numbers. I think this is a fascinating issue, but can only give a quick synopsis of how it might be resolved. The question can be formulated as follows.

The problem is this. There needs to be some principled way to distinguish our choosing an infinite value over another. As it stands, the *modest proposal* is simply to say the set of possibilities with א0 are sufficient *as the information stands*. While mathematics can theorize about alternative cardinalities, our physics need not take mathematical possibility seriously in regards to applying those conclusions to conclusions about physical possibility. Moreover, the Wave Function can only be discussed using natural numbers, thus prompting a limitation on infinite from the standpoint of how we meaningfully engage with QM systems formally.

The alternative, or the *open door proposal*, says that if we grant that there are infinitely many possibilities for a given physical process, we might say it is conceivable that our physical possibilities do not obey constraints of any kind, namely, limits on our set of possibilities to א0. I think there are good reasons for preferring the *modest proposal* over the *open door proposal*, for reasons mentioned above, but find in conversations of infinite, it is non-trivial in establishing why we prefer one kind over the other.

Thus, possibility 3 looks to be the best solution given our commitment to i) the set of possible worlds accounted for in modal realism is a superset of the possible worlds account for under the Everett Interpretation, and ii) there being currently no reason to believe the cardinality of infinite possibility allowed for by both sets of worlds being over א0.

Conclusion

There may be additional worries of compatibility here. After all, two such disparate ways of believing in the reality of possibility worlds may have disagreement over the nature of modality *simplicter*. For starters, it is not clear if we have license to make the move from a semantic argument from understanding modal propositions to making statements about the semantics behind statements directed at empirical data.

Also, the issue of the the relative cardinalities for each sets of infinite worlds deserves a much more thorough treatment at another time. Although there has been work to discuss the size of possible worlds, there is little on how it can be the case that we may speak of cardinalities of infinite without seeing those cardinalities represented in our set of LWs. In other words, for the set of LWs to be countably infinite whereas the occupants at some world *w* to speak of cardinalities that are uncountably infinite for their sets of LWs raises concerns over what makes countably many possible worlds capable of discussing infinites that are not countable in mathematics.

Works cited

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