The Relative Facts Interpretation and Everett's *note added in proof*

1 Introduction

One of the benefits of considering metaphysical interpretations of physics is that by doing so, one can hope to come to new and fruitful interpretations of seminal pieces of work. I will argue that the development of what I take to be the most charitable, faithful and conservative interpretation of Hugh Everett's pure wave mechanics, the relative facts interpretation, leads to a new and interesting reading of probably the most famous quote of his dissertation: the *note added in proof*. This note has given rise to such varied interpretations of Everett as the many worlds, many minds, many histories and many threads interpretations.[1] I propose a new interpretation of Everett, the relative facts interpretation [RFI], that takes seriously Everett's placement of relative facts at the center of his work.

There are several difficulties facing any Everett interpreter: the question of probability, the preferred basis problem, the problem of determinate measurement records and how to make sense of Everett's claim that "*all* elements of a superposition (all "branches") are "actual," none any more "real" than the rest." What concerns me here is the latter of these. In what follows I present the RFI, in brief, and show how it leads, by necessity, to a new interpretation of the *note added in proof* using evidence found in letters written by and to Everett. Given that this footnote is often the strongest proof offered for any of the various interpretations of Everett, it is of vital importance to the project of Everettian interpretation that one understands this footnote properly.

2 The Relative Facts Interpretation

My interpretation of Everett, what I call the Relative Facts Interpretation [RFI],[2] has a straightforward proposal: there is but one world and it is pop-

[1] The relevant passage is quoted in full in the appendix.

[2] I borrow the name "relative facts" from Jeff Barrett's discussion of Simon Saunders' development of what I will call E-relativism ([3], p. 214-5). Insofar as Barrett's discussion is a discussion of Saunders, I believe it mistakenly characterizes Saunders' position to be one of a single-world interpretation. Insofar as Barrett's discussion is of a single-world

ulated by relative facts. By this I mean that generally all facts in the world are relations, and this implies that generally all properties are relations.

When one considers the pure wave mechanics that Everett proposes, one cannot help but be struck by the fact that generally every system will be in an increasingly complex non-separable entanglement with the other systems with which it interacts. Regardless of the position one takes on the measurement problem and the collapse postulate, entanglement is an inescapable part of the quantum mechanical world. This has led philosophers to argue that non-separable, entangled quantum mechanical states imply that there are relations that are strongly non-supervenient on non-relational properties of their relata, and that this leads to quantum holism and a metaphysics consisting of non-reducible relations ([6], [12], [13], [22], [25] and [43]). These philosophers are not generally working in the context of pure wave mechanics, but with a conception of quantum mechanics in some general, vague sense, but this metaphysical picture can be used by the RFI to describe the world modeled by Everett's pure wave mechanics.

2.1 Absolute and Relative Facts in Everettian Quantum Mechanics

2.1.1 Absolute Facts

When a system is in an eigenstate of an observable there is some absolute fact about the value of that observable for the system, assuming that we preserve the eigenvalue-eigenstate link—and we do. However, when a system is in a non-separable entangled superposition, it is no longer possible to consider one element of the superposition without also considering the rest of the elements, again because of the eigenvalue-eigenstate link. We cannot then say that there are any absolute facts about the components of the system taken individually. Rather, there are only relative facts. These relative facts do not supervene on any non-relational properties of their relata, but instead supervene on some structural feature of the system such as a relation that obtains between the components of the system.

Consider the example of two particles, p and q, in the singlet state:

relative facts interpretation, it describes the mechanism, due to Saunders, that the RFI will use to explain determinate measurement records, but Barrett too quickly dismisses a relative facts interpretation.

$$|SSS\rangle = \frac{1}{\sqrt{2}}(|\uparrow_x\rangle_p|\downarrow_x\rangle_q + |\downarrow_x\rangle_p|\uparrow_x\rangle_q)$$

.

If we consider the composite system consisting of p and q as isolated, forgetting for a moment the ubiquity of correlations that prevents such a system from being considered a truly isolated system, it is in an eigenstate of some observable, let us call it *components with opposite x-spin.* Then the eigenvalue-eigenstate link gives us that the system determinately has the absolute property *components with opposite x-spin.* So, if we ask of the system whether it has the absolute property *components with opposite x-spin*, we will always get the answer "yes".

2.1.2 Relative Facts

When p and q are in the singlet state, because of the eigenvalue-eigenstate link, neither particle has any determinate absolute spin property independent of the spin property of the other. However, each does have determinate *relative* spin properties: p has the determinate (relative) property "x-spin up relative to q being x-spin down" and the determinate (relative) property "x-spin down relative to q being x-spin up"; q has the determinate (relative) property "x-spin up relative to p being x-spin down" and the determinate (relative) property "x-spin down relative to p being x-spin up".

I formally define relative facts as follows: Suppose that $\mathcal{S}$ is a (proper) subsystem of $\mathcal{U}$, where $\mathcal{U}$ is the universe taken as an isolated system, and $\mathcal{U}$ is in the state $\psi_{\mathcal{U}} = \Sigma_i \alpha_i \psi^i_{\mathcal{S}} \psi^i_{\mathcal{S}'}$, where $\mathcal{S}'$ is the complement of $\mathcal{S}$; the state of $\mathcal{S}'$, relative to $\mathcal{S}$ being $\psi^i_{\mathcal{S}}$, is $\psi^i_{\mathcal{S}'}$.[3] If $\Sigma|\alpha_i|^2 \neq 1$ for any i,[4] then neither system $\mathcal{S}$ nor $\mathcal{S}'$ have any absolute properties (or states). If we hit the vector that represents $\mathcal{S}$ with the operator $\mathcal{P}$, we will get that $\mathcal{P}_{\psi^i_{\mathcal{S}}} = +1$, but we

[3] What we are essentially doing here is dividing up the terms of the universal state into two subsets: the set of terms that make up the description of the state of the subsystem $\mathcal{S}$ and the rest of the terms that make up the description of the state of the subsystem $\mathcal{S}'$. Since $\mathcal{S}$ is a proper subset of $\mathcal{U}$ then the number of terms in $\mathcal{S}$ must be less than the number in $\mathcal{U}$. The choice we make about what terms make up $\mathcal{S}$ is arbitrary. The state of $\mathcal{S}'$ is determined by the choice of terms that go to make up the description of the state of $\mathcal{S}$.

[4] If $\mathcal{S}$ is a proper subsystem of the global system $\mathcal{U}$, then the sum of the square of the norms of the coefficients will necessarily be less than 1 since $\mathcal{S}$ will just be a tensor product of the entangled α_i.

do not want to say that this means that $\mathcal{S}$ has an absolute property, since we have just argued that it does not. Rather, we have to also hit the vector that represents $\mathcal{S}'$ with the operator $\mathcal{Q}$, and determine its outcome. If we get that $\mathcal{Q}_{\psi^i_{\mathcal{S}'}} = +1$, then we can say, "$\mathcal{S}$ determinately has the property P, *relative to* $\mathcal{S}'$ determinately having the property Q". Likewise we can say, "$\mathcal{S}'$ determinately has the property Q *relative to* $\mathcal{S}$ determinately having the property P".[5] We can also express this by saying that there is a relative fact that is true of both $\mathcal{S}$ and $\mathcal{S}'$.

To talk about the truth of propositions about systems in non-separable entangled quantum mechanical states, let us again use the singlet state. If we ask of the system whether p and q have opposite x-spins, we will get the answer "yes" since the composite system is in an eigenstate of *components with opposite x-spin*. If we ask of the system whether p, taken on its own, has any determinate x-spin properties, we will get the answer "yes" since in the first term, if our observer is a reliable and truthful observer,[6] he will report "yes", and the same for the second term. This puts our observer in an eigenstate of saying "yes".

Now, suppose we ask of our system whether p, taken on its own, has the determinate property x-spin up. Then our answer will be "no" since p is not in an eigenstate of either x-spin up or x-spin down. The same is true of q, taken on its own. However, if we ask whether p is x-spin up *relative to* q being x-spin down, we will get the answer "yes". The phrase *relative to* directs us to apply the projection operator to just the term in which the target of relativization appears with the property specified. In this case, we are directed to the term in which q is x-spin down.

2.2 Objects

With our understanding of absolute and relative facts, the RFI gives rise to a rather strange metaphysical picture of the world: if there are objects, and if we take an object to be a proper subsystem of the universe, then the properties of those objects are typically relational; because of entanglement, objects may have an infinite number of relational properties, many of which

[5] There will always be some observable for which $\mathcal{O}_{\psi^i_{\mathcal{S}'}} = +1$.

[6] By "reliable" I mean that when we ask him whether he has a measurement record, if he has one then he will answer that he does; if he does not have one, he will answer that he does not.

are contradictory with one another; because of a distinction we must draw between the local and the global level for not only perspectives but also objects, it is unclear what exactly constitutes an object.

The implications that can be drawn from this metaphysical picture, seem to go against our intuitions about how the world is at its most fundamental level. If properties are typically relational, then this seems to imply that there are no intrinsic properties of objects, which then leads one to question how we are meant to individuate objects if not by their intrinsic properties. If objects have an infinite number of relational properties, then it is unclear whether some proper subset of them is sufficient for the individuation of objects. If the objects that I am interacting with on a daily basis are merely the local parts of a global object, and if those local parts have a different character from the global whole, then it is unclear how I am to understand what a global object even is.

All of these problems stem from the RFI attempt to account for value-definiteness in our measurements. Some might argue that the price RFI exacts is higher than its worth [3]. However, the questions and problems with the RFI are generally no more intractable than problems we already face in a more garden-variety metaphysics. Their solutions come from the standard metaphysical literature and can be readily adapted to the context of a purely relational metaphysics.[7]

It may be noted that the RFI is very similar in structure to a MWI. It borrows liberally from Simon Saunders' solutions to some problems faced by any interpreter of Everett ([35], [36], [37], [38] and [39]). Where MWI theorists and the RFI part ways is over the question of how many worlds there are. MWI theorists generally reify branches and take each to be, or be describing, an actual world. The RFI, on the other hand, does not reify the branches. It takes them to be partial descriptions of "the way the world is", but each branch is certainly not a physical world that has an equal claim to be called the actual world.[8] In any regard, one owes an explanation of Everett's claim that all the branches are equally "actual". To get an answer to this in the context of the RFI, it is first important that we consider how the RFI proposes we understand objects, for only then can we consider how we are to make sense of the claim that they "actually" have most all possible

[7]The argument for these claims goes beyond the scope of this project, but it is possible to make them.

[8]David Albert and Jeff Barrett have also argued that whatever the branches are taken to be, they cannot possibly be real physical worlds [2].

values for most all of their properties.

2.2.1 Objects$_{\mathrm{G}}$ and Objects$_{\mathrm{L}}$

The metaphysics implied by the RFI is a purely relational metaphysics. This means that generally all facts about objects are relations and that all their properties are relational. So it would seem that perhaps even the notion of an object is relational and that solid, stable objects disappear on this metaphysics. But we have to be careful here. We need to make two distinctions at this point: (*i*) between an observer$_{\mathrm{G}}$ and an observer$_{\mathrm{L}}$ and (*ii*) between an object$_{\mathrm{G}}$ and an object$_{\mathrm{L}}$.

An observer$_{\mathrm{G}}$ is the one who has access to all branches of a superposition. An observer$_{\mathrm{G}}$ can be thought of as someone outside the theory who can see the branching structure of the world and who knows every outcome of quantum mechanical experiments. In contrast, an observer$_{\mathrm{L}}$ is an observer who experiences determinate measurement results when conducting quantum mechanical experiments; an observer$_{\mathrm{L}}$ only sees one outcome of every experiment. We as observers$_{\mathrm{L}}$ do not seem to have access to the experiences of observers$_{\mathrm{G}}$.

An object$_{\mathrm{G}}$ is the object that is generally in an infinitely complex entangled superposition of all the values of its properties and with all objects it encounters. An object$_{\mathrm{L}}$ is the object that has relational properties and that is partially described by one term of the object$_{\mathrm{G}}$'s state, written in some basis. This is true for both microscopic objects and macroscopic objects ([15], pp. 86-87).[9]

[9]There are deep epistemological issues involving our knowledge of the world$_{\mathrm{G}}$ and objects$_{\mathrm{G}}$. If we take past experience to be indicative of our typical epistemic access to the world, then it seems that we do not have a perspective$_{\mathrm{G}}$ on the universe, and as observers$_{\mathrm{L}}$ it is unclear whether we can ever get such access. However, I take the limitation to be not a limitation in principle, but rather a practical limitation. It has been suggested that there is a way, in principle, to have evidence of the structure$_{\mathrm{G}}$ of the world [1]. Whether the limitation is one of principle or practicality, the fact remains that we seem to be limited to a perspective$_{\mathrm{L}}$. Why it is that we do not have, and do not see how we can gain, a perspective$_{\mathrm{G}}$ on the universe, are worthy questions, but they go beyond the scope of this paper. Since we are observers$_{\mathrm{L}}$, and as such do not seem to ever have epistemic access to objects$_{\mathrm{G}}$ in order to investigate what we can learn about their nature, we will have to be satisfied with investigating what the RFI tells us is true about objects$_{\mathrm{G}}$. While this story might not accord with our intuition about objects in general, I would argue that the misgivings one might feel regarding this metaphysical picture of objects are rooted in epistemological rather than metaphysical concerns, concerns that we are not considering

Let us consider a system that consists of an object (without first making a distinction between object$_{\text{L}}$ and object$_{\text{G}}$) and an observer. If the object, O, is in an eigenstate of z-spin up, then we know that it is in a superposition of being x-spin up and x-spin down. If an observer measures the x-spin of the particle, then she will enter into an entangled superposition with the object. Their state can be described this way:

$$\frac{1}{\sqrt{2}}(|\uparrow_x\rangle_O|\text{``}x - \text{spin up''}\rangle_{observer} + |\downarrow_x\rangle_O|\text{``}x - \text{spin down''}\rangle_{observer})$$

This is the state of the object$_{\text{G}}$ and the observer$_{\text{G}}$. Each of the two terms describes a different object$_{\text{L}}$ and observer$_{\text{L}}$. So $|\uparrow_x\rangle_O|\text{``}x - \text{spin up''}\rangle_{observer}$ describes an $x$-spin up object$_{\text{L}}$ and an observer$_{\text{L}}$ getting "$x$-spin up" as the result of her measurement of that object$_{\text{L}}$, and $|\downarrow_x\rangle_O|\text{``}x - \text{spin down''}\rangle_{observer}$ describes an x-spin down object and an observer$_{\text{L}}$ getting "x-spin down" as the result of her measurement of that object$_{\text{L}}$.

So, in a sense, each object$_{\text{L}}$ is a part of an object$_{\text{G}}$. In the above example, there is an object$_{\text{L}}$ that is x-spin up, relative to the branch on which it finds itself, that is a part of the object$_{G}$, and there is an object$_{\text{L}}$ that is x-spin down, relative to the branch on which it finds itself, that is a part of the object$_{\text{G}}$.[10] Additionally we can say that each object$_{\text{L}}$ has a counterpart of itself on another branch. So the object$_{\text{L}}$ with the relative property x-spin up has a counterpart object$_{\text{L}}$ with the relative property x-spin down.

2.2.2 Individuating Objects

It might be thought that a purely relational metaphysics leaves us with not only a relative notion of facts and properties, but of objects themselves, thereby eliminating any notion of stable, solid objects. But the situation is not this dire. We still have solid objects: the objects$_{\text{L}}$. They are the objects that we encounter in our everyday life. We find ourselves in less familiar territory when we consider the nature of objects$_{\text{G}}$ and how we are to individuate them, but since what mainly concerns us here are objects$_{\text{L}}$, we will sidestep the issues that arise for objects$_{\text{G}}$.

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here.

[10]There are problems with self-location that may need to be resolved, but to discuss them here would take us far afield of the subject at hand. For the purposes of this paper, suffice it to say that self-location is not an issue. For discussions of the issue of self-location in the context of a MWI, see [26], [27], [41], [44], and [45].

I propose that we consider an object$_L$ to be individuated by the bundle of its (relational) properties.[11] This should cause little difficulty for the individuation of objects$_L$. Even pre-theoretically, objects in our world are such that they have many unique relations to other objects that can help us to differentiate them from each other. But there are several reasons why one might raise an objection to such an idea.

One place where a problem might arise is in the context of a world like that suggested by Max Black in which the only things that exist are two apparently identical spheres [4]. In the context of the RFI they would share all their relational properties with one another and so it would seem that they would be incapable of being differentiated. But the present metaphysical picture does not introduce any more difficulty with the verification of Leibniz's Principle of the Identity of Indiscernibles in the context of this example than already exists in a more traditional metaphysics of objects and properties.

A second potential problem comes in at the quantum level. There are quantum objects that have all of their properties, relational or otherwise, in common. It has been argued, independent of our concerns here, that Leibniz's Principle of the Identity of Indiscernibles is either inapplicable or invalid in the realm of quantum mechanics.[12] So, again, I do not see that the metaphysics proposed here adds any difficulty to this problem.[13]

A third problem, that seems to be unique to the present metaphysics, is that one might think that because of entanglement, objects have an infinite number of relational properties, and it is unclear how we are to choose which among those are necessary or sufficient for the individuation of an object. But this is to lose sight of the distinction that we drew between objects$_L$ and objects$_G$. Objects$_L$ have no more properties than objects do on a standard, garden-variety metaphysics, their properties just happen to be relational.

Now that we have some sense of what it is that we are taking to be objects and how we are to individuate them, let us consider more carefully what it is that we mean when we say that an object$_L$'s properties are all relational

[11] See [12] for an argument that this is a coherent way to treat objects.

[12] See [21], [22], [23], [32] and [40]. A good bibliography of the literature can be found in [40].

[13] And, in fact, in [22] French argues that one suggestion for recovering a supervenience basis for relational properties even in non-separable entangled states (the bundle theory) is not feasible due to the fact that Leibniz's Principle of the Identity of Indiscernibles needs to be invoked. However, he rejects this possibility in the context of quantum mechanics (pp. 15-6).

and how it is that we seem to get determinate values when we measure the properties of an object_L. Without a single determinate measurement record, it is far from clear how anyone could claim that objects "actually" have most all the possible values of most all of their properties.

2.3 The Relational Properties of Objects

Objects_L seem to have determinate properties, but if we allow quantum mechanics, our best physical description of the world, to inform our answers as to why things happen the way we seem to perceive them, then a question that has a (perhaps) surprising surfeit of answers is: Why does it appear to me that my coffee cup is on my desk?

In an effort to understand how one gets determinate measurement records, in the context of a MWI, Simon Saunders presents a very compelling analogy between relational facts and tensed facts ([34], [35], [36], [37], [38], [39]). Despite the differences between the RFI and any MWI, the analogy that Saunders suggests as the justification for the use of branch indexicals in his MWI to confer value-definiteness on measurement records can also be used to understand value-definiteness in the RFI.

Let us continue to leave aside questions of epistemology. Let us assume that what appears to be the case, is in fact the case, and that we are tracking the truth about the world when we make statements about how the world appears to us. Then, there must be something about the world that makes the proposition

(1) My coffee cup is on my desk.

true—this is what is known as the truthmaker principle. But the nature of the truthmaker of (1) is up for debate. Different interpretations of quantum mechanics will take different positions in the debate. The standard interpretation of quantum mechanics says that the truthmaker for (1) is an absolute fact about the coffee cup. But on the RFI, objects_L do not have absolute properties. Typically all properties of objects_L are relations and so typically all facts about objects_L are relations.

Saunders has proposed that we understand the truthmaker for (1) analogously to the way B-theorists about time understand the truthmaker for a proposition like:

(2) My coffee cup was at home.

A B-theorist takes the truthmaker for (2) to be a fundamentally *relational* fact.

Saunders draws an analogy between what he takes to be the nature of the truthmaker for a proposition about the property of an object and what a B-theorist takes to be the nature of the truthmaker for a proposition about the property of an event:

(3) Event e is past.

In both cases the truthmaker is some fundamentally *relative* fact.[14]

On both Saunders' E-relativism and on the RFI, most every physical system$_{\mathrm{G}}$ will typically have most every possible relative value for a property, just as every event has all of the qualities of past, present and future. So, it is true to say:[15]

(4) X has value x.

and

(5) X has value x'.

even if $x \neq x'$, and the two are mutually exclusive. But if so, then (4) and (5) are contradictory.

However, if we now introduce two parameters, Y and Y', such that $Y \neq Y'$, and that themselves can take values, we can restate (4) and (5) as:

[14]It may be noted that Saunders' analogy can be read as implying two different commitments on the number of worlds that exist. *Prima facie*, the analogy implies that there is only one world, and this is how Barrett understands him in [3]. We do not need different worlds to explain relational tensed facts, and so, if we take the analogy seriously, we should not need different worlds to explain relational value-definiteness. On the other hand, one may argue that many worlds are required to explain relational value-definiteness. Each fact is determinate relative to the world in which it obtains. This may be seen as one point at which the analogy breaks down. Saunders has indicated that the many worlds view is the one from which he considers himself to be working (in personal correspondence), but he does not discuss this potential point of disanalogy.

[15]What follows is adapted from [35].

(6) X has value x relative to Y having value y.
(7) X has value x' relative to Y' having value y'.

It is clear that (6) and (7) are not contradictory.

On this view, an event's having a seemingly particular (tensed) time is analogous to an object having a seemingly particular (determinate) value for a property. An event happened in the past (or future) *relative to* another time. Likewise, an object$_L$ has a determinate value *relative to* some parameter.

By relativizing the property of an object, what we are doing is explicitly changing the focus of our discussion from that of the properties of an object$_G$ to that of the properties of an object$_L$. So in (4) and (5) it is to X_{G} that we are referring, but in (6) and (7) it is to X_{L} that we are referring.

The question then becomes, what are the relativizing parameters Y and Y'? For Saunders, the parameters are worlds, or branches.[16] In light of this, consider again (1). In analogy with the B-theory, one recourse for explaining its truth (when it is in fact true) is to say that it is true because there is a determinate relative fact that consists in the coffee cup being on my desk. Each possible fact about the value for the coffee cup$_{\mathrm{G}}$'s position occurs in a different world. So Saunders makes sense of the truth of a proposition like (1) by relativizing the cup$_{\mathrm{L}}$'s position value to the world in which it finds itself. Relative to being in this world, the coffee cup$_{\mathrm{L}}$ is on my desk; relative to being in a different world, the coffee cup$_{\mathrm{L}}$ is in the Mariana Trench; relative to being in yet another world, the coffee cup$_{\mathrm{L}}$ is in my mother's kitchen. Thus, the fact that makes (1) true is a relation between the position value for the coffee cup$_{\mathrm{L}}$ and the world in which the coffee cup$_{\mathrm{L}}$ finds itself.

Saunders is a bit more precise about the target of relativization. Since the coffee cup$_{\mathrm{G}}$ is entangled with everything else that makes up its system, we need to isolate the determinate property with which we are concerned. There are (at least) two options for the target of relativization, the collection of properties of the world in the here and now, and the collection of properties that make up a description of the entire history of the world. Saunders suggests we choose the former ([35], pp. 243-4). In other words, the coffee

[16]The terms "world" and "branch" are most often used interchangeably in the many worlds literature. For a discussion of some of the philosophical differences between the two, see [5].

cup_L's position is relative to a branch at a particular time.

The RFI defines the parameters Y and Y' a bit differently; the target of relativization for the RFI should be taken to be the (relative) state of the complement of the system that we are considering. So while the coffee cup_G has many possible values for its position, each value is relative to something different and goes to make up a partial description of a different coffee cup_L, many of which are counterparts of others. So we can make sense of the truth of a proposition like (1) by relativizing a coffee cup_L's position to the state of the complement of the system of which it is a part.

Of course I also have to be a bit more precise when identifying the target of relativization since we are taking entanglement to be understood as non-separability, and since the coffee cup_G is entangled with everything else that makes up its system. The second relata in the correlation will generally be a large conjunction of facts. My coffee cup_L is on my desk relative to my having put it there, but also to my desk being in my office, to my not having knocked the cup off, etc. Of course the fact that my desk is in my office is relative to some other collection of relative facts about the complement of *its* system (the movers that put it there being a part of that), and this goes on *ad infinitum*. Likewise my coffee cup_L is in the Mariana Trench relative to my having decided to take a cruise in the Pacific, and my having dropped my coffee cup over the side of the ship at the right time, etc.

Let us go back to the question with which we began. What is the nature of the truthmaker for propositions like (1)? The metaphysics here proposed implies that it is a relative fact. The two relata of this fact are a relative fact about the coffee cup_L and the conjunction of relative facts about the complement of the system of which the coffee cup is a part. So now that we understand how an object_L comes to have determinate properties, we must address the question of the quote from Everett with which we began this paper.

On the most popular and influential reading of the *note added in proof*, the coffee cup_L *actually has all* of the possible values for position, in the full sense of "actually" that we have come to expect: it actually has the property of being on my desk and it actually has the property of being in the Mariana Trench (among others), and these two properties are not the same and are (generally) mutually exclusive. Saunders shows how we can dissolve the apparent contradiction in the context of E-relativism by extending the analogy with tense and relativizing "actually" in the same way one relativizes "now" ([35]). The RFI can also use a relativization mechanism like that used by Saunders to dissolve the apparent contradiction. But this account requires a shift in the way we understand Everett's footnote.

3 *Note added in proof*

3.1 The Now and the Actual

In the context of the RFI we can relativize to branches. But since the RFI does not take branches to be actual worlds, it owes an explanation of Everett's claim that "From the viewpoint of the theory *all* elements of a superposition (all 'branches') are 'actual,' none any more 'real' than the rest". We can try to make sense of what Everett may have meant by taking seriously both his claim that this assertion is made "from the viewpoint of the theory" and by considering responses Everett made to critiques of and comments on his thesis.

Consider first the "viewpoint of the theory". What Everett writes to Bryce DeWitt regarding this, while discussing the nature and purpose of his (Everett's) theory, *qua* physical theory, is the following:

> To me, any physical theory is a logical construct (model) consisting of symbols and rules for their manipulation, some of whose elements are associated with elements of the perceived world... When one is using a theory, one naturally pretends that the constructs of the theory are "real" or "exist." If the theory is highly successful (i.e. correctly predicts the sense perceptions of the user of the theory) then the confidence in the theory is built up and its constructs tend to be identified "elements of real physical world." This is, however, a purely psychological matter. No mental constructs (and this goes for everyday, prescientific conceptions about the nature of things, objects, etc., as well as elements of formal theories) should ever be regarded as more "real" than any others. We simply have more confidence in some than others ([18], 1-2, Everett's emphasis).[17]

Everett then goes on to deliver the precursor to the footnote:

[17]These ideas also appears in the second appendix to the long thesis ([15], pp. 133-37).

> From the viewpoint of the theory, all elements of a superposition (all "branches") are "actual," none any more "real" than another. It is completely unnecessary to suppose that after an observation somehow one element of the final superposition is selected to be awarded with a mysterious quality called "reality" and the others condemned to oblivion. We can be more charitable and allow the others to coexist – they won't cause any trouble anyway because all the separate elements of the superposition ("branches") individually obey the wave equation with complete indifference to the presence or absence ("actuality" or not) of any other elements ([18], 3).

In my view, Everett's use of scare quotes here and in his footnote, is meant to indicate that he is speaking from within the theory when he talks about the reality or actuality of the terms of the superposition. In the theory, each element of the superposition should have the same level of reality as any other. After all, when doing the mathematics of physics, one does not write the global state of the universe in some basis, pick out one of the terms of the superposition, call it the real world by fiat and then ignore the other terms. Neither, according to Everett, is one term selected in some mysterious way to become the real world and all the others then disappear. But of course it is not sufficient to merely talk about what is happening within the theory. We want to be able to make sense of the universe that is described by the theory. So we should consider what this means for our everyday physical universe.

In April, 1957, Norbert Wiener wrote a letter to Everett and John Wheeler. Wiener also seemed interested in the implications of Everett's theory for the real world. Wiener writes: "Another point where your theory needs amplification... is that I do not find an adequate discussion of what it means to say that a certain fact or a certain group of facts is actually realized." In the margins of Everett's copy of that letter Everett responds:

> ...no such statements ever made in theory like "case A actually realized", except <u>relative</u> to some other state! All possibilities "actually realized", with corresp[onding] observer states ([46], marginalia, page 3, Everett's emphasis).

In his formal response to Wiener, Everett crafts this as:

> You also raise the question of what it means to say that a fact or a group of facts is actually realized. Now I realize that this question poses a serious difficulty for the conventional formulation of quantum mechanics, and was in fact one of the main motives for my reformulation. The difficulty is removed in the new formulation, however, since it is quite unnecessary in this theory ever to say anything like "Case A is actually realized."
>
> Since I have discussed this point of the transition from "possible to actual" with Dr. Bryce DeWitt, who also raised the question, I am enclosing a copy of our correspondence in lieu of a fuller discussion here ([17], p. 1. The letter from Everett to DeWitt to which Everett is referring is presumably [18], the relevant sections having been quoted just above.).

Here Everett is explicit that the states of things are actual only relative to the state of some other subsystem. Though he drops the phrase "except relative to some other state" in his formal response to Wiener, when Everett writes, "it is quite unnecessary in this theory ever to say anything like 'Case A is actually realized,' " I take him to mean that we will never utter that phrase and come to a full stop. We will only utter that phrase when it is followed by a suitable relativizing phrase such as "relative to some observer state", or "relative to some other state".

If we accept this interpretation of the footnote, then according to Everett, the following two statements are *not* both true, contrary to the MWI theorists's claims:

(8) The coffee cup is actually on my desk.
(9) The coffee cup is actually in the Mariana Trench.

What is true however are these statements:

(10) My coffee cup is actually on my desk relative to my having put it there...[18]
(11) My coffee cup is actually in the Mariana Trench relative to my having dropped it there...

[18] The ellipses indicate that the target of relativization, as we know, is more complex than just one statement.

Each of (10) and (11) are actually realized in relation to the state of the complement of the coffee cup's system. So, relative to my sitting at my desk, writing this, having gotten a cup of coffee earlier, ..., my coffee cup is actually on my desk. Relative to my sitting in a deck chair on a cruise ship in the Pacific Ocean, lamenting having dropped my coffee cup over the side this morning, ..., my coffee cup is actually in the Mariana Trench. This is nothing more exotic than two partial descriptions of the actual world, each with a different target of relativization. Using myself sitting at my desk as part of the target of relativization, the world described in part by (10) is the actual world. Using myself sitting on a cruise ship as part of the target of relativization, the world described in part by (11) is the actual world. I happen to be the $\mathrm{I_L}$ who is living in the world described in part by (10) and so that world is actual relative, in part, to me. But that does not mean that the world described in part by (11) does not have equal claim to be the actual world *relative to the counterpart of myself who is part of the target of relativization for that system state.*

So what we have now is an account of what Everett could have meant when he claimed that every element of a superposition is equally "actual" or equally "real". It does not require the reification of multiple branches, as proposed by the MWI theorists. The job can be done with one world and relative facts. We also have an account of how our measurement records come out to be determinate: they are records of determinate relative facts. I have argued that we can use the analogy drawn by Saunders between tense and value-definiteness to explain value-definiteness in the context of the RFI, despite the fact that pure wave mechanics predicts that objects will generally not have determinate values for their properties. We first make a distinction between $\mathrm{objects_G}$ and $\mathrm{objects_L}$. Then by relativizing to the complement of the system of the object under consideration, we explain that an object has a determinate value for a property only *relative to* that target of relativization. What underlies everything that has gone thus far, is Everett's fundamental idea that the value of any system is determinate only *relative to* its complement.

Appendices

A *The note added in proof*

Everett writes:

> We thus arrive at the following picture: Throughout all of a sequence of observation processes there is only one physical system representing the observer, yet there is no single unique *state* of the observer (which follows from the representations of interacting systems). Nevertheless, there is a representation in terms of a *superposition*, each element of which contains a definite observer state and a corresponding system state. Thus with each succeeding observation (or interaction), the observer state "branches" into a number of different states. Each branch represents a different outcome of the measurement and the *corresponding* eigenstate for the object-system state. All branches exist simultaneously in the superposition after any given sequence of observations.‡
>
> ‡*Note added in proof.*—In reply to a preprint of this article some correspondents have raised the question of the "transition from possible to actual," arguing that in "reality" there is—as our experience testifies—no such splitting of observer states, so that only one branch can ever actually exist. Since this point may occur to other readers the following is offered in explanation.
>
> The whole issue of the transition from "possible" to "actual" is taken care of in the theory in a very simple way—there is no such transition, nor is such a transition necessary for the theory to be in accord with our experience. From the viewpoint of the theory *all* elements of a superposition (all "branches") are "actual," none any more "real" than the rest. It is unnecessary to suppose that all but one are somehow destroyed, since all the separate elements of a superposition individually obey the wave equation with complete indifference to the presence or absence ("actuality" or not) of any other element. This total lack of effect of one branch on another also implies that no observer will ever be aware of any "splitting" process.

> Arguments that the world picture presented by this theory is contradicted by experience, because we are unaware of any branching process, are like the criticism of the Copernican theory that the mobility of the earth as a real physical fact is incompatible with the common sense interpretation of nature because we feel no such motion. In both cases the argument fails when it is shown that the theory itself predicts that our experience will be what it in fact is. (In the Copernican case the addition of Newtonian physics was required to be able to show that the earth's inhabitants would be unaware of any motion of the earth.) ([16], 146-7).

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