Personal Identity and Uncertainty in Everett’s Multiverse
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ABSTRACT

The deterministic nature of EQM seems to be inconsistent to the probability talk in EQM, and this is called the “incoherence problem”. Sanders and Wallace try to invoke the Lewisian account of personal identity to solve the incoherence problem. In my paper, I clarify the objections to their solution and illustrate the only two interpretations of their solution. I argue that, if there is only one 3-dimensional entity of each type which supervenes on one single physical state, their solution would fail to solve the incoherence problem. Consequently, there should be more than one 3-dimensional entity of at least one type which supervenes on one single physical state. I further argue that this remaining interpretation is inconsistent with physicalism. This suggests us to pay more attention to issues of personal identity and possible non-physicalism interpretations of EQM.

1 Introduction: The Incoherence Problem

The Everett Interpretation of Quantum Mechanics (EQM) is a deterministic physical theory, but it is also a theory dealing with probability via the Born Rule. The deterministic nature of EQM seems to be inconsistent (incoherent) with the probability talk in EQM. This has been called the “incoherence problem” of EQM (Saunders and Wallace 2008a).

For simplicity, consider a branching process with only two branches. Suppose an observer, Alice, measures the z-spin of an electron being in a superposition of different z-spins. The initial state of the whole system is $\frac{1}{\sqrt{2}} (|\uparrow> + |\downarrow>) \otimes |\text{Alice } 0>$, where $\frac{1}{\sqrt{2}} (|\uparrow> + |\downarrow>)$ is the initial state of the electron, and $|\text{Alice } 0>$ is the initial state of Alice. When the measurement is completed, the state of the whole system evolves to $\frac{1}{\sqrt{2}} |\uparrow> \otimes |\text{Alice } \uparrow> + \frac{1}{\sqrt{2}} |\downarrow> \otimes |\text{Alice } \downarrow>$, where $|\text{Alice } \uparrow>$ ($|\text{Alice } \downarrow>$) is the state of Alice recording z-spin down (up). From the “outside” view, all branches exist.
after the measurement, and thus both the probabilities of Alice recording z-spin up and Alice recording z-spin down are 1. But from the “inside” view, one can only obtain a single result after the measurement. Thus, according to the Born rule, both the probabilities of Alice recording z-spin up and z-spin down are 1/2 (Tegmark 1998).

In a deterministic theory, the following principle is commonly held true:

Ignorance   In order to make propositions such as “the probability for an event E to happen is $p$” meaningful in a deterministic universe, we must be ignorant of some facts about E.

*Ignorance* is commonly acknowledged in classical physics. In the background of classical mechanics as a deterministic physical theory, whether it will be raining tomorrow is determined by the physical state of a given moment $s$. But we cannot distinguish which physical state it is from a vast array of similar physical states $\{s\}'$. This is the root of probability talk in classical mechanics. Loosely speaking, if the measure of all states $\{s\}'$ is $A$, and the measure of those states in $\{s\}'$ which lead to tomorrow’s rain is $B$, then the probability that it will rain tomorrow is $B/A$ according to $s$. Such probability comes from our ignorance of what the precise physical state of this moment is.

Saunders and Wallace give a solution to the incoherence problem given *Ignorance.* (Saunders 1998, Wallace 2005, 2006, 2012, Saunders and Wallace 2008a) They argue that, although Alice knows that the state of the whole system will be $\frac{1}{\sqrt{2}} | \uparrow> \otimes | Alice \uparrow> + \frac{1}{\sqrt{2}} | \downarrow> \otimes | Alice \downarrow>$, she still lacks some *indexical knowledge* of the future, namely, she is uncertain about which person in the future she is identical to. Their solution is based on the Lewisian account of personal identity (David Lewis 1976, 1983). Peter Lewis (2007) and Tappenden (2008) object that, even if the Lewisian account is correct, Alice will fail to refer to one single future self in any possible utterances before the branching. It makes no sense then, to say that Alice is ignorant of which person she is identical to before the branching. Recent literature tries to answer this objection by resorting to the philosophy of language in EQM (Belnap and Müller 2011, Wilson 2011, for instance). These authors try to develop a semantics theory of EQM to resolve their disagreements. In this paper, I shall focus exclusively on the

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1 Papineau (1996) and Tappenden (2000) reject *Ignorance* as the root to solve the incoherence problem, but I shall not discuss their views here.
ontological issues of personal identity associated with the issues in order to clarify the relevant disagreements.

In the following section (Section 2), I shall first present Saunders and Wallace’s solution and then P. Lewis and Tappenden’s objection. I explain that there can be two possible interpretations of Saunders and Wallace’s solution. I argue that, if there is only one 3-dimensional entity of each type which supervenes on one single physical state before branching, their solution would fail to solve the incoherence problem as P. Lewis and Tappenden object. Consequently, there should be more than one 3-dimensional entity of at least one type which supervenes on one single physical state.

In Section 3, however, I further argue that this revision of Saunders and Wallace’s solution to the incoherence problem is inconsistent with physicalism. This means that we need to pay a great price if we want to invoke the Lewisian account of personal identity to solve the incoherence problem in the way Saunders and Wallace have proposed.

2 Saunders and Wallace’s Lewisian solution

2.1 Preliminary: The Lewisian Account

The Lewisian account of personal identity, developed by David Lewis (1976, 1983), is an attempt to retain personal identity as a definite and transitive relation after Parfit’s (1971, 1984) destructive arguments via his personal fission thought experiment.

In virtue of the obvious analogy between the brain splitting case and branching in EQM, I shall simply use the branching case in EQM to illustrate the Parfitian account and the Lewisian account of personal identity here. In our case, the quantum state after branching is $\frac{1}{\sqrt{2}} |\uparrow \rangle \otimes |\uparrow \rangle + \frac{1}{\sqrt{2}} |\downarrow \rangle \otimes |\downarrow \rangle$. Let us denote the person represented by $|\uparrow \rangle$ as Alice↑ and the person represented by $|\downarrow \rangle$ as Alice↓.

According to Parfit, if we retain that personal identity is a transitive and definite relation, Alice0 can only be identical to at most one of Alice↑ and Alice↓, for Alice↑ and Alice↓ cannot interact after branching, and they

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2 Namely, if A is personally identical to B, and A is personally identical to C, then A is personally identical to C.

3 Personal identity is a definite relation means that it does not admit of degree.
are different agents who make their separate decisions. It follows then that Alice₀ cannot be identical to both Alice↑ and Alice↓, otherwise it would violate the transitivity of personal identity. Hence, it seems that Alice₀ is identical to only one of Alice↑ and Alice↓. If we retain personal identity as a definite relation, since the branching is highly symmetric, whether Alice₀ is identical to Alice↑ or Alice↓ can only depend on some rather trivial differences between them. Parfit claims that such trivial relations cannot be of much philosophical importance. Hence, either there does not exist such a relation as personal identity which is definite and transitive, or such a relation is trivial and of no significance.

The Lewisian account of personal identity tries to retain the definiteness and transitivity of personal identity by supposing that there are (at least) two persons present both before and after branching: they coincide before branching, but diverge henceforth. In the case of EQM, there are already two persons present before branching: Alice₀↑ and Alice₀↓. Alice₀↑ (Alice₀↓) is identical to Alice↑ (Alice↓), but Alice₀↑ is not identical to Alice₀↓, hence the definiteness and transitivity of personal identity can be retained.

It is important to notice the 4-dimensionalism nature of the original Lewisian account. According to this account, a person is a 4-dimensional entity rather than a 3-dimensional entity. The claim that Alice₀↑ is identical to Alice↑ is not of *temporal identity*, but merely a trivial claim that Alice₀↑ is identical to *itself*. As the same 4-dimensional entity, Alice↑ is only an alternative name of Alice₀↑. Lewis calls the 3-dimensional slice of a 4-dimensional continuant a 4-dimensional person a *person-stage*, which is usually acknowledged as a fully-present *person* in 3-dimensionalism. A person, as a 4-dimensional entity according to Lewis, is the aggregation of person-stages belonging to different times. In the present case, there is only one person-stage before branching and two person-stages after branching. As the quantum states |Alice₀>, |Alice↑>, and |Alice↓> are all 3-
dimensional, we can use them to represent corresponding person-stages. These three person-stages can constitute at least two (4-dimensional) persons: \{ |Alice 0 >, |Alice ↑ > \} (C_1 in Figure 1) and \{ |Alice 0 >, |Alice ↓ > \} (C_2 in Figure 1).\textsuperscript{4} The claim that there are already two persons present before branching means that before branching, the present 3-dimensional person-stage |Alice > belongs to two 4-dimensional persons. One (\{ |Alice 0 >, |Alice ↑ > \}) is identical to the only person who contains |Alice ↑ >, and the other is identical to the only person who contains |Alice ↓ >.\textsuperscript{5} Such identity relations between the 4-dimensional persons are transitive, but the identity relations between the 3-dimensional persons (Lewis calls it I-relation, namely, two person-stages are in I-relation if, and only if, there is at least one person containing them) can be intransitive. Both the person-stages represented by |Alice ↑ > and |Alice ↓ > share the I-relation with |Alice 0 >, but |Alice ↑ > does not share the I-relation with |Alice ↓ >.

\section*{2.2 Saunders and Wallace’s Lewisian solution and its objection}

Saunders and Wallace invoke the Lewisian account as the basis to solve the incoherence problem given Ignorance. Before the branching, Alice might be fully aware that the quantum state after branching will be \( \frac{1}{\sqrt{2}} |↑ > \otimes |Alice ↑ > + \frac{1}{\sqrt{2}} |↓ > \otimes |Alice ↓ > \), but she lacks knowledge of whether she is Alice0↑ or Alice0↓, hence she is uncertain whether she would observe the electron in the state |↑ > or |↓ >. There are no ways of distinguishing between Alice0↑ and Alice0↓ before branching, for they are physically identical up to the moment of branching. If this is true, then there can be some subjective uncertainty in EQM, although the evolution of the quantum state is deterministic. Alice is ignorant of who she is before branching.\textsuperscript{6}

This solution is criticized by P. Lewis (2007) and Tappenden (2008).

\textsuperscript{4} For simplicity, I only write down two typical person-stages of each person.

\textsuperscript{5} I suppose there is only one person who contains |Alice ↑ > (or |Alice ↓ >) as its 3-dimensional part for simplicity. Strictly speaking, there can be infinite persons containing them considering the possible infinite occurrences of branching in the future. But this would not influence the following conclusions.

\textsuperscript{6} There are other options to explain the subjective uncertainty in EQM in order to answer the incoherence problem. For instance, Vaidman (1998) argues that it is the uncertainty after branching, namely, after the branching, some Alice does not know whether she is Alice0↑ or Alice0↓. This solution does not necessarily require the Lewisian account.
They argue that, even if the Lewisian account is correct, neither Alice₀↑ nor Alice₀↓ could successfully refer to herself before branching. Alice₀↑ and Alice₀↓ can only successfully refer to the single person stage represented by |Alice > before branching, which is commonly shared by all persons in this scene. They conclude that it thus makes no sense to claim that Alice₀↑ is ignorant of some indexical information of herself, because the utterance “I do not know whether I am Alice₀↑ or Alice₀↓” fails to express that “Alice₀↑ does not know whether Alice₀↑ is Alice₀↑ or Alice₀↓”. In other words, their argument goes as follows: Before branching, any singular terms in Alice₀↑’s expressions cannot singularly refer to Alice₀↑, but refer to all persons who supervene on |Alice > at the same time; thus, the incoherence problem cannot be solved along this line.

Saunders and Wallace’s reply that, they grant that, the tokening’s of thoughts and utterances are purely local events, but they claim that “the content of thoughts and utterances is another thing altogether.” Though there is only one single utterance, there can be two propositions. Such a single utterance could have two semantic contents from the perspective of semantics externalism. Thus, according to them, the “I” in each proposition refers to a different person, who is the speaker of the sentence (Saunders and Wallace 2008a, 295-296). They claim that, in more details “we do better to attribute thoughts and utterances at t to continuants C at t, that is, thoughts or utterances are attributed to ordered parts <C, t>” (295), where “C” means the continuant person as a 4-dimensional entity. If they are right, the alleged semantics failure of their solution would seem to be avoided.

2.3 Two possible interpretations

This problem, however, is not a mere practical problem of semantics and pragmatics as I maintain, but also a serious ontological problem. In the following, I try to illustrate in what circumstances their reply succeeds. I shall argue that, if there is only one 3-dimensional entity of each type which supervenes on one single physical state |Alice 0> before branching, then Saunders and Wallace’s solution will fail to solve the incoherence problem. Only if there is more than one 3-dimensional entity of at least one type which supervenes on one single physical state |Alice 0>, can the objection to Saunders and Wallace’s solution be resolved.

First, a person in the Lewisian account is constituted of 3-dimensional person-stages at different times. Then it seems that the person-stage is a primitive notion in the Lewisian theory, and that the notion of person is
grounded in the notion of the person-stage. It is in some degree arbitrary
to determine whether some certain person-stages can constitute a person.
(Instead of acknowledging whether two persons are identical can be
indefinite as Parfit does, David Lewis acknowledges that the existence of
a 4-dimensional person can be a matter of degree.\(^7\) He does not give any
present principles, and it also seems implausible to give a series of
fundamental principles to determine this. On the contrary, whether
something is a person-stage can in principle be determined by definite,
natural principles. The quantum state \(|Alice\ 0\rangle\), our mental states and
thoughts, and our acts are all 3-dimensional entities rather than 4-
dimensional entities.\(^8\) These 3-dimensional entities are directed related to
the 3-dimensional person-stage, and only related to the 4-dimensional
person indirectly via their relations to the person-stage: It is the person-
stage who thinks, acts, and utters the utterance in the first place, and the 4-
dimensional persons only think and utter utterances in a derivate sense.

The key point is that, if all the 3-dimensional entities supervening on
\(|Alice\ 0\rangle\) are singular, there are no further facts to determine whether it is
Alice\(0\uparrow\) or Alice\(0\downarrow\) (as 4-dimensional persons) who is uncertain before the
branching. If we include Alice’s person-stage before the branching and the
person-stage who observes \(|\uparrow\rangle\) as part of the 4-dimensional person denoted
by “I”, we can replace the “I” in the utterance with “Alice\(\uparrow\)”. Then, Alice\(\uparrow\)
is the speaker of the utterance. If we chooses Alice’s person-stage before
the branching and the person-stage who observes \(|\downarrow\rangle\) as part of the 4-
dimensional person denoted by “I”, we can replace the “I” in the utterance
by “Alice\(\downarrow\)”. Then, Alice\(\downarrow\) is the speaker of the utterance. Following this
line, whether Alice\(\uparrow\) or Alice\(\downarrow\) is speaking is not a further fact to be ignorant
of, but something up to our theoretical choice as I just argued. The
allegedly two overlapping persons are some philosophical constructions
including certain future entities. It is this single person-stage who is
thinking and acting at this moment. The description of person-stages at this
time would already exhaust all information of physical properties and
mental properties before branching.

But if there is more than one 3-dimensional entity of at least one type
which supervenes on one single physical state \(|Alice\ 0\rangle\), the present problem

\(^7\) See D. Lewis’s discussions of longevity. (1976, Section IV and Section V)
\(^8\) Such a claim is approximate, since our mental states, etc. usually supervene on the
physical state of a finite time rather than a true infinitesimal moment. But this claim is
far from that our mental states supervene on the physical state of the whole “space-time
worm” as ourselves in the first place.
can be solved. These two options exhaust possible interpretations of Saunders and Wallace’s solution. Suppose there are two 3-dimensional person-stages, \( (\text{Alice}_0\uparrow)_3 \) and \( (\text{Alice}_0\downarrow)_3 \) before the branching, both of which supervene on \( |\text{Alice}_0\rangle \). That is, although Alice may only have one singular physical body corresponding to \( |\text{Alice}_0\rangle \) before the branching, there are multiple mental states, or whatsoever, which supervene on \( |\text{Alice}_0\rangle \). It follows then that although there is only one singular “physical” utterance (only one string of voices is uttered in the whole universe), there are at least two mental states, two thoughts corresponding to the utterance. These mental states are qualitatively identical (the content of each mental state is the same), but not numerically identical. Saunders and Wallace’s Lewisian solution can be saved along this line. When Alice utters “I do not know whether I will be Alice\(\uparrow\) or Alice\(\downarrow\) after the branching”, such an utterance can be translated to different propositions for different mental states. \( (\text{Alice}_0\uparrow)_3 \) is uncertain whether \( (\text{Alice}_0\uparrow)_3 \) will be Alice\(\uparrow\) or Alice\(\downarrow\), and the situation is similar for \( (\text{Alice}_0\downarrow)_3 \).

It seems that Saunders and Wallace have grasped something of the above discussions. They ask “(It is) true enough (that there can be only one semantics content of the utterance), if there is only one thought. But why not if there are two, as follows if the referent of ‘I myself’, thought or uttered at time t is the continuant who thinks or utters the phrase, as in the non-branching case?” But they do not put it clearly what it means to say that there are two thoughts. In the original Lewisian account, there is one thought shared by two 4-dimensional persons, whence their solution would fail to solve the incoherence problem. If they do literally claim that there are two numerically different 3-dimensional thoughts, their solution may succeed. But Saunders and Wallace never distinguish these two options.

This revised solution is similar to some kind of the “Many Minds Interpretation of Quantum Mechanics” (MMI) (Albert and Lower 1988, Lockwood 1996a, 1996b) MMI claims that there are indefinite minds which supervene on one singular physical state of ourselves. But in the following section, I shall argue that this is inconsistent with physicalism if we want to use this view to solve the incoherence problem. MMI theorists do not necessarily need to worry about this, because they do not need to give a definite and transitive account of personal identity in MMI, which is necessary to solve the incoherence problem following Ignorance.\(^9\)

\(^9\) For instance, Lockwood (1996a, 1996b) does not give any account of personal identity in his MMI theory, and he rejects Ignorance as necessary. He claims that his theory is consistent with physicalism.
Because we have duplicated the person-stages in this section, the so-called “I-relation” between different person-stages is recovered as a definite and one-to-one relation. This makes it possible to replace “I-relation” to “personal identity” if we accept 3-dimensionalism without influencing the conclusions. The following discussions would be neutral to whether we accept 3-dimensionalism or 4-dimensionalism. For simplicity, I simply use Alice↑0 and Alice↓0 to represent (Alice↑0)3 and (Alice↓0)3, and use “personal identity” to describe the relation between corresponding 3-dimensional entities rather than “I-relation” in the following.

3 The Problem of Supervenience

I use the term ‘physicalism’ to represent the view that all mental existences are in essence physical existences.10 According to physicalism, a person is a physical existence, and personal identity can be determined if the physical state of the whole universe is determined and can in principle be deduced from the latter. If physicalism is true, at least the following principle is acknowledged:

\[ \text{Supervenience} \quad \text{The personal identity relations in a possible universe}^{11} w' \text{ are the same as the personal identity relations in a possible universe} \ w, \text{ if} \ w \text{ and} \ w' \text{ are physically identical. (That is to say, personal identity in a universe supervenes on its physical state.)} \]

This is trivial from physicalism, but a non-physicalist can also accept this. A substance dualist maintains that mental existences and physical existences are in essence different things, but she does not necessarily reject the possibility that the former can supervene on the latter in realistic scenes.12 But physicalism cannot be true if Supervenience fails.

The modified view presented in the previous section does not

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10 It is not possible to give a full-fledged and substantive definition here, but it would not affect the following conclusion.

11 In the terminology of EQM the term “universe” is used to denote the whole physical existences described by the formulation of QM, while “world” is used to denote a particular branch in the universe under decoherence. So I use “possible universe” rather than “possible world” here.

12 When we do not involve in discussions of the resurrection after death, and other scenes far away from our realistic life. See (van Inwagen 2018).
necessarily contradict doctrines of physicalism, for physicalism does not necessarily demand that only one mental subject can supervene on one single physical human body. But it is still necessary to investigate whether Supervenience can be satisfied. I shall argue that Supervenience cannot be satisfied in the modified Lewisian solution. Let us answer the following question first: What physical existence, what physical state does one single person supervene on?

The quantum state before branching is \( \frac{1}{\sqrt{2}} (|\uparrow\rangle + |\downarrow\rangle) \otimes |Alice\ 0\ >. \) Following discussions in the previous section, Alice0\(\uparrow\) and Alice0\(\downarrow\) both supervene on \(|Alice\ 0\ > \) approximately.\(^{13}\) |Alice\ 0\ > represents one single physical state and at least two numerically different mental states, which correspond to two different persons. One simple option is that these explains what physical existences different persons supervene on without any further facts. In the following, I shall show that this choice cannot reconcile Supervenience in the branching process.

Suppose that, the person Alice0\(\uparrow\) before branching is identical to Alice\(\uparrow\) after branching (and Alice0\(\downarrow\) is identical to Alice\(\downarrow\)). This relation as personal identity is either deterministic or indeterministic. “Deterministic” means that which person after branching Alice0\(\uparrow\) is identical to is fully determined by all facts (physical and non-physical) before branching.

If this relation is deterministic, no physical facts can fully explain how this relation is determined. Since all we know about the relation between Alice0\(\uparrow\), Alice0\(\downarrow\), and |Alice\ 0\ > is the bare fact that both Alice0\(\uparrow\) and Alice0\(\downarrow\) supervene on |Alice\ 0\ >. Then, there are physical facts to distinguish Alice0\(\uparrow\), Alice0\(\downarrow\) in their physical structures. Also, there are no physical facts to ground the fact that Alice0\(\uparrow\) is identical to one person supervening on one certain physical state, but Alice0\(\downarrow\) is not. Hence, there must be some non-physical facts to determine the personal identity of those states. If, in a different universe, we have these non-physical facts differently but the physical state of the universe does not change, we would get a different result of whether Alice0\(\uparrow\) is identical to Alice\(\uparrow\). This, however, would violate Supervenience.

If this relation is indeterministic (as suggested by Albert and Lower (1988), personal identity in EQM is irreducibly probabilistic), it would

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\(^{13}\) |Alice\ 0\ > is the instantaneous physical state. “Approximately” here means that, strictly speaking, Alice0\(\uparrow\) and Alice0\(\downarrow\) do not supervene on mere |Alice\ 0\ >, see the last paragraph.
violate *Supervenience* immediately. The claim that it is indeterministic that $Alice_0^\uparrow$ is identical to $Alice^\uparrow$ means that in a different possible universe, this proposition may be false, which is against *Supervenience*.

The failure of the previous solution indicates that we ought to give a more “fine-grained” account on how different persons supervene on the physical states. The quantum state of an object at certain time is commonly taken as the *minimal* depiction of such object which contains all the information of such object at that time. That means that, in order to illustrate all the physical information of an object at a certain time, we must give *at least* the quantum state of that object at that time. But the failure of the previous solution suggests that we should try to divide the state $|Alice\,0\rangle$ into different parts in its mathematical formulation, each of which represents (is supervened by) a different person respectively. We can rewrite the state before branching as follows:

$$\frac{1}{\sqrt{2}}(|\uparrow\rangle + |\downarrow\rangle) \otimes |Alice\,0\rangle$$

= $$\frac{1}{\sqrt{2}}(|\uparrow\rangle + |\downarrow\rangle) \otimes \frac{1}{2} |Alice\,0(\uparrow)\rangle + \frac{1}{\sqrt{2}}(|\uparrow\rangle + |\downarrow\rangle) \otimes \frac{1}{2} |Alice\,0(\downarrow)\rangle$$

where $Alice_0^\uparrow$ supervenes on the state $|Alice\,0(\uparrow)\rangle$ and $Alice_0^\downarrow$ supervenes on the state $|Alice\,0(\downarrow)\rangle$. Treated as the function over a subset of the overall direct product of configuration spaces in QM’s formulation\(^\text{14}\), $|Alice\,0(\uparrow)\rangle$ and $|Alice\,0(\downarrow)\rangle$ have the same values. To distinguish $|Alice\,0(\uparrow)\rangle$ and $|Alice\,0(\downarrow)\rangle$ as different physical states, we ought to give a different understanding of what a physical state is according to its mathematical formulation.\(^\text{15}\) And we may need to give a new mathematical formulation of QM to distinguish them in mathematics.

According to this, a quantum state with none-zero coefficient means *indefinite overlapping physical states* by itself. For instance, let us draw a directed line segment on paper and divide it into two. The segment on one side represents $|Alice\,0\,(\uparrow)\rangle$ and the segment on the other side represents $|Alice\,0\,(\downarrow)\rangle$. This may change the formulation of QM into some kind of

\(^{14}\) The quantum state of n particles, as the “wave function”, is a function over the direct product of n configuration spaces of the background space manifold.

\(^{15}\) It is not unacceptable, since there is already an enormous amount of literature on the so-called “the hole problem” in general relativity which suggests a different understanding of how a physical state and corresponding mathematical formulation are related. This suggestion in my paper is similar to those discussions. (Norton 2019)
fiber bundle theory\textsuperscript{16}, which gives a new geometry and algebra theory to clarify such descriptions in QM.\textsuperscript{17}

But this route still cannot reconcile Supervenience for similar reasons. Even if we can distinguish $|\text{Alice 0}(\uparrow)\rangle$ and $|\text{Alice 0}(\downarrow)\rangle$ by their mathematical forms, there still can be no physical facts to answer why the person supervening on $|\text{Alice 0}(\uparrow)\rangle$ is identical to the person who supervenes on $|\text{Alice \uparrow}\rangle$, not $|\text{Alice \downarrow}\rangle$. We lack any plausible reasons to determine this, since $|\text{Alice 0}(\uparrow)\rangle$ and $|\text{Alice 0}(\downarrow)\rangle$ have the same values understood as functions. And the formulation of fiber bundle theory still lacks enough asymmetry between them to determine this.

As Barrett (1999, 185-206) suggests, giving a deterministic law of such identity mentioned above would lead to some kind of hidden variable theories. Otherwise we cannot give an account of why Alice$^\uparrow$ is identical to Alice$^\uparrow$. But this would not influence the conclusion of my paper. First, EQM with any hidden variables is not an EQM anymore, for the spirit of EQM is that the formulation of QM itself suffices to give its interpretation. Adding any hidden variables to EQM to solve the incoherence problem would change the core nature of EQM, which is a huge cost. Second, such hidden variable theories would be too ad hoc to accept. If these hidden variables are only made to solve the issues of personal identity, it means that we have some special connecting rules for mental existences, not for all physical objects. Besides, even though we generalize such rules to all physical existences, it is still difficult to see how such connecting rules can be. We may try to label $|\text{Alice 0}(\uparrow)\rangle$ with a hidden variable “$\uparrow$”, but this would indicate fatalism requiring that Alice must measure the z-spin of the electron at the time before branching, because if Alice goes to measure the x-spin of the electron rather than to measure the z-spin of the electron, the hidden variable “$\uparrow$” can hardly work to determine the personal identity relations.

In conclusion, within the frame of EQM, we still need some non-physical facts to determine relations as personal identity. Hence, the solution to the incoherence problem of EQM via the Lewisian account of personal identity is inconsistent with physicalism.

\textsuperscript{16} Figuratively speaking, a fiber bundle is something like a hairbrush. In fiber bundle theory, the base space is alike a hairbrush’s cylinder and the fibers are alike its bristles. $|\text{Alice 0}(\uparrow)\rangle$ and $|\text{Alice 0}(\downarrow)\rangle$ might be different as fibers, which are upon the same element $|\text{Alice 0}\rangle$ in the base space.

\textsuperscript{17} Some philosophers try to give some kind of new understandings of geometry in physics, see (Maudlin 2014).
4 Conclusion

I have argued that Saunders and Wallace’s Lewisian solution to the incoherence problem of EQM is inconsistent with physicalism. Having explained in detail the 4-dimensionalism nature of the Lewisian account and the objections by P. Lewis and Tappenden to Saunders and Wallace, I argued that, if there is only one 3-dimensional entity of each type which supervenes on one single physical state, then Saunders and Wallace’s solution will fail to construct the correct uncertainty in order to solve the incoherence problem just as P. Lewis and Tappenden have argued. I explained that there thus ought to be more than one 3-dimensional entity of at least one type which supervenes on one single physical state, and that Saunders and Wallace’s solution may succeed if it is revised accordingly. I further argued, however, that such revised solution cannot be consistent with Supervenience, that is, the principle according to which personal identity must supervene on physical states of the universe. Since this principle must be satisfied if physicalism is true, it follows that Saunders and Wallace’s solution is inconsistent with physicalism.

This reveals a serious problem we have long overlooked within EQM. The problem of Saunders and Wallace’s solution suggests that we need to pay more attention to issues of personal identity in EQM, as Butterfield (1996) has emphasized. If we want to solve the incoherence problem of EQM, it seems that we should give a definite and transitive account of personal identity in EQM, but this might lead to some kind of non-physicalism (there are other solutions to the incoherence problem, by abandoning Ignorance (Papineau (1996)) or by invoking the so-called after-the-measurement uncertainty (P. Lewis (2007)), both of which do not need to give a definite and transitive account of personal identity, but they still face much criticism which I cannot illustrate here). We will need to pay a high price if we accept non-physicalism of EQM. This reminds us to scrutinize and re-think of the possible non-physicalism interpretations of EQM (such as Albert and Lower (1988)) in the future research.

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