# A Challenge for Humean Everettians

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**Abstract**

I show that recent attempts to develop Humean Everettianism are inconsistent with the Principal Principle. Wilhelm (2022) develops an account of probability in Everettian Quantum Mechanics that purports to solve the problems faced by the wide range of existing approaches; he does so by linking probabilities to a Lewis-style Best System Analysis of the outcomes along branches, resulting in 'centered chances'. Unfortunately, this approach cannot work: it implies that physically identical timeslices of individuals will have a great many distinct credences at any time, and provides no account of which credence in particular should be accepted. As such, this view of probability does not provide a guide to action and severs the credence-chance link. I develop this worry and argue that it stems from a conflation of two types of probability that come apart in many world settings.

Keywords: Everettian probability; centered chances; Best System; Everettian Quantum Mechanics; Principal Principle

## 1 Introduction

Acolytes of David Lewis's account of probability face a serious problem when it comes to Everettian Quantum Mechanics. According to

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Lewis, probabilities supervene on the distribution of events in the actual world, and yet the Everettian is committed to the view that there are branches/worlds in which events are distributed in such a way that a branch-relative Lewisian Best System Analysis would result in probabilities in radical disagreement with the Born rule and the predictions of Orthodox Quantum Mechanics. The standard response, defended by Papineau (2010) and Wallace (2012), is to rule out the Lewisian option; though Wilson (2020) offers a distinct defence of Lewis's approach in the Everett context. But a recent alternative has been defended by Isaac Wilhelm (2022); this approach seeks to retain the advantages of a Lewisian approach to probability – that frequencies and chances are closely linked – and it's the goal of this short article to show that this is too good to be true.

Wilhelm claims that on Maverick branches – those where the distribution of events radically differs from that predicted by the Born rule, see DeWitt (1970) – the probabilities just are different, and, by applying the Principal Principle, agents should expect to see different outcomes. But the problem is that it's a straightforward consequence of the theory that some of my successors will experience outcomes that wildly differ from those predicted by the Born rule. Even if one accepts the so-called 'divergence' picture – where individuals are identified with distinct four-dimensional spacetime worms at all times, i.e. there is no splitting – there are countless individuals that share a qualitatively identical timeslice in me right now; and on Wilhelm's proposal each of those individuals should have different credences. But it's not possible for qualitatively identical timeslices of individuals to have distinct credences at a time unless one has a *very* outlandish philosophy of mind.

Moreover Wilhelm's account does not allow for any predictions or confirmations made on the basis of Everettian Quantum Mechanics – that's because, in principle, I have no way of distinguishing between the co-located individuals who will see the outcomes predicted by the Born rule, and those who will see Maverick outcomes. What then should *I* expect? How should I choose between the many radically different credences putatively assigned to the many individuals co-located in my chair right now? This simply moves the pressing questions about probability in Everett – if all outcomes occur why should I expect to see those with higher Born rule weight? – back a stage: if all outcomes occur why should I assign my credences according to those of the co-located individual with a high Born weight future? And to that latter question Wilhelm has no response.

In the remainder, I'll go through that argument in a little more detail and attempt a diagnosis of the mistake – in short, that there are two ways of thinking about probability and possibility that coincide in single-world contexts but that come apart in many world contexts. Wilhelm's mistake is to assume that in an Everettian setting one can import down-branch considerations, relevant to observed frequencies, into practical contexts where cross-branch probabilities are relevant.

## 2 Centred Everettian Probability

Wilhelm's project is, in my view, very well motivated. He aims to develop an account of chances/objective probabilities in the Everett interpretation that does not appeal to credences or decision theory. However, unfortunately I do not think that this aim is met, at least unless one ends up rejecting the claim that objective probability is a guide to action (a link that Wilhelm is keen to retain), for his account still leaves it entirely open what to expect or how to set one's credences. On that basis his account, if it's to be accepted, requires supplementation with a decision-theoretic type strategy and the rejection of the Principal Principle. This contradicts Wilhelm's claim (p. 1026) that "centered chances are those objective, worldly states which constrain rational centered credences".

Wilhelm (2022) argues that physics leaves out a set of facts relevant to probabilities in many worlds – those are the centred facts, which describe the branch-relative evolution of an individual. He says that once we include these facts we observe that, despite fundamental determinism, there are many branches that exhibit various outcomes.

For Wilhelm (ibid. p. 1021-2): "branches are infinitely extended towards the past and the future. Branches do not come into existence when a split occurs. Rather, a split separates two branches which had always existed. Those branches were just exact physical duplicates of one another, before the split".

In the high Born weight branches agents will observe a randomly distributed sequence of events with proportions in accordance with the Born rule. This follows from an important result due to Everett himself, whose analysis is summarised by Barrett (2023) as follows (for proof, see Barrett (1999, pp. 100–107)):

Everett argued that in the limit as the number of measurements gets large, almost all branches in measure $m$ will describe sequences of measurement records that are randomly distributed with the standard quantum statistics. While he just sketched the corresponding results, one can show that:

**Relative Frequency:** For any $\delta > 0$ and $\epsilon > 0$, there exists a $k$ such that after $k$ measurements the sum of the norm-squared of the amplitude associated with each branch where the distribution of spin-up results is within $\epsilon$ of $|\alpha|^2$ and the distribution of spin-down results is within $\epsilon$ of $|\beta|^2$ is within $\delta$ of one. and

**Randomness:** The sum of the norm-squared of the amplitude associated with each branch where the sequence of relative records satisfies any standard criterion for being random goes to one as the number of measurements gets large. This result holds for any criterion of randomness that classifies at most a countable number of $\omega$-length binary sequences as nonrandom.

Let's (tendentiously) call worlds/branches with relatively high measure $m$ 'typical$^\dagger$ worlds/branches' (where the dagger steps back slightly from the tendentiousness). The Everett/Barrett analysis tells us that in typical$^\dagger$ branches stable relative frequencies with appropriately randomly distributed outcomes emerge from fundamental determinism.

Thus, we have as good a reason as we can ever have for thinking there are objective probabilities in typical$^\dagger$ branches, assuming that somehow probabilities are related to such relative frequencies. One might expect that probabilities are fundamental in quantum mechanics, but this is not compatible with the view that sets probabilities equal to mod-squared amplitudes. On the contrary, we may not regard fundamental amplitudes as corresponding to probabilities before decoherence because such amplitudes interfere. If one were, for example, to regard the amplitudes half way between the double slit and the screen as probabilities in the double slit experiment, one would end up with the wrong predictions. It's only once decoherence has ensured effective non-interference that mod-square amplitudes behave as probabilities.[1]

[1] I use this observation in Franklin (2023) to argue that emergence in Everettian quantum mechanics can be established without settling questions of probability.

An interesting feature of emergent probability is that, just as with other instances of emergence, one must specify a level, or spatiotemporal domain, in order to identify the dependency/probability. So, rather than asking in any particular case what the chance of some outcome is, we evaluate the chance relative to a sequence or history – in Wilhelm's terms a 'branch'. If one is in a typical$^{\dagger}$ branch, then the probabilities will conform to the standard predictions of quantum mechanics.

Assuming we have stable relative frequencies in each branch, are these chances? Hoefer (2019) argues (in other contexts) that they are – following David Lewis's account of fundamental chance, he claims that one can identify chances with higher-level distributions of events that have stable frequencies and are appropriately randomly distributed. The chances follow from the best systematisation of those events at that level. This follows from the well-established deterministic chance tradition (see e.g. Glynn (2010)). And Wilhelm endorses an analysis of this kind.

However, what should we make of the Maverick branches?

It's certainly the case that there are some branches in which the long-run sequences of outcomes do not correspond to the Born rule expectations and there are even branches in which there are no well-defined relative frequencies at all, but the Lewis/Hoefer style analysis of these branches makes the determination of the chances in such branches somewhat more complex. On such accounts probabilities supervene on the 'best systematisation' of the distribution of events. What goes into that systematisation is of course contested. But one might think that *some* not-too-Maverick branches will still give rise to Born rule probabilities on systematisation. That's because the Born rule measure also plays a more fundamental dynamical role predecoherence. For example, higher amplitude terms are dynamically privileged within quantum physics – they make more of a difference to quantities with which they interact. And due to Gleason's theorem (see Brown and Ben Porath (2020) and Earman (2022) for discussions) the Born rule measure is uniquely specified by certain theoretical constraints. As such, a Humean of this sort should not regard *all* branches with deviant statistics as having non-Born rule probabilities.

Nonetheless there are certainly some branches which, according to the Lewis/Hoefer/Wilhelm approach will feature non-Born rule chances or no chances at all. This is what motivates Papineau (2010) and Wallace (2012) to rule out Humean accounts of probability.

On the other hand, Wilhelm (2022) argues that, not only are probabilities different in Maverick branches, but that rational observers in such branches should expect different results. Likewise Brown and Ben Porath (2020) argue that in Maverick branches observers should have different credences – though for Brown and Ben Porath this is a serious problem for such an account.

Wilhelm (2022, p. 1027): "On other branches, however, the Born rule probabilities get the frequency facts wrong ... different branches have different best systems, and so different branches have different laws". He goes on to claim that (p. 1029) "God gives the centered Born rule to *you*. God would not give the centered Born rule to individuals who (i) temporarily look exactly like you, but (ii) belong to branches where the centered frequency facts deviate from the Born rule probabilities. To help guide those individuals' guesses as to where they might be, God would give them different chancy rules."

But this must be wrong. Unless Wilhelm is endorsing a rather extraordinary position in the philosophy of mind, he would agree that exact physical duplicates at a time cannot have distinct beliefs at that time.[2] And yet, according to the divergence metaphysics on which the worm view that Wilhelm advocates depends, there are a great many versions of me writing this in my chair right now. All share the same history, thoughts, and experiences, but will have different futures. It's a straightforward consequence of the Everett interpretation that some of my successors, that is some of the folks who share this timeslice of me, will experience radically different futures with outcomes radically divergent from those predicted by the Born rule. Not even God could talk to just one of us because the set-up is such that we are all indistinguishable right now, and share the same spatiotemporal location etc. So, even if it's the case that different laws are associated with each of us, how could it be that we have different credences?

Exact physical duplicates at a time are widely assumed to have the same beliefs. Given that some of my duplicates will experience different futures, which will on Wilhelm's account have different probabilities associated with them, when I am asked what to expect I cannot answer. Perhaps one could develop a view where my credence at a time is determined by all

[2]Of course, someone might wish to endorse a form of dualism in which the mental fails to supervene on the physical, or in which beliefs at a time depend on an individual's entire future, but this coupled with a Humean and an Everettian view would be a remarkable metaphysical package and notable as such.

my future experiences, but this would be a radical position in the philosophy of mind and would completely sever the link between my beliefs and the evidence available to me. Moreover, if my beliefs are to supervene on my future rather than present evidence, then why use probabilities at all? One could simply say that I ought to expect to observe the precise sequence of events that I will observe, which may be right in a sense, but not at all practically relevant in the way that the Lewisian approach to probability is meant to be. The salient question is: 'what should I expect right now?' and Wilhelm's account does not help at all in answering that question.

It's a nice observation that on an Everettian theory we can have objective probabilities, but if these bear *no* relation to the credences (and they can't because one set of credences and all the same evidence is shared by individuals with many futures who consequently have many numerically distinct chances), then it violates the Principal Principle – the idea that chances, credences, and evidence are intimately related. According to Lewis "this principle seems to me to capture all we know about chance" (Lewis (1986, p. 86)). Of course one could argue that what's claimed is about what credences an individual *should* have, but then if it's in principle impossible to know which credences one should have, the view remains rather unattractive.

If in fact I should expect to see outcomes distributed according to the Born rule – as is reasonable, and as everyone reasonable would bet if you asked them – then either Wilhelm's account is entirely to be denied, or, at least, the Principal Principle is false. That's because my credences would not accord to the objective probabilities plus available evidence for the versions of me with Maverick futures. There is, in fact, no situation at all in which it's preferable to bet against the Born rule, because whatever one's history, there are futures that accord to the Born rule, and futures that don't – and the centred chance analysis does not help at all in deciding how to set one's credences among those options.

## 3 Diagnosis

Greaves (2007), Papineau (2010), Saunders et al. (2010), Sebens and Carroll (2018), Vaidman (2011), Wallace (2012), and Wilson (2020), and others put forward a range of related arguments that rational observers should assign credences in accordance with the Born rule.[3] I will not rehearse such arguments here. However, I will note a crucial feature – that such arguments are based on symmetries and other relevant features of the range of possible outcomes consequent upon branches splitting or diverging from one another.

Of course there are those who question the specific details of the decision theoretic arguments, however I won't respond to these arguments here. My goal is not to provide a full-throated defence of probability in Everett, rather to suggest a diagnosis for the issues discussed above.

To that end at this point I want to note a common feature of all analyses of practical/epistemic probability: that they are across-branch (horizontal in figure 1)! That is, they are based on the reasoning of an observer facing a number of futures, when, in retrospect, they will only have observed a single outcome. This is in contrast to down-branch probabilities (vertical in figure 1) that relate to the four-dimensional spacetime worm, branch, history, or sequence of unique outcomes of experiments.

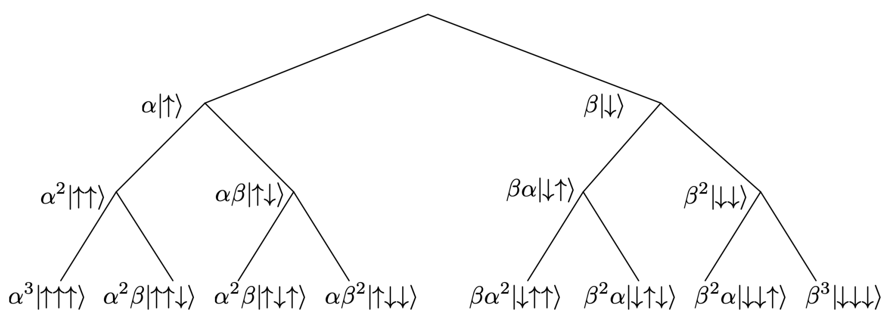


Figure 1: From Barrett (2019, p. 152).

In the ordinary one-world metaphysics to which we're habituated, this doesn't bear mentioning: that's because down-world frequencies are what inform our sense of across-world possibilities. But in the Everettian case these come apart. All the epistemic/practical arguments just cited, of necessity, are built upon an analysis that is indirectly related to what we observe.

[3]Alastair Wilson's account builds on Lewis's work and so might seem oddly placed in this list, however for Wilson the chance of some outcome corresponds to the chance that an individual's world is amongst the set of worlds that feature that outcome. Thus, we can see that he takes the across-world possibilities as the basis for his analysis.

Why think that across-world possibilities and down-world frequencies are intimately related in single-world but come apart in many world contexts? And why think that's relevant to the question of the relationship between epistemic/practical probability and objective probability?

I'll respond to the second question first. There's a sense in which it's up to us quite what meaning we assign to the concept 'probability', especially in a setting so alien to that in which we assumed we were located when our concepts developed. However it shouldn't be controversial that practical/epistemic probabilities accord to the range of possibilities available to a given observer at a given time: decisions are made at a time, and so it makes sense to think of the range of possible futures at that time when making decisions.

On the other hand there's an obvious connection between down-world frequencies – observed frequencies – and probabilities. Probabilities are used to explain what we observe, and predict what we are going to observe (Elliott (2021)). Humean theories of probability (such as Glynn (2010) and Hoefer (2019)) as well as Sober (2010)'s no-theory theory make this connection almost analytic. That's why down-world and across-world may be taken, respectively, to relate to objective probabilities and practical/epistemic probabilities.

Let's return to the first question: how are these related in a single world scenario? In that context, one infers possibilities from outcomes: if A and B only ever occur and the observed frequency A:B approximates 1:2 it's inferred that A and B are the possibilities and that B is more likely to occur than A. The logic of probabilistic inference of course allows that in the future one will only ever observe A, but it seems to Humeans and other empiricists that, if one were never to observe a B again, the probabilities would either have changed, or have always been different from what we'd thought they were.[4]

By contrast, in the Everettian context it's known that some branches will exhibit down-branch frequencies that radically differ from the range of possibilities facing a given observer at a splitting. In some branches, looking backwards at a given system's observed history or looking forward by singling out a sequence of descendants' observations, only Bs will be observed, and in other branches only As, and in many further branches the

[4]See Barrett and Chen (2023) for an interesting account of probabilistic laws that would avoid these issues.

proportion of As to Bs will be such that they don't at all accord with the Born rule.

In a non-Everettian single-world context at least one can say that we *expect* the down-world frequencies to match the across-world (across the set of physically possible worlds at a time) range of possibilities, but in the Everettian context we know that in some cases these radically diverge.

Faced with this observation, many are tempted to dismiss Everettian quantum mechanics as empirically unacceptable.[5] But many such claims are based on the conflation of down-world frequencies with across-world possibilities and positing a close link between practical/epistemic and Hoefer/Lewis objective probabilities as codified in the Principal Principle. If that conflation is resisted, then these unfortunate consequences may be avoided.[6]

It's not that I wish to argue that a close link between these two kinds of probability is unattractive – of course, it is intuitive! However, it's certainly an assumption being made by various analyses of the Everett theory, and if, in certain Maverick branches, these probabilities come apart, it's not clear why that would be such a bad thing. There are still practical/epistemic probabilities that accord to the Born rule because these do rely on across-branch possibilities at a time, and that's true even if one's history is such that those frequencies are not exhibited in one's branch. In other words, we might well grant that, at least on some theories of probability, objective probabilities in Maverick branches deviate from the Born rule, but even in such worlds you'd still do best to bet with Born rule credences, *pace* Wilhelm (2022).[7] So if Wilhelm's account of objective probability as centred chances is to be accepted, he still requires something like the decision theoretic arguments to tell us how to set our credences, and the Principal Principle's link between centred chances and credences will be violated.

[5] A related argument motivates Adlam (2014).

[6] Avoiding that conflation might also undermine some recent arguments for branch counting (Dizadji-Bahmani (2015) and Khawaja (n.d.)) – as these tend to appeal to an indifference principle across worlds/branches, where indifference principles are usually motivated down-branch.

[7] Alternatively one may follow Papineau (2010) and argue that only a propensity theory is adequate to the Everettian case.

## 4 Conclusion

Probability in the Everett interpretation of quantum mechanics will, inevitably, lose some of the conceptual associations of probability in single world contexts. That's not at all surprising: the theory is revisionary and probability theory was developed at a time when a multiverse as a serious scientific proposition was not envisaged. It's most common in the literature to contemplate revising our notion of uncertainty, however, Wilhelm's analysis seems far more radical: it forces us to give up on the relationship between chance and credence known as the 'Principal Principle'. That's because, on his analysis, a single observer at a time with a single set of credences will be a member of many temporally extended branches, to each of which Wilhelm assigns different chances.

I've argued that this mistake is a consequence of the fact that two more basic notions – across-branch possibilities and down-branch frequencies – come apart in many world scenarios.

Overall, it should be clear that one may draw various conclusions about the nature of chance in Everettian Quantum Mechanics, but that the best arguments for making sense of credence assignments are those that depend on across-world probabilities rather than the down-branch distribution of events. Indeed, anyone who wishes to bet otherwise will find many people willing to accept the wager!


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