Rationalizing the Principal Principle for Non-Humean Chance

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The major divide in the metaphysics of chance is between Humean accounts, for which the objective chances reduce to patterns in the history of occurrent events, such as frequencies, and non-Humean accounts, for which chances are irreducibly modal features of the world, such as brute propensities, chancemaking relations between universals, or constituents of fundamentally stochastic dynamical laws.[1] But whatever chances turn out to be – and whatever the direction of *metaphysical* explanation between chances and occurrent events – they play an important role in explaining statistical regularities and licensing scientific explanations. At the same time, it is widely believed that chances should somehow constrain our credences: on pain of irrationality, agents ought to match their credences in certain propositions to what they believe to be the chances of those propositions. This idea is captured by David Lewis' Principal Principle (PP):[2]

$$(PP): \quad Cr(A|X \wedge E) = x$$

Here, Cr is a rational initial credence function, X is a proposition to the effect that the chance of A is x, where $x \in [0,1]$, and E is any "admissible" proposition. Admissibility is difficult to define, and Lewis offers no precise definition. However, he does offer a characterization of admissibility: admissible information informs us about a proposition only by way of telling us about the *chance* of that proposition. On this characterization, for example, the reading of a crystal ball that carried future information about the outcome of a chancy event would be inadmissible. Moreover, Lewis offers two sufficient conditions for admissibility. Firstly, *historical* information up to a time t is admissible at t. Secondly, the general chance theory of a world – namely a set of "history-to-chance conditionals" which give an account of which antecedent conditions give rise to which chance distributions – is always admissible. Therefore, a more specific implication of (PP) includes these sufficient conditions for admissibility, where H_{tw} is the history of world w up to time t, T_w is the theory of chance that holds at w, and P_{tw} is the probability function for w at t generated

[1] I will hereby refer to propensity theories, and, following Gillies (2000), I will consider propensity theories, broadly construed, as any objective, non-frequency, non-reductive theory of probability. More specifically, propensities are thought of as intrinsic dispositions, logically distinct from the frequencies, to generate events with a particular probability. These probabilities are taken to explain the observed relative frequencies.

[2] See Lewis 1980.

by w's theory of chance:

$$(PP_{\mathrm{HT}}): \quad Cr(A|H_{\mathrm{tw}} \wedge T_w) = P_{\mathrm{tw}}(A).$$

($\mathrm{PP_{HT}}$) follows from (PP) given that $H_{\mathrm{tw}} \wedge T_w$ entails that the chance of A is $P_{\mathrm{tw}}(A)$. Informally, (PP) and its implication ($\mathrm{PP_{HT}}$) instruct agents to match their degrees of belief to their subjective estimates of the objective chances.[3]

Despite its intuitive force, (PP) turns out to be somewhat difficult to justify. The issue becomes especially pressing insofar as it encroaches on the aforementioned metaphysical debates about chance. That *some* chance-credence norm holds seems to be an indispensable aspect of the chance-role (i.e., the function of the concept of chance), and the proponents of any metaphysical account of chance had better be able to explain why their candidate filler of the chance-role is up to the task of constraining rational credence. Lewis (1994, 484) famously quipped that it was utterly mysterious how the "unHumean whatnots" posited by his opponents could constrain rational credence. That non-Humean accounts of chance are unable to rationalize adherence to (PP) has since become a common argument in the literature that such accounts are unsatisfactory. For shorthand, I will call this the Credence Argument against non-Humean chance.

The aim of this paper is to justify (PP) in a manner that is available to non-Humeans. I will proceed as follows. First, I will review the informal statements of the Credence Argument and offer a more substantive formulation (sec. 1). Second, I will offer two separate justifications of (PP) for non-Humean chance (sec. 2), arguing first that adherence to (PP) can be rationalized based on its implications for an agent's outright beliefs about frequencies (sec. 2.1) and second that adherence to (PP) can be rationalized based on its implications for the accuracy of an agent's credence function (sec. 2.2). Finally, I will consider an objection and offer replies (sec. 3).

1 The Credence Argument

Lewis never clearly formulated his argument that non-Humean accounts of chance failed to rationalize adherence to (PP). His complaint is raised only in the following passage:

> Be my guest – posit all the primitive unHumean whatnots you like. (I only ask that your alleged truths should supervene on being.) But play fair in naming your whatnots. Don't call any alleged feature of reality 'chance' unless you've already shown that you have something, knowledge of which could constrain rational credence. I think I see, dimly but well enough, how knowledge of frequencies and symmetries and best systems could constrain rational credence.

[3]More precisely: (PP) constrains an agent's ur-credence function *synchronically*, by prescribing a hodgepodge of conditional probabilities that she should adopt at the beggining of her epistemic life. Agents implement (PP) *diachronically*, by matching their unconditional credences to their subjective estimates of the chances.

> I don't begin to see, for instance, how knowledge that two universals stand in a certain special relation N* could constrain rational credence about the future coinstantiation of those universals (1994, 484).

Lewis' complaint, here, is that it is unclear why (for instance) two universals standing in some non-Humean chancemaking relation N* should constrain our expectation about the actual patterns of coinstantiation between the two universals. This complaint has intuitive pull, but Lewis gives little by way of further argumentation. No especially sharp formulation of the argument has been presented in the literature, but the general idea is commonplace among Humeans, and has been slightly expanded upon by Loewer (2004), Eagle (2004), and Hall (2004).[4] Loewer offers a compelling statement of Lewis' objection to non-Humean chance:

> Without [relying] on the PP there is no non-question begging reason to think that setting one's degrees of belief by propensity chances will result in having high degrees of belief in truths and low degrees of belief in falsehoods. And since propositions about propensity chances are facts logically completely distinct from the propositions they assign chances to it is utterly mysterious why they should tell us anything about what degrees of belief to have in those propositions (2004, 1123).

Similarly, Hall asks whether we show that a chance-credence norm like the Principal Principle follows from what normative constraints on our beliefs and credences that concern merely the "categorical" features of the world, and answers this question in the negative:

> If the correct account of the metaphysics of objective chance is a thoroughgoing non-reductionist account – that is, an account according to which the categorical facts about a world place virtually no constraints on the ur-chance function for that world – then the answer is clearly 'no'. For that is a metaphysics of objective chance that gives the categorical constraints no purchase. Commit yourself to such a metaphysics, and it appears that you must introduce the Principal Principle as a *sui generis* normative principle governing rational credence (2004, 107).

Finally, Eagle formulates the objection as follows:

> Severing the constitutive link between frequencies and chances means that we have no logical connection between the concepts of probability and rational expectation. Since, as we have seen, the events that occur in a world and the chances of those events are not logically related, why should knowledge of the chances tell us anything about which events to expect to occur? There seems no way that these single case propensities can rationalise adherence to Lewis' Principal Principle or anything like it; but without the Principal Principle we have no link between the two major uses of probability (2004, 401).

[4] 2004 was a rough year for propensity theorists!

The common idea behind these objections to non-Humean accounts of chance seems to be that, because facts about frequency, accuracy, informativeness, and the like bear no constitutive link to facts about the non-Humean chances, it is unclear why we should be rationally compelled to align our credences with those chances.

One way of interpreting this objection is that it is unclear how to derive a chance-credence norm like (PP) from purely *non-normative* facts about the world. Hacking (2006, 12) famously remarked that the concept of probability is "janus-faced" – it is both concerned with licensing scientific explanations of worldly statistical processes, and also with offering normative guidance for rational degrees of belief. It may be thought that this 'dual' role for objective probability is mysterious, just as it is mysterious how, in meta-ethics, purely *descriptive* properties, as though by pure magic, instantiate moral or evaluative properties. Perhaps, then, Humeans allege that their chances are better-suited to explain this mysterious, apparently dual function of objective probability. But I take it that this is not the objection pressed against non-Humean accounts of chance. After all, it is not even 'dimly' visible how Humean accounts of chance could help us to derive an 'ought' from an 'is,' i.e., to explain why we are normatively constrained to act in a certain way *solely* in virtue of the non-normative facts about the world. The axioms of the Humean systematization of our world would not, just by virtue of being simple and informative, contain a whit of normative content, so there is no transparent way to derive (PP) from those axioms alone, without supplementing the Humean chances with some further normative principles about what beliefs and credences we ought to have.

Presumably, then, the challenge leveled against non-Humean accounts of chance doesn't concern how to derive normative principles of rationality from non-normative facts about the non-Humean chances alone. Rather, the challenge is that, even once we have posited normative principles which aim at promoting true belief or accurate credence, it is unclear how to get (PP) from these principles, while for Humean accounts of chance, (PP) follows almost immediately from seemingly more foundational normative principles. For example, suppose we started off with only two ingredients: an objective Humean chance function, and a norm which instructs agents to form true beliefs about the relative frequencies. Since propositions about the Humean chances are somehow logically connected to propositions about the relative frequencies, it seems that we should be able to explain how the Humean chances bear on the truth of various propositions about frequencies and hence on what agents are rationally compelled to believe. But for non-Humean accounts of chance, there is no logical connection between chance and frequency, so it is less clear why an agent instructed or motivated to believe truths would thereby be compelled to align their credences with the objective chances. Or suppose, for instance, that our foundational norm of rationality instructed agents to adopt a credence function that has a high degree of accuracy, i.e., one which assigns high degree of belief to truths and low degree of belief to falsehoods. It seems similarly transparent, because the Humean chances supervene on patterns in actually-occurring events, that an agent interested in maximizing accuracy would be thereby compelled to defer to these Humean chances, while it is much less clear why the ineffable 'metaphysical glows' posited by propensity theorists should have any bearing on rational credence. This is the basic challenge, it seems, being pressed against non-Humeans. For shorthand, I will refer to it as the Credence Argument.

2 Justifying (PP)

My goal, then, is to show that non-Humeans can offer a satisfying justification of (PP) from independently plausible antecedent principles of rationality. I will offer two such justifications. The first approach justifies (PP) via the role it plays in informing outright beliefs about long-run frequencies. The second approach justifies (PP) by showing that adherence to (PP), even for non-Humean chance, minimizes expected inaccuracy according to the actual objective chance function.

2.1 Outright beliefs about frequencies

My first attempt at justifying (PP) in a propensity-friendly manner will, approximately, have the following form: in the long run, adherence to (PP) has an objective probability approaching 1 of producing true beliefs about the relative frequencies, thereby contributing positively to an agent's ratio of true to false beliefs. The argument will rely on three assumptions, each of which (I think) carries independent plausibility. The first assumption is what I will call:

> *Chance Reliabilism*: Agents should adopt the belief-formation processes which have the highest objective chance of producing belief sets with high ratios of true to false belief, provided that the processes are sufficiently operationalizable.

Call a belief set with a high ratio of true to false belief an apt belief set, where aptness increases in proportion to the ratio of truths to falsehoods. Chance Reliabilism states that what makes a belief rational is that it was formed by a process which has a high chance of producing an apt belief set. We can cash out Chance Reliabilism more precisely as saying that agents ought to adopt the belief-formation process that maximizes ch-expected aptness, $\mathrm{EA}_{\mathrm{ch}}$:

$$EA_{\mathrm{ch}}(R, \mathcal{F}) = \sum_{\langle w, \mathcal{B} \rangle} ch(w) Ap(\mathcal{B}, w) ch(A_{\mathcal{B}} | A_R)$$

Here, R is a belief-forming process (which we may think of as a function from situations to actions), $\mathcal{F}$ is an algebra of propositions, w is a possible world – i.e., a classically consistent assignment of truth values to the propositions in $\mathcal{F}, \mathcal{B}$ is an agent's belief set, $A_{\mathcal{B}}$ is the proposition that the agent will adopt belief set $\mathcal{B}, A_R$ is the proposition that the agent adheres to process R, and $Ap(\mathcal{B}, w)$ is the measure of $\mathcal{B}'s$ aptness:

$$Ap(\mathcal{B}, w) = \frac{|B_T|}{|B_F|}$$

where the belief set $B_T = \{b : b \in \mathcal{B} \ \& \ b \text{ is true at } w\}, B_F = \{b : b \in \mathcal{B} \ \& \ b \text{ is false at } w\}$

and $|B_T|$ and $|B_F|$ are the respective cardinalities. The value of EA_{ch} is a sum over possible world-belief set pairs which expresses how apt the actual objective chance function expects your belief set to be, *given* that you are adhering to process R. In other words, Chance Reliabilism instructs agents to adopt a belief-formation process which is likely, according to the chance function, to yield a belief set which the chance function regards as likely to be apt. Chance Reliabilism is constrained only to prescribe processes that are sufficiently operationalizable. This operationalizability constraint is admittedly vague, but the intuitive idea is that Chance Reliabilism should only make prescriptions that agents have the reasonable practical ability to implement. For instance, "believe only truths" is exceedingly difficult to operationalize, while "always believe your parents" is highly operationalizable.

What might motivate the adoption of a principle like Chance Reliabilism? Reliability is often understood, in the epistemology literature, as high objective probability of producing an apt belief set, and analyzing epistemic justification in terms of reliability is a prominent project in epistemology.[5] The informal statements of the Credence Argument seem to suggest that the issue with non-Humean chance is that, since the *logical* connection between chances and actually-occurring events has been severed, we similarly cannot draw any logical connection between chance and rational expectations about those events. On a Humean view, chances supervene on the actual history of occurrent events, and so facts about the chances just are, in some way, facts about the history of occurrent events.[6] The trouble for non-Humean chance was supposed to be that there is no transparent link between concepts like truth or accuracy on the one hand and the concept of objective chance, on the other. Hence, insofar as what we are ultimately interested in is truth or accuracy, we need some principle(s) which will bridge the manifest divide between (a) our normative interest in believing true propositions or possessing accurate credences about propositions that are true or false *outright*, and (b) the non-truth-functional *chances* of those propositions.

But consider what form the underlying rationality principles employed to justify (PP) might take. One might think that Humeans can get away with positing fundamental normative principles that are, as it were, 'unqualified.' While Chance Reliabilism merely promotes true belief by instructing agents to maximize the *likelihood* that their belief-sets will be apt, Humeans have no need to bring chance into the picture in this roundabout way. Humeans, instead, might be able to posit truth- or accuracy- norms that simply instruct agents to 'maximize truth' or 'maximize accuracy,' without appeal to the chancy disposition of (PP) to bring about true belief or accurate credence, as the non-Humean must do.[7]

But I don't think that such unqualified antecedent normative principles are genuinely available for Humeans. This is because (PP) is itself a conditional principle of rationality: *given* your belief that a particular chance function obtains, you should match your credences to that probability function. Consequently, the principles of rationality that we employ in justifying (PP) must also be able to secure our rational access to the objective

[5] See Alston (1988), Pettigrew (2021), and Comesaña (2018), Dunn (2015), and Tang (2016), for example.

[6] See, again, Hoefer (2019).

[7] See Hoefer (2019) and Hicks (2017) for such Humean accounts.

chances, if they are to bridge the gap between the internally relevant facts (i.e., concerning our beliefs about the chances) and externally relevant facts (i.e., concerning the chances themselves). But there is no logical or constitutive guarantee of epistemic success when it comes to our beliefs about the chances. Thus, Humean accounts of chance can't ensure that agents will satisfy some unqualified truth or accuracy norm just by adhering to (PP), as there is no guarantee that their subjective estimates of the chances will be accurate.

Imagine asking a Humean how an agent is to rationally form beliefs about the objective chances. This agent, after all, does not have epistemic access to the entire actual history of occurrent events on which the Humean chances supervene. The agent's total evidence *indicates*, but does not *guarantee*, that the global frequencies, and so the objective chances, have certain values. One way of cashing this idea out is that it is objectively likely that an agent's total evidence will be an adequate, non-misleading guide to the Humean chances. Thus, while a Humean could say that adherence to (PP) guarantees success *conditional* on one's knowing what the chances are, the underlying account of epistemic justification must not forbid this condition from coming to bear.[8]

Humeans should lower their standards. In particular, they should de-emphasize the supposed guarantee of success that the chances are supposed to bring about and accept that our justification of (PP) may reasonably refer to which belief- and credence- forming processes have the highest objective chance of performing well over the long run. As I will discuss in Section 3, this is not the only strategy available to Humeans; but it is not obvious that the alternatives are preferable to positing a fundamental chance-involving norm like Chance Reliabilism. (Much more on this later.) For now, Chance Reliabilism seems like a fairly reasonable starting point, because (as I will argue) it is plausible that Chance Reliabilism offers realistic and implementable guidance on how to form justified beliefs about the objective chances, *and* on what credences to adopt, given an agent's subjective estimate of the objective chances. The aim, then, is to offer an account of how the objective chances provide external reasons – via principles like Chance Reliabilism – that allows us to derive (PP) without circularity. My goal here is to offer a sketch of such an account.[9]

With that, the second assumption that I will make concerns the probabilistic connection between chances and frequencies, as observed in the well-known Weak Law of Large Numbers (WLLN), which says that for any coherent probability function P, and any ϵ between 0 and 1:

$$\lim_{n\to\infty} P(|f_\phi - P(\phi)| < \epsilon) = 1$$

Here, ϕ is a repeatable proposition-type concerning independent and identically distributed (i.i.d.) events (e.g. that a fair coin will land heads), f_ϕ is the frequency of ϕ in a sequence

[8]Fernandes (forthcoming) makes this point vividly. First, there is some non-trivial chance that the local frequencies in a given region will diverge from the global frequencies. Secondly, there is even a small chance that the global frequencies will diverge from the Humean chances in the case of undermining futures.

[9]I acknowledge that such an approach may appear circular, or may appear to assume that non-Humean chances already possess the requisite truth-making powers to be relevant for rationality. I will address both of these concerns in Section 3.

of n trials, and ϵ is an arbitrary constant. WLLN is a theorem of the probability calculus which says, intuitively, that the probability that the frequencies and the single-case probabilities will diverge approaches zero as the number of trials gets infinitely large.

Assuming that the chance function is itself probabilistically coherent, an implication of (WLLN) is what I will call the Chancy Law of Large Numbers (CLLN), which says that for any ϵ between 0 and 1:

$$\lim_{n\to\infty} ch(|f_\phi - ch(\phi)| < \epsilon) = 1$$

Finally, I will assume that a rational agent's credence function is probabilistically coherent, which, together with (WLLN), entails that the agent ought to expect that the frequency of an event-type in the relevant reference class is approximately equal to their single-case credence that the event will occur. I will call the Subjective Law of Large Numbers (SLLN), which says that, for any ϵ between 0 and 1:

$$\lim_{n\to\infty} Cr(|f_\phi - Cr(\phi)| < \epsilon) = 1$$

SLLN is, again, meant to apply to repeatable and i.i.d. events, and it merely demands of agents that their credence function be probabilistically coherent, since SLLN, too, is a theorem of the probability calculus, assuming that Cr obeys the probability axioms. Both CLLN and SLLN play important roles in the first justification of the Principal Principle for propensity chances that I will offer.

The last assumption I will make is known as

> *Lockean Thesis*: If one's credence in p is sufficiently high, then one should take up the outright belief that p.

There are a number of different versions of the Lockean Thesis. It is sometimes taken that sufficiently high credence is necessary and sufficient, or just necessary, for outright belief. For my purposes, suitably high credence will need to be sufficient, but not necessary, for rational outright belief. How to understand "sufficiently high" is also a point of contention in the literature. Some, for instance, take it that there is a fixed threshold for sufficiently high credence, while others take it that the relevant threshold is context- and proposition-dependent.[10] For whatever level of credence $1 - \epsilon$ one thinks is suitably high to justify application of the Lockean Thesis, one simply needs to consider a sample size sufficiently large to generate a divergence of single-case and long-run credence of less than ϵ via SLLN.

Given these three assumptions, we can justify the Principal Principle. I will start by assuming that (PP)-adhering agents start off with true beliefs about the chances, addressing the question of how Chance Reliabilism informs such beliefs at the end of this subsection.

[10] See Jackson (2020) for an overview of the Lockean Thesis, and see Dorst (2019) for a recent argument to the effect that adherence to the Lockean Thesis maximizes expected epistemic utility.

First, as an example, consider a sufficiently long sequence of chancy events: tosses of a fair coin, where $ch(\mathrm{H}) = 0.5$, let's say. If an agent S obeys (PP), and thereby generalizes their credence function Cr(-) via SLLN from single events to long sequences, we will have:

$$Cr(f_H \approx 0.5) \approx 1.$$

This is because, given an arbitrarily small constant ϵ, as the number of trials approaches infinity, SLLN instructs agents to set their credence that the frequency of heads differs from their single-case credence $Cr(\mathrm{H})$ by ϵ or greater equal to zero. Thus, for any ϵ, there is a finite – but perhaps very long – sequence, such that an SLLN-obeying agent will assign a credence of approximately 1 to the proposition that the frequency of heads will be within ϵ of 0.5.

It follows from CLLN that for any ϵ, there is a large enough value of n such that, in a sequence of n trials, there is a chance of approximately 1 that the frequency of heads will be within ϵ of 0.5. Consequently, given a sufficiently small ϵ-value, and a correspondingly long sequence, we can obtain:

$$ch(f_H \approx 0.5) \approx 1.$$

Since S has a credence in $f_H \approx 0.5$ of approximately 1, application of the Lockean Thesis yields the result that S believes outright that the frequency of heads will be approximately 0.5. Consequently, given that S's belief is true just in case $f_H \approx 0.5$, it follows that ch(S's belief is true) is *also* approximately 1.

It is similarly clear, moreover, that an agent who adopts a non-PP-obeying credence function will have a much lower chance of believing the truth about the frequency of heads over long sequences. For instance, imagine an agent $S*$ with credence function $Cr*$ such that $Cr*(\mathrm{H}) = 0.8$. Similarly, $S*$ obeys SLLN. $S*$ will consequently disbelieve truths and believe falsehoods with a very high objective probability. This is because $S*$ will have a very high credence in the proposition that the frequency of heads is approximately 0.8:

$$Cr^*(f_H \approx 0.8) \approx 1.$$

This occurs for just the same reason that S, above, had a credence of approximately 1 in the proposition that the frequency of heads is approximately 0.5. As before, if $S*$ obeys the Lockean Thesis, then $S*$ will believe outright that the frequency of heads is approximately 0.8. Yet, the objective chance that this belief is true will be incredibly low:

$$ch(f_H \approx 0.8) \approx 0.$$

S^* will similarly have a credence approximating zero in the proposition that the frequency of heads is approximately 0.5, and thus disbelieve outright that the frequency of heads will be approximately 0.5. As established above, the objective chance of this proposition is very high, so it is very likely that S^* will disbelieve a true proposition (and believe a false one).

The above example, I hope, begins to make lucid why agents who fail to obey (PP) are objectively unlikely to form true beliefs about frequencies, while those who obey (PP) are objectively likely to do so. It can also be shown more generally that any credence function which differs non-trivially from the objective chances is expected by the chance function to yield false beliefs about long-run frequencies. Suppose, for a proposition-type ϕ, that $Cr(\phi) = ch(\phi)$ and $Cr^*(\phi) = ch(\phi) + \epsilon$ for an arbitrary ϵ. Then, by CLLN, as the number of sequences gets sufficiently large:

$$ch(|f_\phi - Cr(\phi)| < \epsilon) \approx 1$$

However, in order that $|f_\phi - Cr^*(\phi)| < \epsilon$, it must be the case that $|f_\phi - ch(\phi)| > \epsilon$, since ch_ϕ and Cr^*_ϕ differ by a factor of ϵ. Therefore, by CLLN, as the number of sequences gets sufficiently large:

$$ch(|f_\phi - Cr^*(\phi)| < \epsilon) \approx 0$$

Cr obeys (PP), while Cr fails to obey (PP). Consequently, Cr is almost certain to converge with the frequencies in a long enough sequence of trials. Cr^*, by contrast, has the opposite result. Therefore, an agent who obeys (PP) by setting their credence function equal to the objective chance function will, in the long run, have an objective chance approximately equal to 1 of having their credences fall within some arbitrarily small interval from the frequencies. Consequently, they will be very likely to possess accurate outright expectations about the frequencies, via adherence to both SLLN and the Lockean Thesis. An agent who adopts a credence function such as Cr^*, on the other hand, has a very low objective chance of yielding accurate expectations about the frequencies. Hence, an agent adhering to (PP) is objectively very likely to make a positive contribution to the aptness of their belief-set via outright beliefs about the frequencies, while an agent who fails to adhere to (PP) is likely to do the opposite.

Therefore, an agent who fails to adhere to (PP) is much less likely to possess an apt belief set than an otherwise similarly situated agent who does adhere to (PP).[11] Moreover, Chance Reliabilism is only concerned with outright belief – that is, the probability that one will believe truths or falsehoods outright – rather than credence. Therefore, when it comes to the sorts of credences that we should have, Chance Reliabilism instructs us only with regard to the outright beliefs that can be generated from our credences, via

[11] It is important to note that this will only apply when the belief sets are defined over the same reference class as the chance function.

adherence to the Lockean Thesis. In the chancy cases, these are (ordinarily) just the cases that involve long sequences.[12] Consequently, what has just been established is sufficient to rationalize adherence to (PP) via Chance Reliabilism in the ideal case where agents have true beliefs about the chances.[13]

What happens, though, when we relax the assumption that agents possess true beliefs about the chances? (PP) crucially instructs agents with misleading evidence about chance hypotheses *not* to set their credences equal to the actual objective chances, so this is an important question. The basic answer is that the above argument establishes merely that an agent who has *already* reliably obtained information about the objective chances will have a high chance of epistemic success if they adhere to (PP). If we can also find a strategy which has a similarly high chance of producing true beliefs about the chances, then we can safely assume that the idealized justification of (PP) offered above will be a good approximation of ordinary circumstances. The chance that (PP) will deliver epistemic success remains high; it is merely discounted by the chance that a given agent will in fact get the chances right, which will itself be very high if they form their beliefs about the chances via a process which is also sanctioned by Chance Reliabilism.

Beliefs about the objective chances are typically informed by updating on evidence obtained from observing relative frequencies, via rules like Bayes' Theorem. While I can't give a comprehensive reliabilist justification of conditionalization here, it seems relatively straightforward how such an account would go: first, the objective chance function ch makes certain relative frequencies for i.i.d. propositions – those which approximately mirror ch – very likely. Agents who conditionalize on those frequencies will thereby obtain a high credence that ch (approximately) matches the true objective chances. Hence, ch assigns a high probability to the proposition that an agent adhering to an updating rule will come to believe that ch itself is the objective chance function.[14] This at least makes plausible that Chance Reliabilism can offer agents a reasonably operationalizable approach to forming beliefs about the chances, namely by conditionalizing on observed frequencies. Consequently, it is safe to make the idealizing assumption that agents adhering to (PP) have already gotten the chances right, for purposes of giving a reliabilist justification of (PP). This is appropriate, because agents adhering to conditionalization are already very

[12]There are a few exceptions, such as single cases involving statistical-mechanical probabilities that approximate 1 (e.g., that the gas will spread throughout the box when a divider is removed). In such cases, again, application of the Lockean Thesis in conjunction with adherence to (PP) will generate outright beliefs which are virtually certain to be true.

[13]The scope of this justification of (PP) can be extended to non-repeatable, non-i.i.d., and non-long-run cases, given a few plausible additional assumptions. Take a proposition like P = ¡Democrats will hold the Senate in 2024¿. If a propensity account of chance is correct, then whether P obtains will presumably supervene on chancy events that occur at a more fundamental level, such as wavefunction collapses for many of the universe's elementary degrees of freedom. These events are very plausibly repeatable, unlike some of the macroscopic events that they together realize. As a result, (PP) picks out a rational credence function for them. We then only need to add the assumption that, if Cr is your credence function and ϕ and χ are mutually entailing, where χ is the non-i.i.d. proposition and ϕ is a disjunction of (conjunctions of) subvening i.i.d. propositions, then it should be the case that $Cr(\chi) = Cr(\phi)$, to obtain the result that your credences in non-repeatable, non-i.i.d. propositions ought to obey (PP) as well. If there are events which neither belong to repeatable i.i.d. reference classes *nor* have very high (or very low) single-case propensities, *nor* supervene on i.i.d. events, then this justification of (PP) would be somewhat inapplicable to them, save for the fact that adherence to (PP) is a *globally* reliable strategy, and it would simply be easier for agents to apply such a strategy across the board, including for those extremely rare chance events which might have no connection whatsoever to some or other i.i.d. events.

[14]See also the next subsection, for more details on how to connect a reliabilist account of conditionalization with my justifications of (PP).

likely to get the chances right, and hence there is a high chance that their credences will approximately match the chances when they also obey (PP). While agents with misleading evidence would do better to match their credences to the actual chances, there is no plausibly operationalizable strategy for doing so which does not go by way of the agent's beliefs about the chances. Hence, given the operationalizability constraint, the best we can do is offer guidance on how to reliably obtain information about the chances, and then to assume that an agent has gotten the chances right in determining what credences they should adopt. The two strategies, taken together, will constitute a globally very reliable method of belief/credence-formation.

2.2 Accuracy

Before getting into the crux of my case about accuracy, and the assumptions I will make in giving the argument, I will give some background regarding the notions of accuracy and vindication.

In the literature on accuracy measures for credence functions, we start out with a *fully vindicated* credence function. In particular, for a world w, the fully vindicated credence function is just the truth-function, v_w, which assigns 1 to all truths and 0 to all falsehoods. With this, we can define a particular credence function's accuracy in terms of its distance from vindication, where the distance between two credence functions is often defined as the sum of the squared distances between the credences in each function:

$$D(Cr_j, Cr_k) = \sum_{\gamma \in \Gamma} (Cr_j(\gamma) - Cr_k(\gamma))^2$$

where Γ is a finite set of propositions. We can then define the inaccuracy of any given credence function, *Cr*, at a world w, in terms of its distance from the fully vindicated credence function v_w, called its Brier Inaccuracy:

$$I(Cr, w) = \sum_{\gamma \in \Gamma} (Cr(\gamma) - v_w(\gamma))^2$$

I can now present the central assumption in my second attempt to justify (PP).[15] It is a

[15] Hicks (2017) derives (PP) for Humean accounts of chance on accuracy grounds. Hicks defines Humean chance as the maximally accurate credence function which respects a particular constraint called *Evidential Equivalence*, which says that if no evidence can distinguish E from E*, then *ch*(A—E) = ch(A—E*). So, the chance function is the "most accurate credence function that obeys the same evidential constraints that we do" (942). If an agent fails to satisfy (PP), then, they are either failing to obey Evidential Equivalence, or they have a credence function which is accuracy-dominated. Since chance is defined in terms of accuracy, one can clearly show why adherence to (PP) is rational, via an accuracy norm of belief. This derivation is unobjectionable, as far as I can tell, save for the fact that, as with other Humean justifications of (PP), it seems to apply most naturally to agents who already possess knowledge of the objective chances. On Hicks' view, an agent who obeys (PP) is guaranteed to have an accurate credence function, *conditional* on their beliefs about the objective chances being true, since the actual objective chance function accuracy-

modification of Chance Reliabilism to accommodate accurate credence rather than true belief:

> *Accuracy Reliabilism*: Agents should adopt the credence-forming processes which have a high objective chance of producing accurate credences, subject to the constraint that the processes be sufficiently operationalizable.

While the imposed operationalizability constraint is again vague, what is important to note here is that a credence-forming rule such as "set your credences equal to the actual objective chances" is exceedingly difficult to operationalize, given that it fails to instruct agents as to how they should gain epistemic access to the actual objective chances, while rules like "set your credences equal to what you *take* to be the objective chances" as well as "update your credences in candidate chance theories by conditionalizing on observed frequencies" are both reasonably operationalizable.

The most straightforward way to cash out Accuracy Reliabilism in more formal terms is that it instructs agents to minimize *ch*-expected inaccuracy:[16]

$$EI_{\mathrm{ch}}(R, \mathcal{F}) = \sum_{\langle w, Cr \rangle} ch(w) I(Cr, w) ch(A_{\mathrm{Cr}} | A_R).$$

Here, $\mathcal{F}$ denotes an algebra of propositions, w denotes a possible world belonging to a set W of classically consistent assignments of truth-values to the propositions in $\mathcal{F}$, Cr denotes a credence function such that $Cr : \mathcal{F} \mapsto [0, 1]$, which belongs to the set $\mathbf{C}$ of possible credence functions, A_{Cr}, is the proposition that the agent adopts Cr, R denotes a credence-forming process, and A_R is the proposition that the agent is adhering to the process R. The value of

dominates alternative credence functions respecting Evidential Equivalence. It may be, then, that a unified answer to the questions of (1) how agents should form beliefs about the chances and (2) how agents should set their credences in chance propositions *given* those beliefs, may invoke reliabilist truth- or accuracy-norms. At any rate, it is unclear that a reliabilist answer would be any less satisfying than the few conceivable alternatives.

[16] This is similar to the principle invoked in Pettigrew's (2016) second argument for (PP). Pettigrew suggests that, for any two credence functions *Cr* and *Cr**, where *Cr* obeys (PP) and *Cr** does not, $Exp_{\mathcal{U}}(Cr|ch(-|E)) > Exp_{\mathcal{U}}(Cr^*|ch(-|E))$ for any possible ur-chance function *ch*, where $\mathcal{U}$ is an epistemic utility function. The first thing that needs to be clarified, however, is that it does not seem to be true that the (PP)-adhering credence function *Cr* ur-chance dominates every alternative credence function; rather, it is that adherence to (PP) ur-chance dominates alternative credence-forming *strategies*, insofar as any objective chance function expects that the credence function which adheres to (PP) *for that particular chance function* will minimize inaccuracy. But then, it is not a specific credence function which ur-chance dominates every alternative credence function, but rather a credence-forming *strategy* that does so. Secondly, and more importantly, since (PP) instructs agents to set their credences equal to their subjective estimates of the objective chances, it is difficult to see how an ur-chance *dominance* principle would be able to rationalize adherence to (PP): it is not the case that for any possible ur-chance function, adherence to (PP) is guaranteed to maximize *ch*-expected utility, since an agent may have inaccurate subjective estimates of the chances. Accuracy Reliabilism, though, does not face this difficulty; the operationalizability constraint rules out any requirement that an agent's credences always match the actual objective chances, and it does not rest on any dominance principles, but rather instructs agents to minimize *ch*-expected inaccuracy for the actual chance function *ch*. As I will now argue, Accuracy Reliabilism plausibly can instruct agents to match their credences to their subjective estimates of the chances, while also offering a means by which to form rational credences over candidate chance theories.

EI_{ch} is a sum over possible world-credence function *pairs* which expresses how inaccurate the actual objective chance function expects your credence function to be, *given* that you are adhering to some credence-forming process R. The reason for defining *ch*-expected inaccuracy in this manner is that we are interested in credence-forming processes, which don't necessarily pick out a single unique credence function, but rather render it more or less likely that an agent obeying that process will end up with a certain credence function.

Now, while Brier Inaccuracy is the most popular scoring rule for credence functions, it turns out that the justification of (PP) that I offer will apply to any scoring rule which adheres to the following constraint:

> *Strict Propriety*: A scoring rule is strictly proper if, for any two distinct probability functions P and P^*, where at least P is probabilistically coherent:
>
> $$\sum_w P(w)I(P, w) < \sum_w P(w)I(P^*, w),$$
>
> where $I(P,\ w)$ is the measure of inaccuracy on that particular scoring rule.

In other words, every coherent probability function uniquely expects itself to be the most accurate credence function, on any strictly proper measure of inaccuracy.[17] Now, we can introduce another, more standard measure of expected inaccuracy, defined for particular credence functions rather than processes:

$$EI^*_P(Cr, \mathcal{F}) = \sum_w P(w)I(Cr, w)$$

EI^*_P is just a measure of how accurate the probability function P expect some particular credence function Cr to be, and it is this this measure of expected inaccuracy that is implicated by Strict Propriety. And finally, we can introduce a measure, EI^*_{ch}, of how accurate the actual objective chance function expects some credence function to be:

$$EI^*_{\text{ch}}(Cr, \mathcal{F}) = \sum_w ch(w)I(Cr, w)$$

Recall: I have been emphasizing that (PP), being a conditional norm of credence, should be justified by antecedent rationality principles that also offer agents a reasonably operationalizable means in which to gain epistemic access to the objective chances, such that the credence function they arrive at by obeying (PP) will be *unconditionally* rational. While a decisive argument that Accuracy Reliabilism does so is beyond the scope of this paper, I want to at least make plausible three claims:

[17] Strict Propriety is a popular constraint on scoring rules, to which an extensive literature is dedicated. See, for instance, Joyce (1998, 2009) and Pettigrew (2016, 2020).

1. Among the realistic and operationalizable updating strategies, conditionalizing on observed frequencies minimizes *ch*-expected inaccuracy with respect to credences defined over candidate chance theories.

2. *ch* itself minimizes EI^{*}_{ch}, so that in the idealized case in which an agent becomes certain of the true objective chance function via conditionalization, adherence to (PP) uniquely minimizes EI_{ch}.

3. In the non-ideal case in which conditionalization does *not* uniquely pick out the single objective chance function, agents who adhere to (PP) + conditionalization are able to approximate the ideal case to a high degree.

First, suppose an agent assigns non-zero prior credence to the actual objective chance function. On any particular chance event, the actual objective chance that an agent will observe some event E is equal to $ch(\text{E})$. To the extent that they adhere to conditionalization (to be abbreviated COND), their posterior credence in the proposition that T_{ch} is the true chance theory, upon observing E, is:

$$Cr(T_{\text{ch}}|E) = \frac{Pr(T_{\text{ch}})ch(E)}{Pr(E)}$$

where Pr is the agent's prior credence function. Moreover, as the agent accumulates more evidence of chancy events, certain stable relative frequencies will emerge, and from CLLN it follows that those frequencies will be very likely to approximate the chances. With access to stable enough frequencies, an agent obeying conditionalization will obtain a likelihood function $ch(\text{observed frequencies} \approx ch)$ which is very high for *ch* and for candidate chance theories which are close to *ch*, and get lower and lower as the candidate chance theories get further away from *ch*. This is because, as the agent acquires more robust evidence, it becomes likelier and likelier that the observed frequencies will in fact mirror the actual chances. Consequently, the final term in $EI_{\text{ch}}, ch(Cr \approx ch|A_{\text{COND}} \wedge A_{\text{PP}})$, – suitably adapted – is very high, because it is very likely that the agent will take *ch* to be the actual chance function via COND, and hence that they will set their credences approximately equal to *ch*, via (PP).

What has been established is only intended to make my first claim – that conditionalization renders it very likely that agents will assign high credence to true propositions about the objective chances – plausible. It is difficult to decisively prove that COND is the unique updating strategy that does so, in part because of the vagueness of the operationalizability constraint in Accuracy Reliabilism. However, the only alternatives that I can envision are updating rules which are in some way biased towards the actual objective chances – for instance, an updating rule which tells agents to increase their credence that *ch* is the actual chance function, *no matter the observed chance events*. But such an updating rule would clearly be exceedingly difficult to operationalize, because the only evidence that can distinguish the different chance theories seems to come by way of the frequencies and, to an extent, observable one-shot chance events. Hence, it is plausible that an updating rule like COND will be the best option available to agents, given Accuracy Reliabilism.

It is very straightforward to prove claim (2). After all, it follows from any scoring rule which satisfies Strict Propriety that ch will itself minimize EI^*_{ch},. For example, take the case of Brier Inaccuracy, and suppose that that $ch(\phi) = \delta$. Now suppose $Cr(\phi) = \delta$ and $Cr^*(\phi) = \delta + \epsilon$. Consequently, $|v_w(\phi) - Cr(\phi)|$ is δ with a chance of $1-\delta$ and $1-\delta$ with a chance of δ. Similarly, $|v_w(\phi) - Cr^*(\phi)|$ is $\delta + \epsilon$ with a chance of $1-\delta$, and $1-(\delta+\epsilon)$ with a chance of δ. Thus, on the Brier measure of inaccuracy:

$$EI^*_{\text{ch}}(Cr, \mathcal{F}) = ((1-\delta)\delta^2 + \delta(1-\delta)^2)n$$

$$EI^*_{\text{ch}}(Cr^*, \mathcal{F}) = ((1-\delta)(\delta+\epsilon)^2 + \delta(1-(\delta+\epsilon))^2)n$$

To ensure that $EI^*_{\text{ch}}(Cr, \mathcal{F}) < EI^*_{\text{ch}}(Cr^*, \mathcal{F})$, we need:

$$(1-\delta)\delta^2 + \delta(1-\delta)^2 < (1-\delta)(\delta+\epsilon)^2 + \delta(1-(\delta+\epsilon))^2$$

$$\text{for all } |\epsilon| > 0$$

Which simplifies to $\delta - \delta^2 < \delta - \delta^2 + \epsilon^2$ and finally to $\epsilon^2 > 0$, which is true for all $\epsilon \neq 0$. Now, consider the following case.

> **Ideal Case**. Suppose that an agent has conditionalized on enough evidence that they have settled on the single objective chance function. Consequently, $ch(Cr = ch|A_{\text{PP}}) = 1$, because the agent is certain that ch is the objective chance function, and therefore sets their credences equal to ch when they adhere to (PP). But then EIch simply reduces to EI^*_{ch} for Cr, because the former's $ch(A_{\text{Cr}}|A_R)$ term is equal to 1 for $Cr = ch$. Because ch uniquely minimizes EI^*_{ch} by Strict Propriety, it follows by substitution that Cr does as well. Thus, in the ideal case, adherence to (PP) + COND uniquely minimizes EI_{ch}, and is thus justified by Accuracy Reliabilism.

Hence, we have established claim (2).

Finally, it remains to at least make highly plausible that agents in ordinary epistemic circumstances who obey COND and (PP) can at least approximate the **Ideal Case**. Here, first, are two assumptions:

1. $\sum_w ch(w)I(Cr, w)$ is minimized at $Cr = ch$(which we have proved) and monotonically increases in either direction, as Cr moves away from ch.

2. $ch(A_{\text{Cr}}|A_{\text{COND}} \wedge A_{\text{PP}}$ is maximized at $Cr = ch$ and monotonically decreases in either direction, as Cr moves away from ch.

Intuitively, (1) just says that while ch expects a ch-matching Cr to be the least inaccurate credence function, its expected inaccuracy for alternative credence functions increases monotonically as those credence functions move further away from the chances. (2) merely says that, while the chance function expects that a conditionalizing agent adhering to (PP) is most likely to arrive at a credence function which matches the actual chances, they are monotonically less and less likely to arrive at a credence function the further it diverges from the chances. This follows from the fact that, the further the divergence between the frequencies and the chances, the less likely it is to occur, and the smaller a sample size needed to guarantee that such a divergence won't occur.

But now, we see that for the range of credence functions that COND renders reasonably likely, the ch-expected inaccuracy is very low. And for those credence functions for which the ch-expected inaccuracy is very high, conditionalization ensures that those credence functions are very unlikely! Hence, it is exceedingly plausible that ordinary agents adhering to PP + COND will be able to approximate the **Ideal Case**, for which it has been proved that (PP) satisfies Accuracy Reliabilism.

2.3 The argument reassessed

Let's return to the Credence Argument. The argument fails to consider that, while non-Humean accounts indeed posit no constitutive link between frequency/truth/accuracy/etc. and chance, non-Humean chances can still enter through the "backdoor," as it were, in determining what sorts of belief-formation processes count as reliable and in making certain histories objectively likelier than others. If one accepts Chance Reliabilism or Accuracy Reliabilism, then one accepts that at the bottom of prescriptive epistemic normativity lies an emphasis on the probabilistic disposition of certain belief/credence-forming strategies to generate apt belief sets or accurate credences. That adherence to (PP) is likely, *by the lights of the non-Humean chance distribution which accurately describes our world*, to generate apt belief sets, or to yield accurate credences, is all that it takes to rationalize adherence to (PP).

3 Objections

An objection I would like to address runs as follows. If one is trying to rationalize adherence to (PP) by defining reliability in terms of objective chance, they will have to assume (PP) in order to explain why reliability, so understood, matters in the first place. Why, after all, should agents expect that (say) Chance Reliabilism is a sensible epistemic norm, without first assuming that a certain belief-forming process' having a high propensity to generate apt belief sets thereby entices one to have a high degree of belief that said process will generate apt belief sets?

The problem with this objection is that it presupposes that the only way in which the chances might provide reasons for belief or credence is *internal*: for us to have reason to adopt a particular belief/credence-forming process, we must first have a high *degree of belief* in the truth- or accuracy- conduciveness of that process. But on the picture I am proposing, this is not so.

The objective chances make certain belief-forming processes *objectively reliable*. That certain principles – those which are rationalized by Chance Reliabilism or Accuracy Reliabilism – are genuine requirements of rationality is made true by the objective chances, and they are made so *irrespective of anyone's particular degrees of belief.* An agent could, moreover, reason that (PP) is rationalized by Chance Reliabilism or Accuracy Reliabilism, *before* adopting any beliefs or credences over candidate chance functions. Agents, therefore, are permitted to take advantage of the resulting, Chance Reliabilism- and Accuracy Reliabilism- backed principles of rationality, even when it comes to connecting up the objective chances with their credences in chancy events. What would be circular, for instance, is if the rules employed to justify (PP) instructed agents to minimize expected inaccuracy according to their own credence function, along with the requirement that the EI-guiding credence functions match the objective chances. Such a justification would have to invoke (PP) at the outset, since it is only via (PP) that one is instructed to align these credences with the objective chances. But neither Chance Reliabilism nor Accuracy Reliabilism rests on the assumption that agents have a certain degree of belief that the relevant processes will produce true beliefs or accurate credences. All of the normative work is done externally by the chances, rather than internally by an agent's credences in the truth/accuracy-conduciveness of the relevant processes

One may, instead, worry not that the justification is circular, but that it leaves unexplained the justificatory status of the antecedent, chance-backed rationality principles. The justification of (PP) I have offered treats these rationality principles as normatively fundamental, so the worry is not unfounded. Yet, whether this constitutes a compelling objection to the justifications (and, hence, to non-Humean accounts of chance) depends on whether Humeans can do better. As I have emphasized, Humeans can only guarantee accuracy, truth, and the like, when their agents start off with knowledge of the objective chances. A justification of (PP) which relies on this assumption may be fair game, so long as the underlying rationality principles used to justify (PP) will also offer agents guidance on how to form beliefs about the chances themselves. The justification in this paper has rested on chance-involving norms of reliability. Are there better options available to the Humean?

The only alternative I can imagine, for Humeans, is to appeal to self-locating indifference reasoning. For typical regions of the Humean Mosaic, the local frequencies approximately match the global frequencies – and so the Humean chances. One may reason that, whatever the global frequencies may be, the local frequencies will approximately match the global frequencies in most regions. Hence, an agent who is indifferent between being located in different regions of the mosaic will have a high credence that their observed frequencies are adequate guides to the objective chances. Further, once an agent has applied indifference in this manner, they will have arrived at some belief that the global frequency of some proposition-type ϕ is approximately f_ϕ. The agent can then apply indifference *again*, reasoning that, if the global frequency is f_ϕ, then they ought to have a high credence that the *local* frequencies will be about f_ϕ for forseeable sequences of chance events. Finally, as Schwarz (2014) has shown, the agent's credence function need only be exchangeable – meaning that it is indifferent between distinct sequences that agree on the relative frequencies – to justify adherence to (PP) for single chance propositions.[18] Hence, for Humean chance, one can justify (PP) by appealing to a few slightly distinct but related principles of indifference.

However, it is not immediately clear that such an approach would be more satisfying than approaches – such as those offered in this paper – that posit fundamental chance-involving norms. For starters, it is notoriously difficult to formulate a consistent and plausible principle of indifference, in part because indifference tends to offer conflicting probability assignments when there are multiple partitions of possibility space.[19] Further, the principle of indifference is thought to be especially problematic over infinite domains, and if the mosaic is infinite, then such problems will arise.[20] Finally, the application of indifference reasoning in the first step of this strategy is not of the sort that we are used to. Self-locating indifference usually pertains to agents who know what the universe looks like and are trying to locate themselves in it – for instance, in Everettian quantum mechanics. But here, an agent employs indifference to infer that their local frequencies are approximately equal to the global frequencies (and so the Humean chances). In other words, indifference reasoning aimed at inferring the global Humean chances would seem to get the process backwards, at least as we typically understand indifference reasoning.[21]

Indifference may not be the only strategy available to the Humean. However, it is not immediately clear that there are better alternatives available. Extant Humean justifications – e.g., from Schwarz (2014), Hicks (2017), and Hoefer (2019) – do not directly explain how agents ought to form beliefs about the objective chances. And while this is not a problem with these justifications *per se*, it is crucial that we posit *some* basic rationality principles which can explain both how agents ought to form beliefs about the chances and how they should set their credences, given those beliefs. It isn't clear that the indifference-based strategy for justifying (PP) is more satisfying than the strategies I have proposed, which posit fundamental chance-involving norms. After all, appeals to which belief-formation processes are likely to yield epistemic success already lie at the heart of reliabilist approaches to epistemic justification. I have shown that, if one's epistemology is reliabilist in character, then non-Humeans can justify (PP) from more basic reliabilist constraints – the kind of constraints that ultimately aim at truth or accuracy. Whether Humeans retain their advantage, I take it, is an open question.

Humeans may worry that, even if both Humeans and non-Humeans were pushed to posit fundamental chance-involving norms, Humeans would still be better off in doing so, because what they mean by "chance" is just different from what non-Humeans mean by "chance." And what makes fundamentally chance-involving norms so problematic in the non-Humean case, the thought may go, is that there is just no explicable connection between making P likely and making P the case.[22] After all, the only reason we might think that these fundamental chance-involving norms are remotely plausible is *because*

[18] See Fernandes (forthcoming) for an argument that other extant Humean justifications rely on indifference reasoning as well.
[19] See, e.g., van Fraassen (1989).
[20] See Keynes (1921).
[21] Many thanks to [OMITTED] on this point.
[22] Thanks again to [OMITTED] on this point.

we believe that there is some such connection. I think Humeans would be right to push this line of reply. But for propensity theorists, there *is* a connection between making P likely and making P the case, it is just that this connection is metaphysically primitive. It seems to me that the extent to which one finds chance-involving norms plausible, where the chances involved are non-Humean in nature, is just a matter of how plausible one finds this brute connection. And consequently, the Humean objection should not be cast in terms of whether non-Humeans can offer a satisfactory *justification* of (PP), but rather in terms of whether one is satisfied with a fundamentally dispositional, propensity-based *metaphysics*. And this is a story for another day.

4 Conclusion

I want to emphasize that I have not, in this paper, attempted to issue a global defense of non-Humean accounts of chance. Rather, I have tried to show that one can justify the Principal Principle for non-Humean chance given some independently plausible background assumptions. Surely, though, one could dispute these principles. What I hope to have shown, however, is that the common assumption that non-Humean accounts of chance are unable to rationalize adherence to (PP) is too hasty. I think of the justification of (PP) given in this paper as a proof of concept that the connection between the irreducibly modal domain of non-Humean chance and the kinds of expectations we ought to have about the nonmodal domain of frequencies and the like, can *in principle* be made intelligible. Non-Humean accounts of chance, then, need not take (PP) as a primitive constraint on credence. At the very least, there are other options, and it may even be that both Humean and non-Humean theories of chance are on roughly equal footing, in that they would both be best off in positing some more basic chance-involving norm in order to fully rationalize adherence to (PP), though I don't take myself to have demonstrated this decisively.

This all opens up a puzzle for so-called *functional* analyses of probability, in particular functional analyses which restrict the chance-role to (PP) or similar chance-credence principles, so that chance is just whatever, in the world, plays the role of constraining rational credence in the right way. Lewis, for instance, thought that (PP) captures "all we know about chance" (1980, 266). But the argument advanced in this paper shows that any theory of chance, given some reasonably plausible antecedent principles of rationality, can justify (PP) *on its own terms*. And if this is true, then the chance-role, restricted to the chance-credence link, underdetermines our candidate theories of chance. It is necessary, then, to find another way to assess accounts of chance than via the ability of any given account to rationalize adherence to (PP). We must examine other potential aspects of the chance-role, and see how the competing theories shape up, lest we find ourselves in a dialectical impasse.

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