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Is Kantian Projectivism the Only Hope for Grounding the Principal Principle? (No.)

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ABSTRACT

Kant saw science as presupposing that the natural laws bring maximal diversity under maximal unity. Many philosophers, such as David Lewis, have regarded objective chances as upshots of science's aim at systematic unity—as ideal credences projected onto the world. This Kantian projectivism has seemed the only possible way to account for the rational constraint (codified by the 'Principal Principle') that our credences about chances impose on our credences regarding what they are chances of. This paper examines three ways of elaborating Lewis's Kantian strategy for explaining this rational constraint. After arguing that none of these three approaches is unproblematic, the paper proposes a non-Kantian alternative account according to which a chance measures the strength of a causal tendency.

1. INTRODUCTION

In Kant's Copernican Revolution,

> the order and regularity in the appearances, which we entitle *nature*, we ourselves introduce. We could never find them in appearances, had not we ourselves, or the nature of our mind, originally set them there. (A 125)[1]

For instance,

> Reason presupposes the systematic unity of the various powers, on the ground that special natural laws fall under more general laws, and that parsimony in principles is not only an economical requirement of reason, but is one of nature's own laws. (A650/B678)

Science aims to discover a deductive system of laws exhibiting both simplicity and richness—and, accordingly, is guided by the regulative principles of manifoldness, affinity, and unity (A662/B690).[2] Science does not ascertain empirically that the laws bring maximal diversity under maximal unity. Rather, science presupposes that the laws do. Its discoveries approach this ideal "only as it were asymptotically, i.e., ever more closely without ever reaching them" (A663/B691).

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To many philosophers, the chances figuring in nature's laws have seemed to exemplify this Kantian picture. That chances are artifacts of science's aiming at systematic unity—ideal credences projected onto the world—has seemed to many philosophers, following David Lewis, to be the only remotely plausible approach to explaining an extraordinary constraint on rational credences imposed by beliefs about chances.

In section 2, I will review this constraint: the 'Principal Principle' (PP). In section 3, I will highlight what makes PP so difficult to explain. In section 4, I will examine briefly three ways of elaborating Lewis's Kantian approach to explaining PP. None is obviously satisfactory. But without a plausible alternative, some approach along Kantian lines seemingly must be correct. In section 5, I will propose a non-Kantian alternative that takes a chance as measuring the strength of a causal tendency. I thereby argue that Kantian projectivism is not the only hope for grounding PP.

2. CHANCES AND CREDENCES

Notoriously, probability is a dual concept. What Carnap (1945) called 'probability$_1$' (or, more affectionately, "Little Rudi") concerns the degree to which evidence supports a hypothesis. Although Carnap regarded such 'subjective probability' (a.k.a. degree of belief, opinion, credence) as a logico-mathematical matter, many Bayesians today see it as an agent's own personal probability. In contrast, 'probability$_2$' ("Big Rudi") belongs to the objective physical world, about which we can assemble evidence. For example, perhaps Jones's evidence supports his having 60% confidence (probability$_1$) that a given atomic nucleus now has 80% chance (probability$_2$) of undergoing spontaneous radioactive decay within the next 102 seconds. Natural laws attribute objective single-case probabilities (a.k.a. physical probabilities, chances) to possible outcomes of chance setups, and scientific explanations appeal to these chances. (Consider explanations of a roulette wheel's behavior, a gas's diffusion, the outcome of measuring a quantum particle, or the phenotypes of the progeny of two heterozygotes.)

The trouble with dualisms (whether of mind and body or of credence and chance) is that it is difficult to account for the relation between the two elements. In "A Subjectivist's Guide to Objective Chance," Lewis (1980/1986) codifies the relation between rational credence and beliefs about chances in his 'Principal Principle' (PP).[3] According to Lewis, the relation demands that (in the usual sort of conditions in which we find ourselves when making predictions) if we believe that the chance now is 50% that a given radioactive atom will decay in the next 102 seconds, then we should now have 50% confidence that it will so decay. This relation is captured by PP. Here is one version:

> Let A be any proposition and let X be the proposition that the chance at time t of A is x (i.e., $ch_t(A) = x$). Then for any initial rational credence (i.e., personal probability) function cr, where E is 'admissible' at t and $cr(X\&E) \neq 0$, $cr(A|X\&E) = x$.[4]

We are dealing here with an 'initial' cr—that is, prior to learning X. A proposition is 'admissible' at t if and only if it contains no information (other than their chances)

about the outcomes after *t* of chance processes. In the many actual cases in which we rightly set our credences in the outcomes of chance processes to what we believed their chances to be, we had no inadmissible information despite having had considerable information—not only about the world's history through that time *t*, but also about the chances at various times through *t*, as well as about the laws of nature (some of which specify, for any moment, what the chances at that moment of some outcome would be, if the world's history through that moment had certain features). Since PP is supposed to be the rule by which information about chances should have had an impact on our credences, the 'admissible' information should include all of the information that we had available in actual cases where our credences were rationally fixed by our information about chances.

Lewis contends that a non-Humean account of chance cannot explain the role (codified by PP) that our beliefs about chances should play in guiding our opinions. On a non-Humean account of chance, there is no metaphysical connection between, e.g., the die's current chance of landing 'three' and the Humean base: the worldwide spatiotemporal mosaic of instantiations of the properties that are perfectly natural (rather than gerrymandered), categorical (rather than infected by modalities, laws, chances, dispositions, or counterfactuals), qualitative (rather than haecceitistic), and possessed intrinsically by spacetime points or occupants thereof. Because there is no metaphysical connection between chances and facts about the Humean base, Lewis says, it is difficult to see how our beliefs about chances could rationally constrain our beliefs about the Humean base—e.g., how our belief that the die's current chance of landing 'three' is 1/6 could require us (in the absence of any further relevant information) to have 1/6 (= 16 and 2/3 %) confidence that the die's next toss will land 'three'.

Lewis takes chance's role in PP to be constitutive of chance. Lewis (1980/1986, 98) shows that from chance's role in PP, it follows that chances must obey the axioms of probability, since otherwise, rational credences conforming to PP wouldn't—but they must, on independent grounds (e.g., on pain of making the agent vulnerable to a Dutch Book). PP (when coupled with Bayesian conditionalization) also explains how beliefs about chances are confirmed by evidence. According to Lewis, chances are whatever uniquely most closely (and sufficiently closely) fits whatever is constitutive of chance, chiefly PP. On Lewis's picture, a single-case chance (e.g., an atom's likelihood of decaying in the next 102 seconds) is fixed by some statistical law of nature together with some Humean facts (e.g., that the atom is Iodine-131), and the laws, in turn, are fixed by the Humean base according to his 'Best System' account, about which more below. Lewis believes that if chances are thereby given by way of the Best System, then (in virtue of the Best System's supervenience on what actually happens) it is more or less evident why our beliefs about chances rationally constrain our degrees of belief about what actually happens. In short, because a Humean picture depicts chances as metaphysically tied (by the Best System) to the Humean base, a Humean picture shows more promise than a non-Humean picture for explaining why our beliefs about chances rationally constrain our beliefs about the Humean base:

> Be my guest—posit all the primitive unHumean whatnots you like (. . .). 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. 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 co-instantiation of those universals (. . .). Only if I already see—dimly will do!—how knowing the fact that N^* (J, K) should make me believe to a degree 50% that the next J will be a K will I agree that the N^* relation deserves the name of chancemaker that you have given it. (Lewis 1994/1999, 239–40)

The metaphysical gulf between non-Humean chances and the Humean base makes it difficult to see how opinions about non-Humean chances could rationally constrain opinions about that base.

3. PP IS REMARKABLE

Suppose that Dr. Jones is examining various postoperative patients, such as Smith, with the aim of predicting which of them, having just undergone the surgical procedure, will shortly develop a certain kind of complication. Jones regards certain factors (e.g., whether the patient is over 40 years old, whether the patient smokes, etc.) as relevant to whether the patient will develop the complication. Jones takes other factors (e.g., whether the patient is the fourth to be examined that day) to be irrelevant. Using these factors, Jones discovers Smith's chance now of shortly developing the complication. In accordance with PP, Jones sets her credence in Smith's developing the complication equal to that chance.

Although Jones needed a great deal of past experience to justify linking various factors to some chance (and hence to some credence), she needed no evidence at all to justify linking the chance to the credence. Jones's belief that Smith smokes thus differs sharply from Jones's belief that Smith now has a 40% chance of developing the complication. The link between smoking and the credence is not conceptual and not knowable a priori, whereas the link between the chance and the credence is conceptual and is knowable a priori.

Accordingly, Black (1998, 384) has held that objective chances would be 'queer' in the same manner as Mackie (1977) held that objective moral values would be. Mackie's point was that moral values would be "very strange (. . .) utterly different from anything else in the universe" (1977, 38) since they would be "intrinsically prescriptive" (1977, 40): belief about them would provide a reason for acting independent of desires. To ground rational action, beliefs about moral values must differ from beliefs about (other) matters of fact in that they are automatically linked to rational courses of action; no desires are needed to underwrite that link. Beliefs about moral values thus would ground rational action in a highly unusual way—suggesting that moral values are not, in fact, features of the world, since it is mysterious how a belief about a feature of the world could be so linked to rational action. Similarly,

beliefs about chances ground rational predictions in a highly unusual way since they are automatically linked to rational credences; no empirical beliefs about the world are needed to underwrite that link. This suggests that chances are not, in fact, features of the world, since it is mysterious how a belief about a feature of the world could be so linked to rational credence.

Thau (1994, 494) makes the same point in terms of Moore's open-question argument. The belief that a given course of action is good counts as a reason for pursuing that course, but the belief that the course of action has some naturalistic property does not suffice by itself to constitute a reason for pursuing that course, suggesting that goodness does not consist of any naturalistic property. Likewise, the belief that the patient now has a 40% chance of developing the complication counts as a reason (in the absence of inadmissible information) for having 40% confidence that the complication will develop, but the belief that some naturalistic property is now instantiated (such as the patient's having had a certain history of smoking) does not suffice by itself to constitute a reason for any credence, suggesting that chance does not consist of any naturalistic property. A weakness in each of these arguments is that each presupposes that a given property instance must have the same conceptual connections under any mode of presentation. Nevertheless, the open-question argument asks us to explain why it is unintelligible to ask, "Admittedly, P is a good course of action, but why should I pursue that course?" despite the intelligibility of asking, "Admittedly, P is a course of action with . . . naturalistic property, but why should I pursue that course?" Likewise, we must explain why it is unintelligible to ask, "Admittedly, Smith's chance now of the complication is 40%, but why should I care about that in predicting the complication?" despite the intelligibility of asking, "Admittedly, Smith has a history of smoking, but why should I care about that in predicting the complication?" That the former question is 'closed', though the latter is 'open', demands explanation.

4. CAN KANTIAN PROJECTIVISM EXPLAIN PP?

On the Kantian picture with which we began, chances reflect the system that achieves our scientific aim: maximal diversity brought under maximal unity. Lewis's (1980/1986, 121–31; 1994/1999, 233–36) "Best System account of law and chance" incorporates this Kantian picture. Lewis's account (omitting some details) considers various deductive systems consisting of truths about the Humean base together with 'history-to-chance conditionals' specifying the chances of various events at various times if various Humean facts obtain. (For instance, one 'history-to-chance conditional' is that if a given atom at time t is Iodine-131, then its chance at t of decaying within 102 seconds after t is 50%.) A system is better insofar as it is more 'informative' (as on Kant's regulative principle of manifoldness), better insofar as it is simpler (as on Kant's regulative principle of unity), and better insofar as it has greater 'fit' in that "The higher the chance a system assigns to the true history (or to segments of it given part of the history) the better its fit" (Loewer 2004, 1119).[5] These virtues are generally in tension, and science aims at the 'Best System': the one with the optimal combination of these virtues. The laws are then exactly the generalizations in that system, and the history-to-chance conditionals in that system are true. Consequently, the

actual chances are whatever the system's history-to-chance conditionals, together with the actual Humean history, entail them to be.

The chances are thus creations of what lies at the asymptotic limit of scientific investigation. Let's briefly examine three attempts to use this Kantian/Lewisian picture to explain PP.

One approach is to argue roughly that since the Best System must 'fit' the relative frequencies, the proportion of A-outcomes in a nontrivial number of chance set-ups S must be close to the chance given by the history-to-chance conditional "If S, then ch(A) = x" in the Best System. Therefore, in betting on the outcomes of many trials, you are (absent inadmissible information) almost always going to get a higher return by setting your cr(A) to x than to any other value. Hoefer (2007) gives an especially careful 'consequentialist' account along these lines. A problem with this approach is that the Best System does not maximize fit; it trades off fit against simplicity and informativeness. If we would get the highest return by aligning our credences with the relative frequencies, then we will not get the highest return by departing from relative frequencies for the sake of increasing these other virtues. Hoefer (2007, 586) recognizes that science aims for these other virtues, "which is all to the good in a concept . . . whose nature is bound up with its utility to finite rational agents." But I do not see how it can be "all to the good" on the austerely consequentialist conception of the good motivating this approach.

A second approach is given by Loewer (2004, 1122): "On this proposal the PP is 'built into' the [Lewisian account of law and chance]. It can constrain belief because that is part of the account of how a theory earns its title as 'Best System'." That is because for its claims about chances to help make a system better by contributing to its informativeness regarding the Humean mosaic, the measure of informativeness "must adopt some principle that extracts . . . information about the Humean mosaic from" the chance claims (Loewer 2004, 1123). PP is that principle. This approach again aims to derive PP from the way in which chances are upshots of the aim of science: the laws' systematic unity. Part of that aim is for a system to supply information on manifold phenomena, and "Fit can be understood as a kind of *informativeness*—the information that probabilistic propositions provide concerning the propositions they attribute probability to. (. . .) [T]hese probabilities are informative only to someone who is willing to let them constrain her degrees of belief" (Loewer 2004, 1122).

However, a chance-credence link does not need to be built into the measure of informativeness in order for chance claims to contribute information about the Humean mosaic. A system is informative to the extent that it says "what will happen or what the chances will be when situations of a certain kind arise" (Lewis 1994/1999, 234). So history-to-chance conditionals that cover more possible histories count as more informative independent of a chance–credence link. Loewer's point might be that Lewis is not entitled to stipulate this measure of informativeness because the only information that can contribute to informativeness is information about the Humean mosaic; chances are not property instantiations in the Humean mosaic, so information about when they obtain (given by a history-to-chance conditional) is not information about the Humean mosaic. (The suggestion is that the

history-to-chance conditional "If a given atom at time t is Iodine-131, then its chance of decaying within 102 seconds after t is 50%" supplies no information about the Humean mosaic because a 50% chance is not a 'tile' of the Humean mosaic.) But, I reply, if chances are creations of the best systematization of the Humean mosaic, then a history-to-chance conditional contributes information about the Humean mosaic (even if a chance is not itself a tile of the mosaic): the conditional tells us that the mosaic is such that the best combination of informativeness (by the above measure), simplicity, and fit is achieved by a system incorporating the given history-to-chance conditional.[6]

Part of Loewer's strategy is that we are bound by PP because PP is 'built into' the aim of our science. This is a page out of the Kantian playbook: our science has a certain goal, and if we believe that this goal is achieved by adopting a certain belief, then our failure to adopt that belief would be irrational. If we regard chances as measuring the degrees of belief that we ought to adopt (absent inadmissible information) in order to achieve our scientific goal, then we are bound by PP. Accordingly, Loewer says:

> someone who violates the PP is, in a fairly straightforward sense, being irrational . . . . Such a person is in the position of accepting that a certain person is the best source on what degrees of belief to have regarding certain matters and then opting for different degrees of belief. (Loewer 2004, 1123)

Here Loewer personifies the Best System as an 'expert' on what degrees of belief to have. On this third version of the Kantian/Lewisian approach to explaining PP, a belief about chances just is a belief about what degrees of belief we ought (absent inadmissible information) to have, and it would be irrational for us not to align our credences with what we believe our credences ought to be. Similarly, Hall (2004, 100–101) takes chance to be the credences that a kind of expert adopts and Ismael (2013) characterizes beliefs about chances as second-order beliefs.

Chances, on this view, are Kantian projections of ideal credences onto the world. This rationale for PP is not consequentialist. Rather, the rationale is that to believe $\mathrm{ch}_t(\mathrm{A}) = \mathrm{x}$ just is to believe that whatever the specific aim of science may be, achieving it requires having (absent evidence inadmissible at t) $\mathrm{cr}(\mathrm{A}) = \mathrm{x}$. Whether a chance so understood can help to explain why, e.g., a given radioactive atom decayed is not obvious to me. Presumably, its explanatory power depends on what about the world makes it the case that the hypothetical expert's degree of belief is x.

The advantage of this view is that the following is not an open question: "Granted, the best degree of belief for me to have regarding A is x, but why should my degree of belief regarding A be x?" Nevertheless, we still face the question: what makes x the best degree of belief regarding A for me to have? An irreducibly normative fact seems ill-suited to figuring in scientific explanations. But any naturalistic criterion for bestness threatens to generate an open question about why the degrees of belief satisfying that criterion would be best. This was the challenge that (we saw) faces a consequentialist account of PP. None of these approaches seems satisfactory. But what alternative is there to some version of the Kantian picture? I will give one now.

5. A NON-KANTIAN ALTERNATIVE

Causes come in different strengths. For instance, some causes strongly promote their effects, whereas others weakly inhibit their effects. Suppose that the chance at *t* of A just is a measure of the strength of the world's causal tendency at *t* to develop so as to make it the case that A. That is, roughly speaking, $ch_t(A)$ measures the strength to bring about A of A's 'potential causes' occurring at and before *t*. (In speaking about 'A's causes' where A is a fact rather than an event, I mean the causes of the events in virtue of which A is true.) I say 'potential causes' for two reasons. First, if A does not come to pass, then A has no actual causes, though there may still have been events that had the capacity to bring A about. Second, even if A does come about, $ch_t(A)$ may reflect more than just the strength of A's actual causes. For example, suppose that there are two radioactive sources near a Geiger counter and A is the counter's making a click sometime in the ten seconds after *t*. Perhaps an atom in the first source undergoes radioactive decay during that period, causing the counter to click then, whereas no atom in the second source decays during the period. Then the second source's presence was not an actual cause of the counter's click but the second source's presence contributed to A's chance at *t*. So the second source's presence turned out to be merely a 'potential cause' of A. Let me also note the respect in which it is only roughly the case, on this proposal, that $ch_t(A)$ measures the A-causing strength of A's 'potential causes' occurring at and before *t*. If A has already been made true by the world's events through *t*, then $ch_t(A)$ is trivially maximal even though A is not a potential cause of itself. Nevertheless, $ch_t(A)$ still can be fairly characterized as measuring the strength of the world's causal tendency at *t* to develop so as to make it the case that A; since A has already been fixed by the events through *t*, the world at *t* can be understood as having trivially achieved a maximal causal tendency to develop so as to make it the case that A.[7]

If $ch_t(A)$ measures the strength to bring about A of A's 'potential causes' occurring through *t*, then only propositions that are made true by things that have causes (by events, presumably) have chances. Thus, there is a chance that a given radioactive atom will decay in a given period and there is a chance that at least one atom in some pile will decay in that period. But on a non-Humean view of laws and causal relations (according to which even the world's global manifold of events fails to encompass what makes laws and chances obtain), there is no chance that it is a law that energy is conserved, there is no chance that a celestial collision caused the dinosaurs' extinction, and there is no chance that the general theory of relativity is true. These implications seem correct.

If a chance is a measure of the strength of the world's causal tendency at a given moment, then a chance is not itself a cause. Rather, some events are (potential) causes and $ch_t(A) = x$ is made true by their causal powers. Despite not causing, chances can still figure in causal explanations in that they can supply (contextually relevant) information about the explanandum's causal history. So chances figure in causal explanations in just the way that other noncauses do. The absence of water from the soil, for instance (Beebee 2004), is (arguably) not an event and so is not a cause. But it can help to causally explain the plant's death by supplying contextually relevant information about its causal history.

Of course, this conception of chance is a version of the propensity interpretation (as in Popper [1990, 11–12] and Miller [1994, 182–90]). Later I will look briefly at one familiar objection to such accounts.[8] But for now, I will focus on a topic that advocates of the propensity interpretation have generally not addressed: whether and how it can account for PP.

Lewis (1980/1986, 92) says, "Admissible propositions are the sort of information whose impact on credence about outcomes comes entirely by way of credence about the chances of those outcomes." From this definition of 'admissibility', it follows trivially (for the proposition X that $ch_t(A) = x$) that for any proposition A, any admissible E, and any rational credence function cr where $cr(X\&E) \neq 0$, $cr(A|X\&E) = cr(A|X)$. To account for PP, an account of what chances are must explain not the trivial fact that X screens any admissible E off from A, but rather the nontrivial fact that (as I elaborated in section 1) so much is admissible, as Lewis (1980/1986, 92–95) emphasizes. On my suggestion that $ch_t(A)$ measures the strength of A's potential causes occurring through *t* to bring about A, the reason that so many facts (about the events through *t*, the chances at and before *t*, and the laws) are admissible is that those facts have an impact on cr(A) entirely by way of the agent's credence about A's potential causes (both about what they are and about how strong they are).

For instance, suppose that A is again Smith's developing some postoperative complication. Dr. Jones's observation that Smith's breath before the operation had the odor of cigarettes (E) has an impact on Jones's cr(A) entirely by way of Jones's credence about A's potential causes. In particular, the impact is entirely by way of Jones's credence about Smith's smoking (which Jones takes to be a potential cause of A): if S is that Smith has had a given history of smoking, then $cr(A|S\&E) = cr(A|S)$. On this view, E is admissible at *t* if and only if E has an impact on cr(A) entirely by way of the agent's credences about A's potential causes through *t*. By contrast, let's look at another example. Suppose E is that some newspaper dated in the future (and brought to Jones by a time traveler) reports Smith's death from the postoperative complication. E is inadmissible for Jones at *t* because E has an impact on Jones's cr(A) other than by way of Jones's credences about A's potential causes through *t*. (Likewise, A is inadmissible for Jones at *t*.) What Jones takes to be a full description of A's potential causes through *t* fails to screen off E from A. This newspaper's appearance at *t* does not make $ch_t(A)$ maximal because $ch_t(A)$ measures the strength of the world's causal tendency through *t* to bring about A and so reflects the strength of A's potential causes at and before *t* (with the sole exception of also reflecting whether or not A has been made true by the events through *t*). The newspaper's appearance at *t* is not a potential cause of Smith's developing the complication (nor does it help to constitute the fact that Smith developed the complication).

What Jones takes to be a full description of A's potential causes through *t* must include not just what Jones takes to be A's potential causes, but also what Jones takes to be their strength as reflected in the strength of the world's causal tendency at *t* to generate A—that is, that $ch_t(A) = x$. But this does not make it trivial to say that some E is admissible because this E has an impact on cr(A) entirely by way of credence regarding A's potential causes through *t*. We have some grip, independent of the notion of chance, on what gives some E its confirmatory relevance to A. As an

example of an inadmissible E, we can recognize, prior to the notion of chance, that the future newspaper's report derives its confirmatory relevance to A independent of any information we may have about A's potential causes (including their identity and their strength).

PP says that for an agent's cr(A) to be rationally fixed by her belief regarding $ch_t(A)$, the agent must possess no information that is inadmissible *at t*. Consider, the $ch_{t+}(A)$ where t^+ is later than *t*. (In general, $ch_{t+}(A)$ is unequal to $ch_t(A)$, as when the chance of a given Iodine-131 atom's decaying sometime within 102 seconds after *t* steadily decreases as more and more of the 102-second interval passes without the atom's having yet decayed.) If E is admissible at *t* if and only if E has an impact on cr(A) entirely by way of the agent's credence about A's potential causes through *t*, then a fact about $ch_{t+}(A)$ is inadmissible at *t* because it has an impact on cr(A) partly by way of the agent's credence about A's potential causes *after t*. Accordingly, PP does not require that $cr(A|ch_t(A) = x \;\&\; ch_{t+}(A) = y) = x$. By contrast, consider $ch_{t-}(A)$ where t^- is earlier than *t*. A fact about $ch_{t-}(A)$ is admissible at *t* because it has an impact on cr(A) entirely by way of the agent's credence about A's potential causes before *t*. Accordingly, PP requires that $cr(A|ch_t(A) = x \;\&\; ch_{t-}(A) = y) = x$.

The conception of chance as measuring the world's causal tendency, then, accounts for the scope of 'admissibility'.[9] So much is admissible because $ch_t(A)$ captures so much relevant information about the world through *t*. Now let's consider how this conception of chance accounts for chance's 'queerness'. Roughly, the explanation is that since $ch_t(A)$ captures the strength of the world's causal tendency at *t* to generate A, there is built into $ch_t(A)$ a connection to A. So there is no gulf between chances and facts about the Humean base. The reason why Dr. Jones needed no further evidence in order to take into account her belief regarding Smith's chance of developing the postoperative complication, bringing it to bear on her credence in the complication's developing, is that the chance just is (and is defined as) a measure of the power of the complication's potential causes through *t* to bring the complication about; understanding '$ch_t(A) = x$' requires understanding this connection. In this respect, the complication's chance of developing differs sharply from Smith's history of smoking. That history is not *constituted* by (or defined in terms of) anything to do with a causal relation to a postoperative complication, and that is why an agent could understand that Smith has a certain smoking history without understanding its causal power to bring about that complication. The question "Admittedly, Smith's chance now of the complication is 40%, but why should I care about that in predicting the complication?" is closed because $ch_t(A)$'s epistemic relevance to A is built into $ch_t(A)$ since $ch_t(A)$ measures the strength of A's potential causes through *t*. To ask "I understand that A's potential causes at *t* are strong, but why should I care about that in predicting A?" is as unintelligible as asking "I understand that if P were the case, then Q would be the case, but why should I care about that in predicting Q from my information about P?" Absent inadmissible information, it does seem rationally obligatory for an agent to have greater confidence in A than in B if the agent believes that the world's causal tendency at *t* to develop so as to realize A is stronger than the world's causal tendency at *t* to develop so as to realize B.

So runs the basic idea, and perhaps it suffices to remove the 'queerness' of $ch_t(A)$'s imposing a rational constraint on credences. But to account for PP, we require a further argument. What does the 'strength' of the world's causal tendency to generate A really mean, and how does a belief regarding that strength have built into it the precise cr(A) that PP demands (absent inadmissible evidence) given the agent's belief that $ch_t(A) = x$? Even if the above explanation shows why $ch_t(A)$ is automatically epistemically relevant to A, it has obviously not yet accounted for the precise relevance expressed by PP. In particular, given a Bayesian framework and under the conditions specified by PP (notably that E is admissible), the above argument may suffice to show that a rational agent's belief that $ch_t(A) = x$ fixes her cr(A). In other words, perhaps the above argument suffices to show that (under those conditions) the agent's belief regarding the strength of A's potential causes at t rationally fixes the degree of her belief in A—that there is such a relation between strength and credence that is the same for all A, regardless of the subject matter, since it is only the strength of the causal tendency that matters, not what A is. That is, perhaps the above argument suffices to show that there is a function $f(x)$, holding (under the conditions specified by PP) for all A, where f takes the strength x of A's potential causes at t (according to the agent) and maps x to the agent's rational cr(A). But we still need a further step: from the existence of some $f(x)$ such that under these conditions and for any A, $cr(A|X\&E) = f(x)$, to the conclusion that $f(x) = x$. Only with that further step will PP have been explained.

To take this step, we need to specify precisely how $ch_t(A)$ *measures* the strength of A's potential causes at t. Of what size are the units in terms of which strength is measured and what is the reference point that calibrates the scale? Since (under the conditions specified by PP) the rational agent's cr(A) would be fixed by her belief that the world's causal tendency to yield A has a certain strength, let's take the units of strength to be 'epistemic units': units defined in terms of the cr(A) fixed by the belief that $ch_t(A) = x$. In particular, we can stipulate that we are measuring chances on a scale where if the world's causal tendency to yield A counts as 'twice as strong' as its causal tendency to yield B, then (under the conditions specified by PP) the requisite cr(A) is twice the requisite cr(B). More generally, take the measure of strength to be a real number where if $ch_t(A) = n \cdot ch_t(B)$ for some $n > 0$, then the credences required (under the specified conditions) are such that $cr(A) = n \cdot cr(B)$. Hence, $f(nx) = nf(x)$ for $n > 0$. If we also stipulate that f is continuous, then it follows (Godement 2004, 338) that f is linear: $f(x) = ax$. Now we need our reference point for this scale: let's stipulate for convenience that 'strength' is to be measured so that if the causal tendency at t has the highest measure (that is, it is so strong that it *determines* that A will obtain), then $ch_t(A) = 1$. Then $1 = cr(A|[ch(A)=1]) = f(1)$, so since $f(x) = ax$ entails that $f(1) = a$, it follows that $a = 1$. Therefore $f(x) = x$; we have accounted for PP.

To put this final step in perspective, let's consider an analogy. We can set up a temperature scale (such as the centigrade or Fahrenheit scale) by specifying three things: the size of a degree, one reference point (such as the number of degrees to be assigned to water's freezing point), and a direction (i.e., whether a higher degree of temperature is to be warmer or cooler than a lower degree). We have just used a

similar technique for establishing a scale for measuring the strength of A's potential causes at *t*—namely, by specifying the size of the unit, one reference point, and a direction. Having already shown a rational agent's cr(A) to be determined (under the conditions specified by PP) by her belief that the world's causal tendency to yield A has a certain strength, we found it convenient to use epistemic considerations to fix the unit size, reference point, and direction. The final step demonstrated that natural choices for these yield PP.[10]

There is a familiar objection to propensity interpretations of chances that can also be understood as an objection to the foregoing account's power to explain PP. Here are two nice statements of it:

> We have no way to understand a coin's 'propensity to land heads' unless we *already* know what it means to assign it a probability of landing that way. An *interpretation* of probability, to be worthy of the name, should explain the probability concept in terms that we can understand even if we do not already understand what probability is. (Sober 2000, 64)

> 'Propensity' or 'tendency' are no more than pictorial names for objective single-case probabilities or objective chances. (. . .) [I]f you want to leave the level of mere associations and develop an interpretation of probability based on these ideas, you immediately become involved in a conceptual circle. For what can it mean that a certain possible outcome of a random experiment has a greater tendency or propensity to become actual than another possible outcome? It means either that the first outcome occurs with higher probability in which case the circle is most obvious. Or it means that the outcome would, upon repetition, occur more frequently, which is either false or to be taken as shorthand for 'would with higher probability occur more frequently', in which case the conceptual circle emerges again. (Rosenthal 2006, 109)

The objection, in brief, is that we cannot analyze chance as a measure of the strength of a causal tendency because this 'strength' must, in turn, be analyzed in terms of chance.

I do not think that this objection succeeds, and my response to it is that there is no implicit, illicit appeal to the notion of chance in either step of the above explanation of PP. First, a rough understanding of what a causal relation is, without any appeal to the notion of chance, is enough to give us some grip on 'a measure of the strength of the world's causal tendency to develop so as to realize A'. In particular, we do not need to employ the notion of chance to understand how so much of an agent's evidence would be rendered confirmationally irrelevant to A by beliefs regarding A's potential causes—namely, by beliefs regarding the degree to which the world at *t* is promoting or inhibiting A's development. That is, I do not think that we need any analysis of the 'strength' of a causal tendency in order to understand why so much evidence counts as 'admissible'. Second, we do not appeal to the notion of chance in specifying the 'epistemic units' in terms of which the tendency's strength is to be measured. In short, we do not have to invoke the notion of chance in order to appreciate that in the absence of inadmissible information, it is rationally obligatory for an agent to have greater confidence in A than in B if the agent believes that the

world's causal tendency at *t* to develop so as to realize A is stronger than the world's causal tendency at *t* to develop so as to realize B—and to use this fact to define a unit for measuring that strength.

6. CONCLUSION

I have tried to show that although PP suggests a Kantian picture of chances as projections of ideal credences onto the world, there exists an attractive non-Kantian alternative. However, in one respect, my alternative remains Kantian: chances are measured in 'epistemic units.' Indeed, there is a respect in which my picture is even more Kantian than Lewis's.

Lewis (1980/1986, 98) correctly says that from PP and the fact that rational credences are probabilities, it follows that chances are probabilities. Does this derivation *explain why* chances are probabilities? PP is supposed to arise ultimately from the Best System account. But it is unclear to me that the Best System account can be used to help explain why chances are probabilities. Of course, to perfectly 'fit' relative frequencies, chances must be probabilities. But fit can be traded off against informativeness and simplicity. I see no reason why these tradeoffs could not produce a Best System where the chances are not probabilities. Enough simplicity to win the competition, despite the decreased fit, might be gained by violating the axioms of probability. A system might deem the chance of some outcome to be a simple function of some feature of the setup—a function that purchases its simplicity by ranging beyond [0,1] for some chances.

Thus, I suspect that the axioms of probability must be written into the competition by hand: by stipulating that a system with a 'ch' function (figuring in history-to-ch conditionals) is eligible for the competition for Best System only if ch is a probability function.[11] The explanation of why chances are probabilities is thereby rendered rather thin. By contrast, on my proposal, the explanation of why chances are probabilities appeals to the fact that chances are measured in 'epistemic units'. That chances can be so measured is one version of the Kantian idea that chances as measured are—at least in some respects—projections of the structure of our rational thought onto the world.

NOTES

1. All quotations are from Kant 1965 (where A and B refer as usual to the first and second edition, respectively).
2. For various interpretations of Kant on lawhood, systematicity, and the status of the three regulative principles, see for example Grier (2001), Guyer (2005), and Kitcher (1986). Of course, Kant's discussion of systematicity and its status (logical or transcendental principle) in the Appendix to the Transcendental Dialectic does not map precisely onto Lewis's definition of the Best System (for one, Kant's principle of the continuity of forms in nature harks back to Leibniz and underpins Kant's take on the principles of homogeneity and specification in a way that does not have a counterpart in the Lewisian Best System). However, for the present purpose, I shall take the Kantian idea of striving for systematic unity as a template that has inspired some contemporary interpretations of Lewis's Best System account of lawhood.
3. Later Lewis (1994/1999) elaborated an alternative to PP that (he believed) allowed him to resolve the problem that undermining futures pose for accounts of chances that identify them with facts about the Humean mosaic. However, Lewis continued to regard PP as constitutive of chance. I will not examine

the problem of undermining futures. I will assume that whatever the precise chance-credence link, PP comes close enough to capturing it that an account of PP's grounds could be adapted to any more refined chance-credence link.

4. Lewis 1980/1986, 87. This is slightly different from Lewis's formulation: he assumes that $cr(B) = 0$ (for an initial rational credence function) if and only if B is logically false. This demands infinitesimal probabilities.
5. The notion of 'fit' must be refined to accommodate continuous chance distributions and infinitely many chance events.
6. For instance, it tells us that a certain 'undermining future' (see note 3) will not obtain.
7. In saying that $ch_t(A)$ measures the strength to bring about A of A's 'potential causes' occurring at *and before t*, I am leaving room for 'action at a temporal distance'; there is no reason for an account of chance to rule out causes that make their influence felt across temporal gaps.
8. Another much-discussed objection to propensity interpretations is Humphreys's objection that not all conditional probabilities reflect causal powers. I believe there are several promising responses.
9. According to some philosophers, even if a world is deterministic at the fundamental level, there could still be chances at some macroscopic level; for instance, a coin and flipper might have a 50% chance of yielding a 'head' even if the chance setup's microstate together with microlaws entail the microstate that will result. The conception of chance that I have just sketched can accommodate such macrochances by interpreting a given macrolevel $ch_t(A)$ as measuring the strength to bring about A of a certain restricted range of A's 'potential causes' occurring through t (namely, causes at the macrolevel) and making analogous adjustments to the notion of 'admissibility'.
10. Why not simply stipulate directly (at the point in the explanation reached at the start of the previous paragraph) that the 'epistemic units' in which the causal tendency's strength is measured are units where belief that $ch_t(A) = x$ rationally fixes $cr(A) = x$ (under the relevant conditions), thereby yielding PP immediately? Because we are trying not merely to derive PP, but to explain it, and to jump in this way directly to PP would weaken the explanation by depicting PP as more of a matter of convention than it is and by failing to locate precisely the conventional elements. A very natural unpacking of the 'strength' of the causal tendency for A (once a belief regarding that tendency's strength has been shown to rationally fix cr(A) under the relevant conditions) is that belief in a 'stronger' causal tendency for A demands a higher cr(A) in direct proportion to the strength. By giving separately the contribution to PP of this unpacking of 'strength', we can isolate the impact of the more purely conventional choice made in setting the maximal strength. We can also then see how any units that meet these two natural-looking conditions will yield PP. That is not shown by directly stipulating the epistemic units to be such as to yield PP. An explanation of PP is more illuminating insofar as it reveals the respects in which PP is inevitable or conventional.
11. Another motivation for this conclusion is that a system is eligible for the competition only if it is deductively closed. The axioms of probability may be needed to determine what deductively follows from a claim in the system involving the uninterpreted function 'ch', such as how ch(A or B) must be related to ch(A), ch(B), and ch(A&B).

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