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# Chance Debugged

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A 'Big Bad Bug' threatens Lewis's Humean metaphysics of chance (Lewis 1986a, p. XIV); his Principal Principle provides an intuitive link between chance and credence. Yet on the one hand, certain future developments are incompatible with the true theory of chance, but on the other hand, such future developments have a positive chance to occur. The combination of these two claims with the Principal Principle leads to inconsistent credences. I present a Humean solution to the Bug: chances are relative to a limited perspective. The perspective comprises facts available as evidence to an ideal cognizer at a point in space-time. As a consequence, the same future event can have different chances of occurring provided the perspective is different. I show how this dissolves the Bug.

Keywords : Chance; Probability; Lewis; Big Bad Bug; Credence; Principal Principle; Humean Supervenience; Humeanism

## 1. The Bug

Lewis's (1986a) metaphysics of chance rests on the idea of Humean Supervenience (HS). The background is a sparse metaphysics: the universe consists of a vast mosaic of spatio-temporally-located particular matters of fact, without necessary connections among them. In this vein, chances supervene on the whole of local matters of fact throughout history. Lewis interprets 'throughout history' as supervenience on the total course of history, past, present and future. This gives rise to the claim that knowing all of history, one can know the chances with certainty (cf. Thau 1994, p. 495). Lewis adds his Best System Analysis (BSA): chances are determined by the scientific theory which strikes the best balance of simplicity, strength and fit (cf. Lewis 1994, p. 478). For reasons of space, I have to refer the reader elsewhere to Lewis's discussion of the BSA. To give a first idea, the difference between frequentism, which identifies the chances with long-run frequencies, and BSA, may be illustrated by Lewis's 'unobtainium' example. There is only one atom of this stuff, and it decays at some point in time. Still, there may be considerations that allow us to figure out the chances of unobtanium decaying, e.g., how unobtainium relates to other elements. For the purposes of this article, except for the discussion of the example in section 3, we may neglect the difference between frequentism and BSA and think of chances as determined by long-run frequencies.

There is a further ingredient which by Lewis's light captures all we know about chance, the Principal Principle (PP). Let $A$ be the proposition that some single event occurs, $H$ history up to some point in time, $T_L$ the true theory of chance à la Lewis, consisting of a set of history-to-chance conditionals which specify the chances for different histories, $Ch_{HTL}(A)$ the chance of $A$ as determined by the combination of $H$ and $T_L$, and $Cr$ a reasonable initial credence function (no evidence so far). Then:

*PP:* $Cr(A|HT_L) = Ch_{HTL}(A)$ (cf. Meacham 2010, p. 410)[1]

In other words, your credence in $A$ given history $H$ and the theory $T_L$ is the chance of A according to $T_L$ and $H$.

Now consider a future $F$, i.e., a total course of future events, relative to the present time $t$ which fulfils the following conditions: $F$ would undermine $T_L$. Since $T_L$ is true, $F$ does not occur. But if $F$ were to occur, the chances at $t$ would be different from the way they are according to $T_L$. $F$ has a positive chance of occurring at $t$. The possibility of $F$ is backed by Humean metaphysics: no tie between the future and the past prevents $F$. According to PP, $Cr(F|H_tT_L) > 0$. Yet $T_L$ and $F$ are mutually inconsistent, so $Cr(F|H_tT_L) = 0$. For example, the half-life of tritium is 12.32 years. The chance of any given atom of tritium of decaying within 12.32 years is 50%. Under HS, no tie in the world prevents tritium atoms from displaying a completely different frequency of decay over time than they have hitherto displayed. Thus, there is a minute positive chance that they *will* display this different frequency (cf. Lewis 1994, p. 482). Having in mind the link between frequencies and chances, we can assume this different frequency gives rise to a different half-life of tritium. Since chances are determined by frequencies throughout the universe, there is a chance that

*1. I use Meacham's preferred formulation of PP. For simplicity, I disregard questions of how to generalize PP such as to accommodate 'statistical mechanical chances and the like' (Meacham 2010, p. 424).*

the half-life of tritium is now different from the way it is. That means there is a 50% chance that the chance of any given atom of tritium decaying within 12.32 years is not 50%. Applying PP leads to inconsistent credences.

I present a new solution to the Bug which allows the reconciliation of two claims.[2] Let $T$ be some true theory of chance which is incompatible with $F$ and let $X$ be the proposition that the chance of $F$ as determined by $H_t$ is $x$ for $x > 0$:[3]

$Cr(F|H_tT) = 0$

$Cr(F|X) > 0$

The first claim, credence in a future $F$ that would lead to chances different from $T$, given $T$ and the history up to $t$, should be 0, for $T$ and $F$ cannot obtain both. The second claim does justice to Humean intuition: even if $T$ is ultimately true, at $t$ nothing prevents $F$. As I will argue, there is a way in which $H_t$ already fixes chances, among them the chance of $F$. These chances are different from the chances as represented by $T$.[4] Knowing just the chances as determined by $H_t$, one should place positive credence in $F$.

The argument to come is as follows: in section 2 I advance the idea that chances supervene not on the total history of the universe, but only on the history up to some point of evaluation; in section 3 I develop the resulting account of chance; in section 4 I introduce a revised version of the Principal Principle; in section 5 I show how this removes the Bug.

## 2. The Relativity of Chance to Perspective: Motivating Considerations

I present two motivating considerations. The first alludes to a metaphysical conundrum: Bigelow et al. (1993) ask whether chances supervene on the total course of history, past, present and future, or only on history up to now, past and present. Whereas they maintain the latter option, Lewis maintains the former.[5] Yet it may be in a Humean spirit to wonder in what way the future is already 'there' such as to determine present chances. The past has the advantage of being settled. Even if past facts do not any longer exist, they have been perfectly determinate and real at their time. Chances may be grounded by that reality just as they are grounded in Lewis's theory by the total course of history. But in what way is one privileged future, the one that will actually come about, already settled? As Lewis says,

'We tend to regard the future as a multitude of alternative possibilities…whereas we regard the past as a unique, settled, immutable actuality.' (Lewis 1986b, p. 36)

Once the future will have come about, how will it be able to determine the present chances? There seems to be no way for the future to determine past and present facts, no counterfactual dependence, retro-causation or the like.[6] The problem ramifies into the metaphysics of time (cf. Hoefer 2007, p. 554). Experts favouring presentism and growing block views, who deny that the future exists or is determinate now, might share my concerns. How can the future fail to exist or be determinate now and nevertheless be a truth-maker for statements about past and present chances? Even eternalists and their kin who do not deny that the future somehow exists or is determinate might ask how the future manages to influence past chances. Unfortunately, from a Humean perspective, accepting that chances supervene on past and present but not on future facts seems to make things worse. Bigelow et al. (1993) propose that the past and present facts fix the chances once and for all. This claim imposes strong constraints on the future. A Humean should doubt that anything could sustain these constraints. I do not deem these metaphysical qualms decisive,[7] but they can be used as prima facie evidence for the view I am going to develop: the *current* chances at some point in time $t$ should be determined by history up to $t$ and not by the future, but this does not necessarily fix chances as being supported by a more comprehensive history.

My second motivational consideration draws on a recent proposal of Jennan Ismael. Ismael denies that chances can be reduced to categorical facts. She uses general probabilities $Pr_G(A|B)$ to define the chance of a single event $e$ as evaluated from some earlier point in time $t$:

*2. Other solutions have been advocated by Hall (1994), Lewis (1994), Thau (1994), Strevens (1995), Hoefer (1997), Halpin (1998), Roberts (2001), Vranas (2002), Schaffer (2003) and Ismael (2008). However, they have not gone uncontested (cf. Briggs 2009).*

*3. In the account to come,* X *specifies the chance of F in the perspective attained at* $H_t$.

*4. Though the main chance values, for instance the half-life of tritium, may stay the same.*
*To be precise, I can only accept some close perspectival analogue of Lewis-chances* $T_L$ *as true, chances as determined by some future course of history which encompasses* not-F. *My conception of chance as determined by total world history somewhat differs from Lewis's (cf. section 5).*

*5. At least before and after 1986, cf. Lewis (1986a, p. 112).*

*6. Lewis denies a backtracking counterfactual dependence of past facts on future facts (in the standard resolution of vagueness for counterfactuals, cf. Lewis 1986b, p. 34). I surmise that the same should go for facts about chances, although it is not clear how this squares with chances supervening on total history. Should not Lewis accept 'If tritium had displayed a completely different frequency of decay after* t, *its half-life before* t *would have been very different' (cf. Bigelow et al. 1993, p. 456)? My proposal allows the denial of backtracking counterfactual dependence without unduly restricting the future.*

*7. They may be assuaged by properly elaborating the metaphysical status of chances: albeit perfectly objective, they do not belong to the basic furniture of the world (to which the ban on retro-determination may apply), but are just the most rational way of guiding expectancies.*

Def: $Ch_t(e) =_{def} Pr_G(e|pre\text{-}t\ history)$

where $Pr_G(A|B)$ is the conditional probability that a random pick from the $B$'s will yield an $A$. (cf. Ismael 2011, p. 425)

The chance of $e$ is the general probability of picking an $e$-type event from pre-$t$ history. This definition pre-supposes a non-relativistic world with an absolute space-time. For a relativistic world, Ismael replaces it by a definition of chance relative to some point $s$ in space-time:

Def *: $Ch_s(e) =_{def} Pr_G(e|$the contents of $s$'s past light cone) (Ismael 2011, p. 436)[8]

Ismael's main motive for conditionalizing on the past (or past light cone) as contrasted to the future or total history is epistemological:[9]

'For creatures like us, historical information is in principle available, whereas information from the future is out of bounds. Chance guides belief because it is probability conditioned on all information that is in principle available to a situated agent.' (Ismael 2011, p. 425)

In principle, we have access to the past (or past light cone) but not to the future or the whole of history. $Pr_G(e|...)$ is determined by the historical frequency of $e$s (cf. Ismael 2011, p. 128). My proposal relates to Ismael's as follows: I adapt Ismael's idea of a situated self to Lewis's Humean framework in order to dissolve the Bug. Chances are relative to our location in (space-)time and what is principally accessible from that location. The metaphysical claim that general probabilities are irreducible gives way to Humean supervenience.[10] Chances supervene on the distribution of perfectly natural categorical facts throughout (some part of) the universe.

## 3. The Perspectival Account of Chance

I distinguish the whole of particular matters of fact on which Lewis has chances supervene (including the future) from *a perspective*. The *perspective* comprises that part of the Humean mosaic which is accessible to an ideal cognizer. The ideal cognizer has unlimited cognitive capacities, but her evidence is limited. For she is bound to a point in (space-)time, just as we are, and absent a crystal ball, she does not know contingent future facts except by their chances as determined by the past frequencies. There are follow-up questions about how the ideal cognizer is related to a non-ideal cognizer, but I think that the former is a good starting point for defining an objective notion of chance.[11] However, I have to prevent a misleading impression: although I talk of the perspective of an (ideal) cognizer, the perspective is perfectly *objective*. It consists simply of the particular matters of fact throughout some part of the universe. The ideal cognizer is ideal as she tracks these particular matters of fact.

The ideal cognizer occurs only when we consider which chances are accessible at some point in history such as to guide credence. The lesson of Ismael's situated self is that we need chances to deal with uncertainty about the future, not about past and present. Thus, the ideal cognizer captures precisely the task of taking in all provided information, past and present, to deal with uncertainty about the future. The ideal cognizer represents the factual basis and analytic powers *we* should try to approximate. Moreover, since the ideal cognizer would also have to face the Bug, a principled solution to the problem should be expected to apply to her. Thus, even if one feels reserved about my idealization, a solution to the ideal case should provide guidance towards a solution for non-ideal cases. The perspective at $t$ boils down to history up to $t$ $H_t$, or, in a relativistic setting, the past light cone of one's spatio-temporal location. For brevity, I will content myself with discussing the Newtonian paradigm, but I see no principled obstacle to a relativistic treatment.

Here is my proposal: chances are not *absolute* but *relative* to a perspective. We should not talk of *the* chances supervening on the Humean mosaic throughout the whole universe. There are only *chances* relative to perspectives forming part of the mosaic. *Again, the perspective is nothing subjective but just some part of the total mosaic of independent facts out there*. Thus, chances are also perfectly objective. The perspective can be made explicit, by talking of the chances relative to perspective $p$. The perspective $p$ can be characterized, e.g., by listing all the facts available to an ideal cognizer. This allows us to detach ourselves from our actual perspective, i.e., history up to now, and to talk of chances as determined by perspectives that diverge from ours. But our normal talk of chances tout court will make *implicit* reference to *our* per-

*8. I have replaced Ismael's index 'p' by 's' to prevent confusion with my perspective index.*
*9. Conditionalizing* A *on* B *is defined as follows:* $P(A|B) =_{def} P(A\cap B)/P(B)$ *provided* $P(B)>0$.
*10. In Ismael's account, one does not conditionalize on all the facts constituting* pre-t *history, but only on the observable* pre-t *frequencies of* es*, regardless of whether they appear typical in light of other, e.g., more fundamental* pre-t *facts or larger ensembles; conditionalizing is interpreted as bracketing anything except the frequencies behind the conditionalization bar. As a consequence, chances seem to be relative to more or less high-level set-ups, as Hoefer (2007) has it.*
*11. To approximate the ideal cognizer from our perspective, one might adapt the recipes indicated in Roberts (2001) and Ismael (2008). There is a concern that these recipes already take care of the Bug. But in light of Briggs' (2009) reservations, it might be good to have an independent solution to the Bug.*

spective. The chances are always the chances as determined by our perspective now. It is a conceptual truth that with any change in perspective, the chances are different.

*$Ch_p(A)$, the chance of A in perspective p is a function from two propositions onto the closed unit interval: the proposition A and a proposition specifying the perspective p, i.e., the facts that constitute p. Ch(A), chance tout court, is chance as determined by the present perspective.*[12]

Now the question is how chances are determined by part of the Humean mosaic. There are several alternatives. For instance, I could follow Ismael in using the actual pre-*t* frequencies. Yet I take the following proposal to be most straightforward within a Lewisian framework: Lewis's metaphysical claim is that the chances are determined by the system which strikes the best balance of simplicity, strength, and fit throughout the whole universe (Lewis 1994, pp. 478-480).[13] To evade the psychological vagaries of intuitive simplicity, Lewis even expresses hope that one system will be robustly best (Lewis 1994, p. 479). The analogous hope would be that even for perspectives like our present one, there is a best system which settles the chances. This hope needs to be motivated.

It may be motivated as follows: Lewis's BSA should apply both to finite and infinite universes. Consider the closest universe to ours which will collapse in a relatively short time span (compared to the duration of our universe) from now. BSA should apply to such a universe as it is a universe *like ours* (cf. Vranas 2002). Just as our universe up to now, it can be expected to be extremely rich and complicated. For the total history of the collapsing universe, if Lewis is right, there should be a robustly best system. Such a universe provides a vast, albeit finite, amount of evidence that is available in principle but in fact never exhausted by our knowledge. We would not hesitate to derive probabilities for a great many things, even from a tiny fraction of this evidence. Our actual perspective is comparable in structure and complexity to the imagined counterpart universe (save for the collapse). There is no metaphysical concern that the information available is not rich enough to close in on the chances, nor is there an epistemological concern that the toil and trouble of figuring out the best system is trivialized.[14]

However, can this motivational consideration be transferred from a finite universe to a finite *fraction* of a larger universe? Consider Lewis's unobtainium isotopes:[15] assume $Un^{346}$ has not been instantiated up to $t_1$; after $t_1$, it occurs for the first time. My approach might be taken to have an unfortunate consequence: in the perspective $p_1$ at $t_1$, the chance of $Un^{346}$ occurring $Ch_{p1}(Un) = 0$. In contrast, in some later perspective $p_2$, $Ch_{p2}(Un) > 0$. But this positive chance cannot be derived from the past chance by conditionalizing on the interval between $t_1$ and $t_2$. Now it is not clear that $Ch_{p1}(Un)$ should be 0. The best system may yield a determinate value different from 0: 'considerations of symmetry, simplicity and so on can make it the case that there are objective chances for events that occur seldom, or even never…' (Hoefer 2007, p. 556). Simplicity and strength may bring fundamental facts to bear on chances. In Lewis's example, half of the $Un^{346}$ atoms decay after 4.8 microseconds; we may nevertheless favour a diverging half-life—provided it accords better with a simple unified model of nuclear structure. Alternatively, chances might be indeterminate. Still, there might be a case where it is best to assign zero chances to an event in a less comprehensive perspective, but not in a more comprehensive perspective. In reply, what the case of $Un^{346}$ shows is that chances relative to a later perspective cannot be obtained in principle by conditionalizing on chances relative to an earlier perspective. But it is not in general the case that $Ch_{t2}(A) = Ch_{t1}(A|I)$ where $I$ is the interval between $t_1$ and the later $t_2$, excluding t1 but including $t_2$. The laws of probability hold for chances *within a perspective*, but not between chances in different perspectives.

There is a further problem; Lewis proposes the following procedure to evaluate fit:

'Lewis suggests evaluating 'fit' in terms of the likelihood of truths. 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. So understood, fit is a kind of informativeness appropriate for chance. The better a theory fits the facts, the more it says about those facts.' (Loewer 2004, p. 1119)

The problem is that in evaluating fit for a perspective *p*, I must occupy, or at least simulate, a position before *p* comes to be actual. But this position must itself give rise to a perspective which is different from *p*. The chance of events within *p* are 0 or 1. Thus, I cannot accept a conceptual link between Lewis's test and fit. I suggest evaluating fit by the relative frequencies encountered throughout the perspective, and then weighing it against simplicity and strength.

Summing up, I propose that $Ch_p(A)$ is the probability assigned to *A* by the system which strikes the best combination

*12. Cf. Schaffer's* Chance-formal *(Schaffer 2007, p. 115).*
*13. Instead of discussing these criteria in detail, I refer to Frigg and Hoefer (2010, pp. 259-261).*
*14. Doubts as to whether chances as determined by a perspective fulfil the chance role will be addressed in sections 6 and 7.*
*15. 'It's hard to make the stuff; in fact in all of space and time, past, present and future, there only ever exist two* $Un^{346}$ *atoms: one with a lifetime of 4.8 microseconds, as chance would have it; the other with a lifetime of 6.1 microseconds. Exactly half of all* $Un^{346}$ *atoms decay in 4.8 microseconds. What does this frequency make true concerning the half-life of* $Un^{346}$*, in other words concerning the chance that an atom of it will decay in a given time? Next to nothing, I should think.'(Lewis 1994, p. 477)*

of strength, simplicity and fit relative to $p$ (provided there are no further relevant virtues of a theory). Chances are by definition indeterminate if there is no unique best system which specifies them. To forestall any air of subjectivity, we might even define chances to be indeterminate if there is no *robustly* best system. I remain neutral with respect to this possibility.

# 4. The Perspectival Principal Principle

How do chances in this conception guide credence? Let $X$ be $Ch_p(A) = x$, the chance of $A$ from perspective $p$ is $x$, and $E$ be any piece of admissible evidence (relative to $Ch_p(A)$):

*PPP:* $Cr(A|EX) = x$

Your credence in $A$ given $E$ and $X$ should be $x$. Note that if A forms part of $p$, its chance in perspective $p$ is 1. I offer the following working characterization of admissible evidence: $E$ must not support the claim that the chance of $A$ is different from $x$ in some perspective which is at least as comprehensive as $p$.[16] For instance, to set our credence in a certain coin falling *heads* to 0.5 as the present perspective has it, we should not have evidence that the chance is 1/3 in some future perspective.

One does not choose a perspective, but is bound to it, just as one does not choose one's position in time. One can only *simulate* but not *occupy* a past or future perspective. Moving forward in time, one automatically proceeds from a less to a more comprehensive perspective, which makes new relevant data available. A more comprehensive future perspective overrides any less comprehensive one in guiding credence.

The chance-credence link proposed is limited compared to Lewis's. He envisages a kinematics of belief which essentially proceeds by conditionalization. $p$ being Lewis-chance as given by $T_L$, $I$ some time interval, excluding the present time $t_1$ but including $t_2$, he maintains:

$$P_2(A) = Cr(A|H_2T_L) = Cr(A|H_1IT_L) = P_1(A|I)$$

(cf. Lewis 1986a, p. 107)

In contrast, the transition from chances in one perspective to chances in another perspective cannot be achieved by conditionalization. One at least in principle needs a completely new theory of chance which strikes the best balance of simplicity, strength and fit with observed frequencies at any point in time. Consider chances as given by perspective $p_2$ which at $t_2$ will succeed $p_1$, the original perspective at $t_1$. In principle, these chances must be derived from the facts assembled in the new perspective and cannot be attained by conditionalizing on chances relative to the earlier one. For if an undermining future comes to pass, the new perspective *revamps* the very chances that would be used to figure out the new chances.[17] In general, the laws of probability hold *within* a perspective, but not between chances in different perspectives.

At first glance, this result might seem hard to swallow. Yet consider when we normally use conditionalization. Assume you bet now (at $t_1$) that the next 10 tosses of a coin will be all heads. You want to know your chances of winning after the next five tosses will have turned out *heads* at $t_2$. To see whether conditionalization might lead you astray, you may invoke a perspectival admissibility constraint (which you would not need in Lewis's kinematics). *Provided the next five tosses falling heads do not amount to inadmissible evidence*, you may settle your present ($t_1$) credence in your eventually winning by conditionalization. You conditionalize on the five tosses falling *heads*:[18]

$$Cr(\text{10 heads}|p_1(\text{5 heads})) = Ch_{p1}(\text{10 heads}|\text{5 heads})$$

This equation holds only provided the five *heads* do not amount to inadmissible evidence: evidence that the chance of 10 *heads* in the perspective $p_2$ that will be attained after five consecutive *heads*, $Ch_{p2}(10\ heads)$, is different from conditional chances in the present perspective $p_1$, $Ch_{p1}(10\ heads|5\ heads)$. Now suppose that the same goes for the whole part of relevant history forming the interval $I$ between $p_1$ and $p_2$. $I$ does not amount to evidence that the chance of future coin tosses turning out *heads* is different in $p_2$. Then we get something very close to Lewis's kinematics:

*16. Except for the disjunctive truth that in some sufficiently comprehensive perspective, the chance of* A *will be 1 or 0, of course. My working characterization is a perspectival analogue of a criterion of admissibility considered by Strevens* ($P_T(A)$ *being the Lewis-chance of* A*): '...if a proposition* B *is to be admissible, it must also be the case that* B *conjoined with* $T_{[L]}$ *tells us no more about* A *than does* $P_T(A)$.*'(Strevens 1995, p. 551)*
*My working characterization also allows the handling of crystal balls (cf. Strevens 1995, 552; Hall 2004, p. 515-516; Meacham 2010, p. 415-416). Information obtained by a crystal ball is inadmissible precisely as far as it provides evidence that the chance of A in some perspective, which is more comprehensive than p, is different from* $Ch_p(A)$*. For instance, if a perfectly reliable crystal ball tells you that a coin which is fair from p will not fall heads, it thereby tells you that the chance of heads will be zero in some future perspective. Thus, it is inadmissible relative to* $Ch_p$(heads).
*17. The new perspective replaces the original one. But that does not mean that the original perspective entailed the wrong chances, of course. From* that *perspective, these chances were perfectly in order. But from the later one, they are no longer fitting.*
*18.* '10 heads' *means 'the next 10 tosses of the coin will be 10 times* heads', '5 heads' *means 'the next five tosses of the coin will be five times* heads'.

$Cr(10\text{ heads}|p1I) = Ch_{p1}(10\text{ heads}|I) = Ch_{p2}(10\text{ heads})$

In my view, this is how we normally use conditionalization. The admissibility clause just considered will be fulfilled: future events we conditionalize on will be short run compared to the huge evidence assembled in our present perspective.[19] Even when we cannot precisely evaluate the chance of an undermining future, we usually can roughly assess how big a fraction of the universe would have to be to amount to an undermining future. We can safely use conditionalization as long as the fraction considered does not reach this dimension.[20]

But what if the evidence is inadmissible? What about perspectives which are rich enough to comprise undermining futures? What if small transitions attained via conditionalization add up? We need a general recipe for figuring out chances in a later perspective compared to an earlier perspective and to double-check the results of conditionalization. I do not think that conditionalization is indispensable in order to proceed from one perspective to the other. To develop a theory of chance in the first place, you begin by just counting frequencies contained in a perspective $p_1$. Once your evidence base is sufficient, you can develop an account of chances in that perspective. After some time, you want to consider chances in a new perspective $p_2$. If you know the interval $I$, you thereby know the newly encountered frequencies. You just have to combine the newly encountered frequencies with those contained in the original perspective $p_1$ and balance the overall frequencies against other virtues of a theory of chance, like simplicity and strength. If the interval undermines chances as delivered by $p_1$, you will obtain new chances for $p_2$ which diverge from the kinematics obtained by conditionalization. The same procedure can be applied to figuring out chances for hypothetical future intervals.

In sum, conditionalization can be used to proceed from one perspective to the other. However, such a use is limited to perspectives which bear no risk of an undermining future. This recalls Carl Hoefer's suggestion that the application of PP should be restricted 'to small parts of the overall pattern of events', such that undermining futures do not come into view (Hoefer 1997, p. 333). The perspectival admissibility clause serves a comparable task. Provided the interval $I$ is not too large compared to the original perspective $p_1$, you can be fairly confident that the new perspective $p_2$ will not yet be sufficient to undermine chances as given by $p_1$. These small-scale transitions will probably be those you are usually interested in. However, this way of using conditionalization is limited. The tiny transitions should not add up. The larger the parts of the universe considered, the more pressing the requirement to double-check the results of conditionalization against newly encountered frequencies.

Perhaps one is dissatisfied with the resulting limits of conditionalization. I discuss a way of removing the limitations imposed on conditionalization: one may adopt a suitable *uniformity presumption*. But how are we to handle such a presumption? As Humeans, we have to accept the possibility that it leads us astray if an undermining future occurs. In my view, the consequence is that the chance of an undermining future, as seen from the present perspective, is positive, and so should our credence be. If we were to place full (or almost full) credence in the uniformity presumption, an inconsistency would ensue. The Bug would rise again. As long as we place positive credence in an undermining future, we cannot place full credence in nature being uniform. If we nevertheless use conditionalization, drawing on the uniformity presumption, we should be fully aware that our heuristic practice will miss the true chances if an undermining future occurs. The actual frequencies encountered in the perspective approximated by conditionalization may prove the uniformity presumption wrong.

But if we cannot simply be confident that nature will be uniform, what could vindicate acting as if it were uniform? By way of an example, I consider a pragmatic stance towards epistemic justification, as proposed by Joshua Schechter and David Enoch:

'Given a project that we are rationally required to engage in, and given a belief-forming method that we must employ if we are to engage successfully in that project, we are justified in employing the method.' (Schechter and Enoch 2006, p. 707)

To Schechter and Enoch, we are justified in adopting any method which is indispensable to successfully pursuing a project which we are rationally required to pursue. What Schechter and Enoch have in mind are very basic methods like reasoning according to Modus Ponens (MP) and Inference to the Best Explanation (IBE). Their notion of a rational requirement is comparably basic. Now if there is any such basic requirement, decision-making in a normal environment is a good candidate: success depends on chancy future events and one's evidence is always finite. Just as far as a uniformity presumption is a prerequisite of coping with uncertainty about the future, we may be justified to use it. One interesting feature of Schechter and Enoch's paradigm of justification is

*19. The assumption that our perspective will usually be sufficiently large also assuages the limits of conditionalization illustrated by the unobtainium example in the last section.*

*20. This can be better appreciated if we look at the fundamental chances Lewis has in mind, instead of the toy example of a coin toss. For instance, it would need a huge amount of tritium decays to contravene the overwhelmingly many tritium decays which have taken place throughout history until now in determining chances. In the coin example, even disregarding problems with high-level chance set-ups, we do not just have to attend to the individual tosses of* this *coin but the overall physical theory bearing on the physical make-up of the coin.*

that one may have low confidence in the reliability of some method of belief formation and still be justified in using it, provided there is no better way to pursue a project one is rationally required to pursue.[21] One acts as if nature were uniform because one knows that there is no other road to success, even if it is open as to whether the remaining road, too, is ultimately barred by undermining futures.

Still, I feel doubts about this pragmatic line of vindicating conditionalization between perspectives. What would be attained at best is not conditionalization unlimited, but only conditionalization as a prerequisite of a project we are rationally required to engage in. Moreover, Humean metaphysics prevents us from simply placing high credence in nature being uniform, or related metaphysical posits which are entailed by the uniformity presumption. The pragmatic line of justification would have to be reconciled with the resulting detachment. Perhaps there are other justificatory strategies. For instance, one might exploit the relationship to uniformity as a prerequisite of inductive reasoning (cf. Strevens 1999, p. 257 and section 6). But the pragmatic line of argument illustrates one general concern about any such strategy: it will prove very difficult to spell out a reasoned attitude towards the uniformity presumption. Such an attitude would have to steer in between the commitment to uniformity incurred by using conditionalization as a heuristic and the detachment required by Humean metaphysics. I do not see a convincing way of elucidating such an attitude. One might try some sort of 'as if'-stance towards uniformity, or treat chances obtained by conditionalization as some sort of idealization. Yet it is beyond the scope of this paper to thoroughly consider such possibilities, especially since I surmise that conditionalization within the limits of the perspectival admissibility clause will mostly suffice. Again, this only amounts to limiting the use of conditionalization and not to limiting PPP. There is always the alternative of proceeding from one perspective to the other by just counting frequencies.

# 5. Removing the Bug

Now I feel prepared for meeting the Bug: future events cannot undermine present chances. Consider a future $F$ relative to the present time $t$ that would undermine some true theory of chance $T$.[22] Since $F$ and $T$ are incompatible, $Cr(F|H_tT) = 0$. Given $T$ will come true, $F$ will not come to pass. Our credence in $F$ given $T$ should be 0.

However, Humean intuition is preserved; none of the futures which would undermine $T$ are precluded from having a positive chance to occur at $t$ and from having an impact on our assignment of chances. Assume $F$ now has a chance of undermining $T$. Its positive chance $Ch(F) = Ch_{pt}(F)$ is not derived from $T$, but from the true theory in our present perspective $p_t$. My credence that $F$ will occur as guided by my *present* perspective $p_t$ should equal this chance, $Cr(F|Ch(F)=x) = x$. What prevents the Bug is that there is no reason to assign zero credence. No future whatsoever can make chances in a past perspective false. My proposal diverges from the position of the majority of eminent Bug hunters (Vranas 2002): while they either deem $F$ inscrutable or recommend zero credence, I opt for non-zero credence. I think this is more plausible, provided we accept that nothing prevents $F$ from coming to pass.

To illustrate my treatment, I consider a toy example of Hoefer's:

Scenario: The end of the world is near. There are just 10 more chance events of type $Q$ left in history (think of them as being, in structure, like flips of a coin). In past history, there have been 30 and exactly 15 were 'heads', nicely distributed temporally. Depending on how the last 10 turn out, the probabilistic laws may take form $T$ (if anywhere from one to nine $Q$-events are 'heads'), $T'$ (if zero are 'heads'), or $T''$ (if 10 are 'heads'). For concreteness, let us suppose these laws are as follows:

> $\boldsymbol{T}$: Each $Q$ has chance 1/2 of being 'heads', and 1/2 of being 'tails'
>
> $\boldsymbol{T'}$: Each $Q$ has chance 1/3 of being 'heads', and 2/3 of being 'tails'
>
> $\boldsymbol{T''}$: Each $Q$ has chance 2/3 of being 'heads', and 1/3 of being 'tails'

In fact, in the world in question, four are 'heads' and $T$ are the laws. But $T$ assigns a non-zero chance to both the zero-heads and 10-heads outcomes [...]

*Question*: What credences in possible future outcomes should a good Humean, knowing $\boldsymbol{H}_{tw}$, $\boldsymbol{T}_w$, and $\boldsymbol{E}$ in these circumstances, have?

*21. In more recent work, Enoch and Schechter elaborate the conditions of pragmatic justification as follows: consider a method of forming beliefs which is indispensable to a project one is rationally required to engage in. The method is justified provided that (i) 'if any method yields success, this one does, too' (Enoch and Schechter 2008, p. 560); (ii) 'there is no sufficiently close world at which the thinker successfully engages in the project but at which the method is ineffective' (Enoch and Schechter 2008, p. 562). This fits the indispensable role I have tentatively envisaged for the uniformity presumption. Yet no requirement can be derived that adopting this presumption* actually *leads to successfully forming credences. So justification à la Enoch and Schechter is compatible in principle with low confidence that the uniformity presumption will actually be fulfilled.*

*22. As a perspectival approximation to Lewis-chances* $T_L$*, one may think of* T *as chances in some advanced future perspective from which it will be settled whether* F *has occurred.*

[...]

*Right Answer*: A good Humean knows only that one of the one-to-nine 'heads' outcomes will happen. She has no reason whatsoever to assign more credence to one than to another (Hoefer 1997, p. 329).

To Hoefer, what the 'good Humean' can do is settle conditional credence in *heads* given Lewis-chances $T_L$.[23] There is one difficulty with adapting the example to my account. The perspective corresponding to Lewis-chances comes about at the end of the universe. If it is part of the perspective that the universe has come to an end, the chance of any past *heads* outcome is 0 or 1 and there is no chance of a further *heads* outcome. Therefore I vary the example: at $t_2$, Hoefer's 10 tosses have taken place; but there is one further coin toss which will not make a difference to the ultimate theory. I will interpret $T$ as true from the respective perspective (and analogously $T'$...). Assume the perspective $p_1$ (at $t_1$) when Hoefer's 10 trials are still to occur sustains a best system of chances $T_1$ (let the chance of heads be 0.5). We should assign positive credence to futures that would undermine $T$: there is a chance that the next 10 trials will end *no heads* and all heads: e.g. $Cr(\text{no heads}|p_1) = Ch_{p1}(\text{no heads}) = 0.5^{10}$. This does not lead to a contradiction, though. For consider an undermining outcome. Say none of the 10 trials has issued in heads at $t_2$. This gives rise to a different perspective $p_2$ and a different theory, Hoefer's $T'$. But this is compatible with $Cr(\text{no heads}|T) = 0$. And it is compatible with the true chances relative to $p_1$ being $T_1$ and with positive credence in *some heads* at $t_1$. Now consider the toss after $t_2$. While $Cr(\text{heads}|p_1) = Ch_{p1}(\text{heads}) = 0.5$, $Cr(\text{heads}|p_2) = Ch_{p2}(\text{heads}) = 1/3$. One may assign non-zero credence to undermining futures from an earlier perspective, just as the original Humean intuition which bothered Lewis has it, for the relativity to a perspective prevents inconsistencies.

To sum up, Humean chances can be debugged by an account of chance which is independently motivated, by considering the limited part of history accessible to cognizers situated in time and reinterpreting this limited base as not just providing an evidential base for figuring out, but as determining objective chances.

*23. Or more precisely: 'heads'.*

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