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WHO'S AFRAID OF UNDERMINING?

Why the Principal Principle Might Not Contradict Humean Supervenience

ABSTRACT. The Principal Principle (PP) says that, for any proposition A, given any admissible evidence and the proposition that the chance of A is $x\%$, one's conditional credence in A should be $x\%$. Humean Supervenience (HS) claims that, among possible worlds like ours, no two differ without differing in the spacetime-point-by-spacetime-point arrangement of local properties. David Lewis (1986b, 1994a) has argued that PP contradicts HS, and the validity of his argument has been endorsed by Bigelow et al. (1993), Thau (1994), Hall (1994), Strevens (1995), Ismael (1996), Hoefer (1997), and Black (1998). Against this consensus, I argue that PP might not contradict HS: Lewis's argument is invalid, and every attempt – within a broad class of attempts – to amend the argument fails.

1. INTRODUCTION[1]

Behold: a uranium atom! Some physicists would claim that *this* uranium atom has a 50% chance of decaying within the next 4.5 billion years or so if left alone. Now I don't profess to fully understand what (objective) chance is, but at least I think I know this much: if I were certain that these physicists are right and I knew nothing else about this uranium atom, then I should, on pain of some kind of irrationality, be 50% confident that this atom will decay within the next 4.5 billion years or so if left alone. In other words, I adopt a *chance-credence principle*: a principle relating chance (objective probability) with credence (subjective probability, degree of belief). This principle, unfortunately, is elementary and rough. Can we say something more sophisticated? Can we be more precise?

Yes, we can. Or so several philosophers seem to think. A prominent example is David Lewis (1980), whose widely discussed 'Principal Principle' (PP) is a chance-credence principle with considerable intuitive appeal. The crux of PP is a distinction between 'admissible' and 'inadmissible' evidence. Suppose I have a crystal ball which on numerous occasions has reliably predicted the spontaneous decay times of uranium atoms. If my crystal ball predicts that this uranium atom will spontaneously decay within the next three minutes, then I should no longer be so confident that

Erkenntnis **57:** 151–174, 2002.

this atom will stay around for billions of years if left alone. The crystal ball evidence would be *inadmissible*: it would break the link between chance and credence. *Admissible* evidence, on the contrary, preserves the link. Irrelevant evidence is always admissible: a storm in the antipodes can hardly affect this uranium atom. But some relevant evidence is also admissible; for instance, evidence that this atom was created three billion years ago. So we have an intuitive grasp of admissibility. Now PP roughly says that, for any proposition A, given any admissible evidence and the proposition that the chance of A is $x\%$, one's conditional credence in A should be $x\%$ (details in Section 2). Is PP, as Lewis (1994a, p. 489) claims, 'the key to our concept of chance'?

Lewis was apparently happy with PP until he came to believe (1986b) that PP contradicts his cherished metaphysical thesis of 'Humean Supervenience' (HS). Take a dot matrix picture. Its global properties (e.g., symmetry) supervene on the point-by-point arrangement of dots: no two pictures differ without differing in the arrangement of dots. Similarly, HS claims that, among possible worlds like ours, no two differ without differing in the spacetime-point-by-spacetime-point arrangement of local properties. HS is inspired by Hume, the great denier of necessary connections: 'all there is to the world is a vast mosaic of local matters of particular fact, just one little thing and then another' (Lewis 1986b, p. ix; details in Section 3). But how on earth is PP supposed to contradict HS? Not directly, but in two steps, which I will now examine in order.

First step. If HS is true, then the configuration of present chances in our world is determined by the total (past, present, and future) arrangement of local properties in our world. Now every possible but nonactual future, in combination with the actual present and past, constitutes a total arrangement of local properties and thus (given HS) determines a possible configuration of present chances, a configuration in general different from the actual one. Suppose that one such future (to repeat, a possible but nonactual future which, in combination with the actual present and past, determines a configuration of present chances different from the actual one), call it F, has a positive (present, actual) chance of occurring. F will not occur, since it's not actual; but *could* it occur? 'Well, yes and no. It could, in the sense that there's non-zero present chance of it. It couldn't, in the sense that its coming to pass contradicts the truth about present chances' (Lewis 1994a, p. 482; details in Section 4). The existence of such *undermining futures*, to which Lewis thinks that acceptance of HS commits him, is arguably very peculiar; but peculiarity is not (yet) contradiction.

Second step. To be specific, suppose that F has chance 60% but determines, in combination with the actual present and past H, a configuration of chances that assigns chance 55% to F. Consider the conjunction C of H (the actual present and past) with the proposition X that the chance of F is 60%. The conjunction CF, namely HXF, entails (via X) that the chance of F is 60%, but also apparently entails (via HF) that the chance of F is 55%. If so, then CF is impossible, so that, given C, one's conditional credence in F should be zero. But given that H is admissible, PP says that this conditional credence should be 60%; hence the (putative) contradiction (details in Section 5).

Lewis is not alone in thinking that PP contradicts HS: variations on the above two-step argument have been approvingly rehearsed by Bigelow et al. (1993), Thau (1994), Hall (1994), Strevens (1995), Hoefer (1997), and Black (1998). Nevertheless, I beg to differ: my first thesis in this paper is that there is a flaw in the above argument.[2] To see the flaw, go back to the beginning, namely to the definition of HS. Lewis defines HS as a thesis of *restricted* supervenience: it's not any two possible worlds whatsoever, but rather any two *among worlds like ours*, that don't differ without differing in the arrangement of local properties. What counts as a world like ours doesn't matter here; what matters is that, given Lewis's definition of HS, a total arrangement of local properties 'determines' (if HS is true) a configuration of chances only among worlds like ours. But then the conjunction CF in the last paragraph need not be *impossible*, false in *every* possible world; therefore, given C, one's conditional credence in F need not be zero, and no contradiction arises (details in Section 5). Can't one, however, rescue the claim that PP contradicts HS by amending the above argument? My second thesis in this paper is that one probably cannot: every attempt – within a broad class of attempts – to amend the argument fails (details in Sections 6 and 7).

Given that my reasoning goes against what seems to be a weighty consensus,[3] I take my time in the body of the paper laying out the issues rigorously: in Sections 2, 3, and 4 I set the stage by formulating PP, HS, and undermining respectively. Then I argue that PP might not contradict HS: the argument for the putative contradiction is invalid (Section 5), and attempts to amend the argument fail (Sections 6–7). I conclude in Section 8.

2. THE PRINCIPAL PRINCIPLE

Let Cr be the credence function of a given person (at some time instant); i.e., the function which assigns to any proposition A about which the person has a belief a number in [0, 1] which is the person's degree of belief in A (assuming, to simplify, that every belief has a degree). Let Ch be the chance function (at some time instant); i.e., the function which assigns to any proposition A which has a chance a number in [0, 1] which is the chance of A. Let $\langle Ch(A) = x\rangle$ be the proposition that $Ch(A)$ is x, x being a number in [0, 1]. Let E be any proposition. Then a very rough but for present purposes adequate formulation of PP is as follows (cf. Lewis 1980, p. 87):

(PP) If E is admissible with respect to $\langle Ch(A) = x\rangle$, then $Cr(A|E\langle Ch(A) = x\rangle)$ should be x.[4]

For my purposes it will be more convenient to use a consequence of PP, which I call the 'Expert Principle' (EP). Let 'f' denote *rigidly* (Kripke 1980, pp. 77–78) a function from propositions to numbers in [0, 1]. Let T_f be the proposition that Ch is f; i.e., that (i) dom Ch = dom f and (ii) for every A in dom f, $Ch(A) = f(A)$. T_f entails propositions (like $\langle Ch(A) = f(A)\rangle$) that specify the chances of various propositions. For example, if $f(A)$ is 0.3, then T_f entails the proposition that $Ch(A)$ is 0.3. Note that 'Ch' denotes the chance function *nonrigidly* (cf. Lewis 1980, p. 89). If T_f in the above example is true, then $Ch(A)$ is in fact 0.3; but if the chance of A had been 0.5, then $Ch(A)$ would have been 0.5 (whereas $f(A)$ would still have been 0.3, so that T_f would have been false). Now it can be shown that PP entails EP:

(EP) If ET_f is admissible with respect to $\langle Ch(A) = f(A)\rangle$, then $Cr(A|ET_f)$ should be $f(A)$.

EP corresponds to Lewis's 'reformulation' of PP (1980, p. 97).[5]

3. HUMEAN SUPERVENIENCE

Lewis calls 'Humean Supervenience' (HS) 'the doctrine that all there is to the world is a vast mosaic of local matters of particular fact, just one little thing and then another' (1986b, p. ix). Here is an analogy (Lewis 1986a, p. 14; cf. 1994b, p. 294):

> A dot-matrix picture has global properties – it is symmetrical, it is cluttered, and whatnot – and yet all there is to the picture is dots and non-dots at each point of the matrix. The global properties are nothing but patterns in the dots. They supervene: no two pictures could differ in their global properties without differing, somewhere, in whether there is or there isn't a dot. ... [Similarly:] The world has its laws of nature, its chances and causal relationships; and yet – perhaps! – all there is to the world is point-by-point distribution of local qualitative character.

Haslanger comments: 'There is a compelling idea here, for it is plausible to think that what happens *over* time, and *over* space, depends on what happens at particular points along the way' (1994, p. 342).

Lewis defines *local qualities* as 'perfectly natural intrinsic properties of points, or of point-sized occupants of points',[6] and understands an *arrangement of qualities* as a 'spatiotemporal arrangement of local qualities throughout all of history, past and present and future' (1994a, p. 474). Then Lewis formulates HS as a thesis of restricted *global* (Kim 1984, 1987) supervenience: 'among *worlds like ours*, no two differ without difference in the arrangement of qualities' (1994a, p. 474). To see why Lewis formulates HS as a thesis of *restricted* supervenience, consider an analogy with materialism: 'to be a materialist one need not deny the very possibility of spirits. Some worlds have spirits, even if ours does not. Instead we look to articulate a materialist thesis which locates our world among a special set of worlds, and postulates, e.g., that between members of this restricted set there is no mental difference without a physical difference' (Haslanger 1994, p. 343; cf. Lewis 1983, pp. 362–364). Similarly, according to Lewis, some worlds differ without differing in the arrangement of qualities. Some of these worlds are not 'like ours'; e.g., 'there might be emergent natural properties of more-than-point-sized things' (1986b, p. x). The details of what counts as a world like ours don't matter for present purposes; what matters is that Lewis uses 'worlds like ours' rigidly (or, as he would say, 'quasi-rigidly'; see 1986a, p. 256) and that, according to Lewis, some worlds are *not* like ours.

Lewis recognizes that HS 'is inspired by classical physics' (1994a, p. 474), but claims that he 'wouldn't grieve' if physics itself were to teach him that HS is false (1986b, p. xi) (e.g., by teaching him that 'many fundamental properties are instantiated not at points but at point-tuples'), because his defence of the philosophical tenability of HS 'can doubtless be adapted to whatever better supervenience thesis may emerge from better physics' (1994a, p. 474). Given that the truth of HS depends on the truth of something like classical physics and is thus an 'empirical' issue (Lewis 1986b, p. xi), HS is *not* a priori true.[7]

4. UNDERMINING

Applied to chances, HS has the following consequence:

(HS_1) For any time instant t and for any worlds w and w' like ours, if w and w' have the same arrangement of qualities, then w and w' have the same chance function at t.

Besides holding HS_1, Lewis (for reasons that don't matter here – see 1994a, p. 484) *denies* HS_2:

(HS_2) There is a time instant t such that, for any worlds w and w' like ours, if w and w' have the same *pre-t* (i.e., over time instants *not later* than t) arrangement of qualities, then w and w' have the same chance function at t.

In Lewis's words: 'present chances supervene upon the whole of history, future as well as present and past; but not upon the past and present alone' (1994a, p. 482).

Now accepting HS_1 while denying HS_2 has an arguably peculiar consequence. Consider a time instant t and suppose that HS_2 is false. Then there are worlds w and w' like ours that have the same pre-t arrangement of qualities, q_-, but different chance functions at t, f and f'. Given HS_1, w and w' have different arrangements of qualities, so they have different *post-t* (i.e., over time instants *later* than t) arrangements of qualities, q_+ and q'_+. Given again HS_1, *any* world like ours that has pre-t arrangement of qualities q_- and post-t arrangement of qualities q'_+ will have chance function f' at t; thus the conjunction (C) of the propositions that the pre-t arrangement of qualities is q_- and that the post-t arrangement of qualities is q'_+ *entails* (among worlds like ours) that Ch is *not* f. What makes this result arguably peculiar is that the conjunction C is *possible* (among worlds like ours), since C is true in w'; therefore, roughly speaking, in w at t there is a possible future whose realization would make the chances at t different from what they are. Lewis comments: 'It's not that if this future came about the present would change retrospectively. Rather, it would never have been what it actually is, and would always have been something different. This undermining is certainly very peculiar' (1994a, pp. 482–483).

What I just showed (following Ismael 1996, p. 82) is that the conjunction of HS_1 with the denial of HS_2 has the consequence that, for any time instant t, there is an *undermining future*, defined formally as follows:

(UN) Given the proposition (H) that the pre-t arrangement of qualities is q_-, the proposition (F) that the post-t arrangement of qualities is q_+ undermines the proposition (T_f) that Ch is f exactly if (1) HT_f and HF are possible among worlds like ours and (2) HF entails among worlds like ours $\neg T_f$. Then F is an *undermining future* and T_f is *underminable*.[8]

Note that *possibility and entailment in UN are restricted to worlds like ours*; this restriction is usually omitted in definitions of undermining[9] but is crucial for my argument in the next section.

5. THE INVALIDITY OF THE ARGUMENT FOR THE PUTATIVE CONTRADICTION

The reasoning purporting to derive a contradiction from the conjunction of EP with the existence of undermining futures can be formulated as follows. Suppose that, given H, F undermines T_f. Suppose also that $f(F)$ is positive[10] and that HT_f is admissible with respect to $\langle Ch(F) = f(F)\rangle$. Then EP (Section 2), with F in the place of A and H in the place of E, gives that $Cr(F|HT_f)$ should be $f(F)$ and should thus be positive. On the other hand, UN gives that HF entails $\neg T_f$, so that $Cr(HFT_f)$, hence also $Cr(F|HT_f)$, should be zero.[11] Contradiction?

No. According to UN, HF entails $\neg T_f$ *among worlds like ours* (Section 4). If some worlds are not like ours (Section 3), then one may *not* conclude that HF entails $\neg T_f$ *simpliciter*. HFT_f is false but need not be *impossible*. One may not conclude that $Cr(HFT_f)$ should be zero. The above reasoning is blocked.

My point in the last paragraph I take to be relatively uncontroversial: although the invalidity of the argument for the putative contradiction has gone so far unnoticed (except by Halpin 1994, p. 337 n. 11), I think it is plain once it is pointed out. Indeed, responding to earlier versions of this paper, most of those who have defended in print the view that a contradiction exists granted my point (Lewis himself included). Nevertheless, most of those who granted my point insisted that a contradiction exists, because they thought that the argument could be easily fixed. In the next two sections, however, I examine a broad class of attempts to amend the argument and I argue that every attempt in this class fails.

6. A SPACE OF POSSIBLE AMENDMENTS TO THE ARGUMENT

Let U be the proposition that, given H, F undermines T_f (suppose that $f(F)$ is positive). Consider the space of possible amendments to the argument for the putative contradiction which have the following structure: (i) they use EP together with an admissibility assumption to conclude, for some propositions A and E, that $Cr(A|ET_f)$ should be $f(F)$ and should thus be positive; (ii) they use U together with one or two epistemic principles to conclude that $Cr(AET_f)$ should be zero. The argument I examined in the last section had F in the place of A and H in the place of E, and used the epistemic principle that every impossible proposition should get credence zero. But these are not the only possible choices: in this section I investigate systematically the above space of possible amendments by varying A, E, and the epistemic principles used.

(1) I will consider two epistemic principles: (i) the principle – call it 'N' – that every necessary proposition should get credence one (and every impossible proposition should get credence zero), and (ii) the principle – call it 'P' – that every proposition which is a priori (knowable to be) true should get credence one (and every a priori false proposition should get credence zero). To conclude that $Cr(AET_f)$ should be zero by using no other epistemic principle, one must argue either that (a) AET_f is impossible or a priori false, or that (b) the conjunction of AET_f with some necessary or a priori true proposition X is impossible or a priori false (so that $Cr(XAET_f)$ and $Cr(\neg X)$, hence also $Cr(AET_f)$, should be zero). The former cases can be subsumed under the latter by letting I be a tautology that is both necessary and a priori true (e.g., the proposition that either Goldbach's Conjecture is true or it is not) and setting $X = I$.

(2) What are the possible choices for A? EP, together with an admissibility assumption, entails that $Cr(A|ET_f)$ should be $f(A)$. To conclude that $Cr(A|ET_f)$ should be $f(F)$ and should thus be positive, one must argue that $f(A) = f(F)$. I will consider two kinds of cases: (a) those in which A is F, and (b) those in which A is the conjunction of F with some proposition Y which is arguably necessary or a priori true (so that $f(A) = f(FY) = f(Y|F)f(F) = f(F)$, assuming that $f(Y|F) = 1$ whenever Y is necessary or a priori true). For convenience I will say that the former cases correspond to $Y = I$.

(3) What are the possible choices for E? To conclude that $Cr(AET_f)$ should be zero by using U, it seems one must use the consequence of U that HFT_f is false among worlds like ours. So it seems that AET_f, namely $FYET_f$, must entail HFT_f. I will consider two kinds of cases: (a) those in which E is H, and (b) those in which E is the conjunction of H with some proposition Z. (I will consider only Z which are arguably necessary or a priori true, given that ZHT_f must be admissible with respect to $\langle Ch(A) = f(A)\rangle$.) I will say that the former cases correspond to $Z = I$.

We have thus a 'three-dimensional' space of possible amendments, the 'dimensions' being X, Y, and Z. In addition to I, I will consider four candidates for X, Y, and Z:

(i) HS, namely Humean Supervenience. As I explained in Section 3, HS is not a priori true because its truth depends on the truth of something like classical physics. On the other hand, HS is necessary if it is true, because it is *noncontingent* (i.e., either necessary or impossible). But doesn't Lewis repeatedly say that HS is contingent? He does,[12] but what he means (charitably understood) is that HS is a thesis of *restricted* supervenience (restricted to worlds like ours). To see why HS is noncontingent, consider any contingent proposition; e.g., the proposition that mammals exist. For any possible world w, the proposition that mammals exist in w is noncontingent: if it is true (in the actual) then it is true in every possible world, and likewise if it is false. Similarly, the proposition that mammals exist in all worlds like ours is noncontingent; and so is HS.

(ii) BSA, namely Lewis's 'best-system analysis of law and chance together'. I take BSA to be the claim that, for any world w like ours, 'the laws [of w] are those regularities that are theorems of the best system' and 'the chances [at w] are what the probabilistic laws of the best system say they are' (Lewis 1994a, p. 480; cf. Section 7.3). What exactly 'the best system' is does not matter here; what matters is that the 'arrangement of qualities provides the candidate true systems', so that BSA 'is Humean' (Lewis 1994a, p. 480). But then BSA, like HS, is not a priori true because its truth depends on the truth of something like classical physics. One might argue, however, that if BSA is a correct *analysis* then it *is* a priori true: *every* analytic claim is a priori true (Kripke 1980, p. 39). To my mind it simply follows that BSA is *not* a correct analysis, but for the sake of argument let me grant that BSA is a priori true. Moreover, like HS, BSA is noncontingent, so it is necessary if it is true.

(iii) U, namely the proposition that, given H, F undermines T_f. Like HS and BSA, U is noncontingent, so it is necessary if it is true. One might argue that, if BSA is a priori true, then U is too. Not so, however. To know a priori not just that undermining futures exist, but also (as U claims) that the *specific* future F is undermining, one would need to know a priori not just that chances supervene on arrangements of qualities, but also enough about the *specific* way in which they supervene; i.e., about the specific chance functions which correspond to specific arrangements of qualities. BSA is too vague for that: it says that the best system is the system that gets the best balance of simplicity, strength (i.e., informativeness), and fit (to the arrangement of qualities), but leaves largely unspecified the standards of simplicity, strength, fit, and balance. Moreover, Lewis concedes that some of these standards may be partly 'a matter of psychology' (1994a, p. 479; cf. Halpin 1999); but then they are not a priori knowable. So I see no good reason to accept that U is a priori true.

(iv) V, namely the proposition we express by the sentence 'the actual world is a world like ours' ('the actual world' being used nonrigidly; recall from Section 3 that Lewis uses 'worlds like ours' rigidly). V is not necessary (it is true exactly in worlds like ours), but is arguably a priori true.

I will partition the above 'three-dimensional' space of possible amendments into four regions, which I will examine in Sections 6.1–6.4: (1) $Y = I$, $Z = I$, $X = I$; (2) $Y = I$, $Z = I$, $X \neq I$; (3) $Y = I$, $Z \neq I$; (4) $Y \neq I$.

6.1. *First Region: Y = I, Z = I, X = I*

This region corresponds to possible amendments which try to show that HFT_f is (1) impossible or (2) a priori false.

(1) As I explained in Section 5, HFT_f *need not* be impossible: although false among worlds like ours, it may be true in some world *unlike ours*. But HFT_f *will* be impossible if F is an undermining future which is true *only* in worlds like ours. And it might seem that such a future is easy to find. For example, given BSA, Lewis (1994a, p. 482) argues that a future F is undermining (with respect to the actual past and the actual present chances) if in F many more tritium atoms come into existence than have existed so far and each of these atoms has a decay time much shorter than the actual half-life of tritium. The details of Lewis's reasoning don't matter here: let me grant that F is undermining. (I am not conceding that U is a priori true: Lewis argues that F is 'most likely' undermining, he does not give an a priori proof.) Now the point is that '[t]he world with this future *will* be a "world like ours" ' (Lewis, personal communication, 6 April 1998): on Lewis's account, a world is unlike ours exactly if in that world some 'alien' natural property is instantiated,[13] but no alien property need be instantiated when tritium atoms with short decay times come into existence. I reply that there is no *unique* world with the above future: although a world with this future *need not* be unlike ours, there is no guarantee that *every* world with this future will be like ours. Recall that a 'future', in the relevant technical sense (Section 4), specifies the (non)instantiation of *local* properties only; but alien natural properties need not be local, so their noninstantiation cannot be guaranteed by specifying a future. In other words, there may be *both* worlds like ours and worlds unlike ours with the future that Lewis describes. So we don't have a future that will serve the proponents of the contradiction, an undermining future which is true *only* in worlds like ours, and this attempt to amend the argument fails.

(But what if we consider a future in which many more tritium atoms come into existence etc. *and* no alien natural property is instantiated? Since, as I just explained, the specification of a future cannot guarantee the noninstantiation of alien natural properties, the idea must be to *conjoin* an undermining future F with the proposition that no alien natural property is instantiated; i.e., with V, the proposition that the actual world is a world like ours. This idea corresponds to cases with $Y = V$, which I will address in Section 6.4.[14])

(2) To argue that HFT_f is a priori false, one might try to argue that its falsity is entailed by some a priori true proposition. Now the falsity of HFT_f is entailed by U, but as we saw U need not be a priori true even if BSA is: BSA need not entail that the *specific* future F is undermining. So I see no way to conclude that HFT_f is a priori false.

6.2. *Second Region: $Y = I$, $Z = I$, $X \neq I$*

This region corresponds to possible amendments which try to show that $Cr(HFT_f)$ should be zero without trying to show that HFT_f is impossible or a priori false. The idea is to argue that, for some (1) necessary or (2) a priori true proposition X (different from I), $XHFT_f$ is impossible or a priori false.

(1) We have three candidates for a *necessary* proposition X: HS, BSA, and U. One might think that any of them, when conjoined with HFT_f, gives an impossible proposition. This seems clearest for U, which entails that HFT_f is false among worlds like ours: how could $UHFT_f$ be true? Here is how: if U is necessary and HFT_f is true in some world unlike ours, then in that world $UHFT_f$ is true. So the conjunction of U (similarly for HS and BSA) with HFT_f need not be impossible, and the amendment can proceed only if such a conjunction is a priori false. Indeed, $UHFT_f$ *is* a priori false: if HFT_f is false, then so is $UHFT_f$, and if HFT_f is true, then U is false, hence so is $UHFT_f$. It's the a priori falsity (rather than the alleged impossibility) of $UHFT_f$ which captures the intuition that $UHFT_f$ 'cannot' be true. (On the other hand, HS and BSA need not entail that the specific future F is undermining, so their conjunctions with HFT_f need not be a priori false.) Here is then how the current amendment goes:

Argument A.	(A1)	$UHFT_f$ is a priori false.
Thus (using P):	(A2)	$Cr(UHFT_f)$ should be zero.
	(A3)	U is necessary.
Thus (using N):	(A4)	$Cr(U)$ should be one.
Thus (from A2 and A4):	(C)	$Cr(HFT_f)$ should be zero.

I reply that, if the reasoning of Argument A is accepted, then the absurd conclusion follows that *every* false proposition should get credence zero. Here is why. Take any false proposition G and call U^* the proposition that G is false in our world. (I use 'our world' rigidly because, as I said, Lewis uses 'worlds like ours' rigidly.) According to the reasoning of Argument

A: (A1′) U^*G is a priori false; (A2′) $Cr(U^*G)$ should be zero; (A3′) U^* is necessary; (A4′) $Cr(U^*)$ should be one; (C′) $Cr(G)$ should be zero. I need not take a stand on how exactly this absurd conclusion is to be avoided;[15] the fact that I have provided a *reductio* of Argument A suffices for my purposes. (This reductio is of more general interest if it demonstrates a conflict between N and P.)

(2) We have two candidates for an *a priori true* proposition X: BSA and V. As we saw, BSAHFT_f need not be impossible or a priori false. But $VHFT_f$ is clearly impossible if U is true: HFT_f is false in every world like ours (if U is true), and V is false in every world unlike ours. (On the other hand, since U need not be a priori true, $VHFT_f$ need not be a priori false.) Here is then how the current amendment goes:

Argument B.	(B1)	$VHFT_f$ is impossible. [Follows from U.]
Thus (using N):	(B2)	$Cr(VHFT_f)$ should be zero.
	(B3)	V is a priori true.[16]
Thus (using P):	(B4)	$Cr(V)$ should be one.
Thus (from B2 and B4):	(C)	$Cr(HFT_f)$ should be zero.

Arguments A and B are in a sense symmetric, and so are my replies. If the reasoning of Argument B is accepted, then the absurd conclusion follows that *every* false proposition should get credence zero. Here is why. Let V^* be the proposition we express by the sentence ‘the actual world is our world’; V^* is true in our world and false in every other possible world.[17] Take any false proposition G. According to the reasoning of Argument B: (B1′) V^*G is impossible; (B2′) $Cr(V^*G)$ should be zero; (B3′) V^* is a priori true; (B4′) $Cr(V^*)$ should be one; (C′) $Cr(G)$ should be zero.[18]

6.3. *Third Region: $Y = I$, $Z \neq I$*

This region corresponds to possible amendments which try to show, for some necessary or a priori true proposition Z (different from I), that (i) $Cr(F|ZHT_f)$ should be $f(F)$ and should thus be positive, whereas (ii) $Cr(FZHT_f)$ should be zero. Given the discussion in Section 6.2, it can be seen that at most two of our four candidates for Z will work for (ii): U and V. Here is how the amendment goes for U (what follows applies mutatis mutandis to V; e.g., substitute ‘impossible’ for ‘a priori false’):

Argument C.	(C1)	$FUHT_f$ is a priori false. [Same as A1.]
Thus (using P):	(C2)	$Cr(FUHT_f)$ should be zero.
	(C3)	UHT_f is admissible with respect to $\langle Ch(F) = f(F)\rangle$.
Thus (using EP):	(C4)	$Cr(F\|UHT_f)$ should be $f(F)$ (and should thus be positive).

In reply I reject C3. There is a simple reason why UHT_f is *not* admissible with respect to $\langle Ch(F) = f(F)\rangle$: given that $FUHT_f$ is a priori false, conditionally on UHT_f one should be certain that the future F will not come about. (This presupposes P, but so does C2; so strictly speaking my point is that *those who accept C2* should reject C3.) But doesn't rejecting C3 'cripple' EP (Lewis 1994a, pp. 485–486) by compromising an integral part of EP, namely the admissibility of (historical information and) information about present chances? No. The presumably integral part of EP is the admissibility of HT_f (and of T_f), not of UHT_f. And there is a principled reason for *accepting* the admissibility of HT_f while *rejecting* the admissibility of UHT_f with respect to $\langle Ch(F) = f(F)\rangle$: FHT_f, unlike $FUHT_f$, need not be a priori false (see Section 6.1.2).

6.4. *Fourth Region: $Y \neq I$*

This region corresponds to possible amendments which try to show, for some necessary or a priori true propositions Y (different from I) and Z, that $Cr(FY|ZHT_f)$ should be positive whereas $Cr(FYZHT_f)$ should be zero. Here is how the amendment goes for $Y = U$ and $Z = I$ (what follows applies mutatis mutandis to $Y = V$ or $Z \neq I$):

Argument D.	(D1)	$FUHT_f$ is a priori false. [Same as C1.]
Thus (using P):	(D2)	$Cr(FUHT_f)$ should be zero. [Same as C2.]
	(D3)	HT_f is admissible with respect to $\langle Ch(FU) = f(FU)\rangle$.
Thus (using EP):	(D4)	$Cr(FU\|HT_f)$ should be $f(FU)$; i.e., $f(U\|F)f(F)$.
	(D5)	$f(U\|F)$ is one (because U is necessary).
Thus (from D4 and D5):	(D6)	$Cr(FU\|HT_f)$ should be $f(F)$ (and should thus be positive).

Note first that, if we can get a contradiction by means of Argument D, then we can also get a contradiction *without assuming HS or the existence of undermining futures*. Here is how. Take any false proposition G such that $f(G)$ is positive and call U' the proposition that GHT_f is false in our world.[19] According to the reasoning of Argument D: (D1′) $GU'HT_f$ is a priori false; (D2′) $Cr(GU'HT_f)$ should be zero; (D3′) HT_f is admissible with respect to $\langle Ch(GU') = f(GU')\rangle$; (D4′) $Cr(GU'|HT_f)$ should be $f(GU')$; i.e., $f(U'|G)f(G)$; (D5′) $f(U'|G)$ is one (because U' is necessary); (D6′) $Cr(GU'|HT_f)$ should be $f(G)$ (and should thus be positive). Now I am not saying that this is a *reductio* of Argument D: one *could* react by accepting that we can indeed get a contradiction without appealing to undermining, so that EP is in even deeper trouble than Lewis thinks.[20] But it seems that a more reasonable reaction is to reject D5′ and D5, two premises for which no support has been adduced. Indeed, those who accept (D2 and) D3 should also accept that $f(FU)$ is zero and thus *should* reject D5. This follows from my reasoning in Section 6.3: given that $FUHT_f$ is a priori false, conditionally on HT_f one should be certain that FU is false, so HT_f is inadmissible with respect to $\langle Ch(FU) = f(FU)\rangle$ *unless* $f(FU)$ is zero. (The case of C3 was different, because $f(F)$ is *by assumption* positive. So I see no conflict between rejecting C3 and accepting D3.) I conclude that, like the previous amendments, the current one fails.[21]

7. THREE FURTHER ATTEMPTS TO DERIVE A CONTRADICTION

In the last section I investigated systematically a space of possible amendments to the argument for the putative contradiction and I concluded that every amendment in that space fails. In this section I examine three amendments which deviate considerably from the original argument and do not belong to the above space.

7.1. *Two Different Positive Values*

Every amendment in Section 6 tried to derive a contradiction of the same basic form: a certain (conditional) credence should be both positive and zero. But one might also try to derive a contradiction of another form: a certain conditional credence should have two different positive values. Here is how.

Argument E.	(E1)	$Cr(F\|HT_f)$ should be $Cr(F\|HT_fU)Cr(U\|HT_f) + Cr(F\|HT_f\neg U)Cr(\neg U\|HT_f)$. [From probability theory.]
From C1 and P (via C2):	(E2)	$Cr(F\|HT_fU)$ should be zero.
	(E3)	$HT_f\neg U$ is admissible with respect to $\langle Ch(F) = f(F)\rangle$.
Thus (using EP):	(E4)	$Cr(F\|HT_f\neg U)$ should be $f(F)$.
Thus (from E1, E2, and E4):	(E5)	$Cr(F\|HT_f)$ should be $f(F)Cr(\neg U\|HT_f)$.
	(E6)	HT_f is admissible with respect to $\langle Ch(F) = f(F)\rangle$.
Thus (from EP):	(E7)	$Cr(F\|HT_f)$ should be $f(F)$.

Given that $f(F)$ is positive, E5 and E7 contradict each other as long as $Cr(\neg U|HT_f)$ need not be one.

(Note that Argument E rejects Principle N, according to which every impossible proposition should get credence zero. Otherwise $\neg U$, being impossible if U is necessary, should get credence zero and $Cr(F|HT_f\neg U)$ in E1 and E4 would be undefined. For the sake of argument let me grant that N is false.)

In reply I reject E3. In Section 6.3 I argued that C3 is false: HT_fU is *not* admissible with respect to $\langle Ch(F) = f(F)\rangle$. My argument against C3 relied on the a priori falsity of FHT_fU and thus does not work *directly* against E3: in contrast to FHT_fU, $FHT_f\neg U$ need not be a priori false. Nevertheless, those who accept my argument against C3 and also accept EP without 'crippling' it (and thus in particular accept E6) *should* reject E3. This is because it is a general consequence of EP that, if HT_f is admissible with respect to $\langle Ch(A) = f(A)\rangle$, then HT_fB is admissible if (and only if) $HT_f\neg B$ is.[22] Substituting F for A and U for B, it follows that, given EP and E6, C3 is true if E3 is; i.e., E3 is false if C3 is. I conclude that the current amendment fails.

7.2. *'Should' Versus 'May'*

The negation of the claim that (i) a certain credence should be positive is not the claim that (ii) this credence *should* be zero; it is rather the weaker claim that (iii) this credence *may* be zero (i.e., that it *need not* be positive).[23] So to derive a contradiction with (i) it is not necessary to argue for (ii) (as every amendment in Section 6 did): it is sufficient to establish (iii). For example:

Argument F.	(F1)	$Cr(UFHT_f)$ should be zero. [Same as A2.]
	(F2)	$Cr(U)$ may be one.
Thus:	(F3)	$Cr(FHT_f)$ may be zero.
From E6 and EP (via E7):	(F4)	$Cr(FHT_f)$ should be positive. [Contradicts F3.]

My reply to Argument F parallels my reply to Argument D (Section 6.4). If we can get a contradiction by means of Argument F, then we can also get a contradiction without assuming HS or the existence of undermining futures. Here is how. Take any false proposition G such that $f(G)$ is positive and call U' the proposition that GHT_f is false in our world. According to the reasoning of Argument F: (F1′) $Cr(U'GHT_f)$ should be zero; (F2′) $Cr(U')$ may be one; (F3′) $Cr(GHT_f)$ may be zero; (F4′) $Cr(GHT_f)$ should be positive. I am not saying that this is a reductio of Argument F: one *could* react by accepting that we can indeed get a contradiction without appealing to undermining, so that EP is in even deeper trouble than Lewis thinks (see, however, note 20). But it seems that a more reasonable reaction is to reject F2′ and F2, two premises for which no support has been adduced. Indeed, F2 (similarly for F2′) is question-begging. F2 says that no epistemic norm prescribes the assignment of credence less than one to U, and it is indeed not obvious where such a norm would come from. But those who accept both F1 and EP's consequence that F3 is false can reply that there *is* such a norm, coming precisely (and nonobviously) from the fact that the conjunction of F1 with the denial of F3 entails that F2 is false.

7.3. *Unrestricted Supervenience of Chances*

My attack on Lewis's argument relies crucially on the fact that HS is a thesis of *restricted* supervenience (Section 3), so that it entails only the restricted supervenience of chances on arrangements of qualities, HS_1 (Section 4). One might argue, however, that an *unrestricted* version of HS_1 – call it HS_1* – is compatible with (without following from) HS and does contradict PP. This contradiction (one might continue) is admittedly between HS_1* and PP rather than HS and PP, but the contradiction is still of interest because HS_1* is both (i) a consequence of Lewis's 'best-system analysis' (Section 6) and (ii) independently plausible. In reply I deny both (i) and (ii). Note first that it is unclear whether Lewis (1994a, pp. 478–482) understands the best-system analysis restrictedly (as BSA) or unrestrictedly (as BSA*):

(BSA) For any world w *like ours*, the laws of w are the regularities that are theorems of the best system and the chances at w are what the probabilistic laws of w say they are.

(BSA*) For any world w *whatsoever*, the laws of w are the regularities that are theorems of the best system and the chances at w are what the probabilistic laws of w say they are.

Even if (as I grant for the sake of argument) BSA* entails HS_1*, BSA does not. To say that the best-system analysis is *analytic* does not resolve the above ambiguity: BSA and BSA* can equally well be analytic.[24] I claim, however, that the best-system analysis should be understood as BSA rather than BSA*. This is because the reasons that Lewis adduces for rejecting an unrestricted version of HS (1986b, p. x; cf. Haslanger 1994, p. 343) apparently commit him to rejecting HS_1* (and thus BSA*) as well. Take a world (not like ours) which has the same arrangement of qualities as our world, but in which some alien natural properties are instantiated:[25] unlocalized stuff undergoes a probabilistic process roughly analogous to our radioactive decay. Such a world has more (including some radically different) kinds of chancy events than ours, so why should it have the same chance functions as ours? It might be objected that no such world exists if BSA* or HS_1* is true. But the point is precisely that such a world seems *conceivable*, so that BSA* seems to give a false 'analysis' of chance and HS_1* is implausible.[26] I conclude that the current amendment fails.[27]

8. CONCLUSION: AGAINST IMPERFECTIONISM

Although I may have refuted several attempts to amend the argument for the existence of a contradiction between PP and HS, I have not shown that no such contradiction exists. One might thus find this paper unsatisfactory: given that several authors, including Lewis, have defended the view that a contradiction exists, don't we need a consideration 'deeper' than a formal problem if we are to reject this view? I don't think we do. Those who have defended the existence of a contradiction have done so by means of a consideration no deeper than a formal argument. This paper suggests that their argument is invalid and that it cannot be easily fixed; so this paper shifts the burden of proof to those who would insist that a contradiction exists.

Proponents of the putative contradiction might nevertheless demand an intuitive explanation of how it can be rational to assign positive credence to a proposition (like HFT_f) which, though not impossible, is false among worlds like ours; wouldn't this be like assigning positive credence to the proposition that some humans are immortal, although among worlds like ours no human is immortal? We must guard against a confusion which may underlie this demand. I granted that we should assign credence zero to the *conjunction* of HFT_f and U; similarly for the conjunction of the propositions that some humans are immortal and that among worlds like ours no human is immortal. These conjunctions are a priori false. But it doesn't follow that we should assign credence zero to the *first conjuncts*: we don't know a priori that the second conjuncts are true. We know a priori that we are in a world like ours, not that in such worlds no human is immortal or the specific future F contradicts HT_f. I granted that the second conjuncts are *necessary* if true, but I argued that attempts to combine the principle that every necessary proposition should get credence one with the principle that every a priori true proposition should get credence one lead to absurd results.

My task in this paper might appear purely negative: I argued that Lewis's argument is invalid and that several attempts to amend the argument fail. But on an alternative reading this paper has the positive task of defending PP (or HS) against a powerful challenge. PP is so intuitive that it cannot be lightly discarded. In fact, Lewis's rejection of PP apparently left him feeling uneasy. In the concluding section (entitled 'Against perfectionism') of his 1994a paper, Lewis wrote: 'A feature of Reality deserves the name of chance to the extent that it occupies the definitive role of chance; and occupying the role means obeying the [Principal] Principle, applied as if information about present chances ... were perfectly admissible. Because of undermining, nothing perfectly occupies the role, so *nothing perfectly deserves the name*. But ... an imperfect candidate may deserve the name quite well enough' (1994a, p. 489, emphasis added; cf. Hoefer 1997, p. 334). If my argument in this paper succeeds, we might be able to escape this unpalatable conclusion. We need not espouse Lewis's imperfectionism. Proponents of PP need not be afraid of undermining.

ACKNOWLEDGEMENTS

I am very grateful to Frank Arntzenius, Robert Black, Allan Gibbard, Alan Hájek, Ned Hall, John Halpin, Carl Hoefer, James Joyce, David Lewis, Barry Loewer, Gerhard Nuffer, Peter Railton, Wolfgang Spohn, Michael Strevens, Scott Sturgeon, and some anonymous reviewers for helpful discussion or comments. Thanks also to Karen Bennett, Mark Crimmins, Sally Haslanger, David Hills, Marion Ledwig, James Tappenden, and Stephen Yablo for assistance. Versions of this paper were presented at the Twentieth World Congress of Philosophy (Boston, August 1998) and at the Sixteenth Biennial Meeting of the Philosophy of Science Association (Kansas City, October 1998).

NOTES

[1] This section presents the issues in a simplified and slightly imprecise way. Rigour is introduced in later sections.

[2] My thesis is that the argument is *invalid*. The above authors take the argument to be valid but *unsound*: they reject the premise that information about the past and present (including information about present chances) is admissible. Only if this premise is considered an integral part of PP can the above authors be said to think that PP contradicts HS.

[3] After an earlier version of this paper was written, John Halpin pointed out to me that he had briefly made a point very similar to my first thesis in footnote 11 of his 1994 paper (contrast Halpin 1998, p. 352). Contrary to my second thesis, however, Halpin had claimed that the problem could be easily fixed.

[4] The converse also holds: if $Cr(A|E\langle Ch(A) = x\rangle)$ should be x, then E is admissible with respect to $\langle Ch(A) = x\rangle$. The intuitive understanding of admissibility developed in Section 1 suffices for present purposes. I define admissibility with respect to $\langle Ch(A) = x\rangle$ rather than with respect to A because E may be admissible with respect to $\langle Ch(A) = x\rangle$ but inadmissible with respect to $\langle Ch(A) = y\rangle$; e.g., if $E = A$, then E is admissible with respect to $\langle Ch(A) = x\rangle$ only if $x = 1$ (because $Cr(A|A\langle Ch(A) = x\rangle)$ should be one).

[5] I borrow the term 'expert' from Gaifman (1988, pp. 192–193) and from van Fraassen (1989, pp. 198–199, 201–202). EP is similar to Skyrms's 'Generalized Miller' principle (1980, p. 124). Here is how EP follows from PP. If ET_f is admissible with respect to $\langle Ch(A) = f(A)\rangle$, then PP gives, with ET_f in the place of E and $f(A)$ in the place of x: $Cr(A|ET_f\langle Ch(A) = f(A)\rangle)$ should be $f(A)$. But T_f entails $\langle Ch(A) = f(A)\rangle$. So PP gives: $Cr(A|ET_f)$ should be $f(A)$. Note that in this conclusion $f(A)$ cannot be replaced with $Ch(A)$ (which may differ from $f(A)$ if T_f is false).

[6] According to Lewis: (a) *Natural* properties are 'the ones whose sharing makes for resemblance, and the ones relevant to causal powers' (1983, p. 347); they 'carve reality at the joints' (1983, p. 346; cf. 1986a, p. 60) and are distinguished from 'unnatural, gerrymandered, gruesome properties' (1986a, p. 60 n. 44). (Contrary to what the term 'natural' might suggest: 'A property is natural or unnatural *simpliciter*, not relative to one or another world' (1986a, p. 61 n. 44).) (b) The difference between natural and unnatural properties admits of degree, and a property is '*perfectly* natural if its members are all and only those things that share some one universal' (1983, p. 347). (c) A 'vector quality associated with a spacetime point . . . shall count as local' (1999a, p. 209).

[7] Cf. Oppy 2000. Lewis takes a related, more general claim to be a priori true, namely that 'truth is supervenient on being' (1994a, p. 473; Bigelow 1988, p. 132) – a claim to which HS is a 'speculative addition' (Lewis 1994a, p. 474).

[8] Cf.: Lewis 1994a, p. 482; Thau 1994, p. 495; Hall 1994, p. 509; Strevens 1995, p. 549; Ismael 1996, p. 81; Hoefer 1997, p. 323; Halpin 1998, p. 351; Black 1998, p. 377;

Loewer 2000. Usually the condition that HT_f be possible (among worlds like ours) is omitted from definitions of undermining, presumably because it's assumed that HT_f is true. (This assumption presumably presupposes a 'world-relative' version of HS (Robinson 1989, p. 399), so that the variable 'w' in HS_1 and in HS_2 is replaced with the constant 'α' (referring to the actual world).) Undermining can also be defined (a) by replacing F with *any* proposition about the future (Hall 1994, p. 509), or (b) by replacing T_f with *any* proposition about present chances (Ismael 1996, p. 81). A special case of (b) is the case in which T_f in UN is replaced with the proposition that $Ch(F)$ is x (a number in [0, 1]); this special case corresponds to what may be called a 'self-undermining' future (cf. Roberts 2001, p. S102). (Note that UN does not presuppose that F is in dom f.)

[9] See previous note for references. (Thau 1994, p. 495 is an exception: he defines undermining not in terms of entailment but rather in terms of a 'reasonable initial credence function'.) Of course one can define undermining as one wishes, but if one defines undermining by means of *unrestricted* entailment, then accepting $HS_1 \wedge \neg HS_2$ gives little reason to believe that undermining futures exist. It is true that if one defines undermining by means of unrestricted entailment and accepts an unrestricted version of HS_1 (and of $\neg HS_2$) then a contradiction with PP arises (Section 5), but why should one accept an unrestricted version of HS_1 given that such a version does not follow from HS? See Section 7.3.

[10] I don't see why $f(F)$ should be positive. Lewis in effect claims that the positivity of $Ch(F)$ follows from the assumption that 'the differences between ... alternative futures are differences in the outcomes of present or future chance events' (1994a, p. 482), and Ismael (1996, p. 82 n. 6) gives a similar reasoning. I disagree: if a coin is to be tossed infinitely many times, then (under suitable assumptions) every particular infinite sequence of heads and tails has chance zero.

[11] This reasoning comes in several related variants. (See: Bigelow et al. 1993, pp. 445–446; Lewis 1980, p. 130, 1994a, p. 483; Thau 1994, p. 496; Hall 1994, pp. 509–510; Strevens 1995, pp. 549–550; Hoefer 1997, p. 325; Halpin 1998, p. 352; Black 1998, pp. 377–378. Ismael 1996, p. 82 n. 6 endorses the reasoning without going through it. Cf. Rosenberg 1992, pp. 314–315.) A variant of the reasoning uses PP instead of EP and *self*-undermining (note 8) instead of undermining futures. This variant goes as follows (cf. Section 1). Let X be the proposition $\langle Ch(F) = x\rangle$ $(x > 0)$. Suppose that F is a self-undermining future with respect to H and X. Suppose also that H is admissible with respect to X. Then PP (Section 2) gives that $Cr(F|HX)$ should be x and should thus be positive; but self-undermining gives that HF entails $\neg X$, so that $Cr(F|HX)$ should be zero.

[12] 'I concede that Humean supervenience is at best a contingent truth' (1986b, p. x); 'I have conceded that Humean supervenience is a contingent, therefore an empirical, issue' (1986b, p. xi); 'Humean Supervenience is meant to be contingent' (1994a, p. 474). Cf.: 'Humean supervenience is contingent' (Haslanger 1994, p. 343); 'Lewis admits that [HS] is a contingent matter' (Bigelow et al. 1993, p. 443); 'Lewis takes [HS] to be contingent' (Carroll 1994, p. 58 n. 1); 'Lewis says that HS is contingent' (Loewer 1996, p. 102); 'Lewis maintains that HS is only a contingent truth' (Roberts 2001, p. S100); 'HS thus defined as contingent ...' (Robinson 1989, p. 399); 'Lewis expressly adds that [HS] is itself contingent' (Spohn 1999, p. 7).

[13] I ignore certain complications. (a) Lewis used to characterize a world like ours as a possible world in which 'no natural properties alien to our world are instantiated', a property being '*alien* to a world iff (1) it is not instantiated by any inhabitant of that world, and (2) it is not analysable as a conjunction of, or as a structural property constructed out of, natural properties all of which are instantiated by inhabitants of that world' (1983, p. 364). (b)

Some other remarks of Lewis (1986a, pp. 91–92) suggest an additional requirement that a world w must meet if w is to count as a world like ours: w must not combine 'in an alien way' properties that are not alien to our world (e.g., w must contain no particles with both positive and negative charge). (c) In response to a criticism by Haslanger (1994), Lewis (1994a, p. 475) has dropped the above characterization(s) of a world like ours, without however suggesting an alternative characterization.

[14] According to Sturgeon (1998, p. 334 n. 4), Lewis at an Eastern APA meeting endorsed the view that, in addition to specifying the arrangement of qualities, the supervenience base in HS should be understood as specifying 'the absence of unHumean qualities' (1998, p. 328) – i.e., the noninstantiation of alien natural properties. On this view a 'future' does guarantee the noninstantiation of alien natural properties; but this view is equivalent to conjoining HF with V, and is thus also addressed in the sequel.

[15] I am inclined to accept A2 (and A2$'$) and to reject N. One might object that A2 relies on P, against which there are putative counterexamples: provable mathematical propositions for which no proof is currently available are arguably a priori true (contrast, e.g., Kitcher 1984), but it seems reasonable to assign credence less than one to such propositions. I reply by replacing P with the weaker principle P^* that every proposition *known* (rather than, as P asserts, *knowable*) a priori to be true should get credence one. One might respond that even P^* is dubious. Suppose that Fermat's Last Theorem is known a priori to be true by those mathematicians who have carefully checked Wiles's proof (Singh 1997). Nevertheless, the proof is so complicated that it seems reasonable for those mathematicians to keep an open mind and assign to the theorem credence less than one. I reply that this response fails when a *simple* proof is available. It's simple to prove that $UHFT_f$ is false, so I find A2 plausible; but I repeat that I need not take a stand.

[16] If V amounts to the proposition we express by the sentence 'in the actual world no natural properties alien to our world are (ever) instantiated', then B3 might seem implausible: how can we know a priori that, e.g., in the actual world no 'emergent natural properties of more-than-point-sized things' (Lewis 1986b, p. x) are instantiated? We cannot, but if they are, then by definition (note 13) they are not alien. We cannot know a priori *which* properties are alien to our world, but this need not prevent us from knowing a priori that in the actual world no natural properties alien to our world are instantiated. So B3 is not implausible (although I need not take a stand on whether B3 is true).

[17] Given that I use 'the actual world' nonrigidly and 'our world' rigidly, the sentence 'the actual world is our world' is analogous to 'the President is Scott', not to 'Scott is Scott'.

[18] Objecting to my reply to Argument B, one might point out that Argument B uses V but 'Argument B$'$' (in my reply) uses V^*, and I have not shown this difference to be insignificant. I respond that I don't need the two arguments to be exactly parallel. I am not reasoning by analogy: I am rather claiming that accepting Argument B commits one to accepting Argument B$'$. And this claim I find easy to support: accepting B1 and B3 commits one to accepting B1$'$ and B3$'$ respectively, and accepting in addition N and P commits one to accepting Argument B$'$. (Similarly, it won't do to object to my reply to Argument B by contesting B1$'$ or B3$'$, because this would commit one to contesting B1 or B3 and thus Argument B.) One might further object to my reply to Argument B that V^*G is impossible 'by construction' and thus need not get credence zero in the way in which logical contradictions should; moreover, one cannot see that V^*G is impossible without first knowing that G is false. I respond that, if V^*G is not a logical contradiction, then $VHFT_f$ is not one either; moreover, one cannot see that $VHFT_f$ is impossible without first knowing that HFT_f is false among worlds like ours.

[19] Strictly speaking I should replace H and T_f with (e.g.) H' and $T_{f'}$, the latter propositions (unlike the former) being chosen without reference to undermining; but I prefer the simpler notation.

[20] However, we get a contradiction even if we replace EP with Lewis's favoured 'New Principle', according to which $Cr(A|HT_f)$ should be $f(A|T_f)$ rather than $f(A)$: choose G so that $f(G|T_f)$ is positive and note that $f(GU'|T_f) = f(U'|GT_f)f(G|T_f)$.

[21] There is also a more direct argument from D3 to the conclusion that $f(FU)$ is zero. If (as D3 claims) HT_f is admissible with respect to $\langle Ch(FU) = f(FU)\rangle$, then HT_f should also be admissible with respect to $\langle Ch(HT_f) = f(HT_f)\rangle$, so that (using EP) $Cr(HT_f|HT_f)$ should be $f(HT_f)$ – which can be the case only if $f(HT_f)$ is one. On the other hand, given that $FUHT_f$ is a priori false, it has chance zero, so $f(FUHT_f)$ is zero. It follows that $f(FU)$ is also zero. But doesn't Lewis deny that $f(HT_f)$ is one? He does (1994a, p. 487), but *in response* to his belief that a contradiction exists, not *to establish* a contradiction. In fact, Lewis would also deny D3 (1994a, pp. 485–486), so Argument D is not available to him. I myself need not take a stand on D3 or on whether $f(HT_f)$ is one. My point is rather that *those who accept D3* should also accept that $f(HT_f)$ is one and thus that $f(FU)$ is zero (and D5 is false), so that Argument D fails to establish a contradiction.

[22] *Proof.* Given EP and the admissibility of HT_f and $HT_f\neg B$, both $Cr(A|HT_f)$ and $Cr(A|HT_f\neg B)$ should be $f(A)$. On the other hand, $Cr(A|HT_f)$ should be $Cr(A|HT_fB)Cr(B|HT_f)+Cr(A|HT_f\neg B)Cr(\neg B|HT_f)$ (cf. E1). It follows that $f(A)$ should be $Cr(A|HT_fB)Cr(B|HT_f) + f(A)Cr(\neg B|HT_f)$. Equivalently: $Cr(A|HT_fB)$ should be $f(A)[1 - Cr(\neg B|HT_f)]/Cr(B|HT_f)$ – i.e., $f(A)$. It follows that HT_fB is admissible with respect to $\langle Ch(A) = f(A)\rangle$ (see beginning of note 4). The 'only if' part can be similarly proven.

[23] If the claim that $Cr(A)$ *should* be x is the claim that *every* rational agent assigns credence x to A (equivalently: some epistemic norm prescribes assigning credence x to A), then the claim that $Cr(A)$ *may* be x is the claim that *some* rational agent assigns credence x to A (equivalently: no epistemic norm prescribes assigning credence other than x to A).

[24] Or rather, equally *badly*, if neither of them is a priori true (because, like HS, they presuppose the truth of something like classical physics; see Section 6).

[25] No such world exists if an 'arrangement of qualities' – and thus the supervenience base in HS_1^* – is understood as specifying the noninstantiation of alien natural properties (Sturgeon 1998, pp. 327–330; cf. note 14). But on this understanding HS_1^* becomes equivalent to HS_1 as understood in the text, so the current amendment does not even get off the ground.

[26] Maybe a non-Humean variant of HS_1^* is plausible, according to which chances unrestrictedly supervene on non-chance properties. But then the corresponding variant of HS_2 (Section 4) would also be plausible (e.g., present chances might supervene on *present* atomic structures), and the derivation of the existence of undermining futures (Section 4) would be blocked.

[27] Is it possible to reconcile PP with an unrestricted version of HS or of HS_1? I don't know. Hoefer (1997), Roberts (2001), and Vranas (2002) propose such reconciliations, but these hinge on modifying PP or restricting its range of applicability.

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