The Probabilistic Explanation of Why There Is Something Rather than Nothing*

Matthew Kotzen
University of North Carolina at Chapel Hill
Department of Philosophy

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1 The Question

Our question is "Why is there something, rather than nothing?" There are at least two different interpretations of this question. First, we might be asking why there are *material things* rather than no material things. Second, we might be asking why there is *anything at all*—material or immaterial—rather than nothing at all. In this essay, I will be addressing one particular explanatory strategy for addressing both questions. To make sure there is no confusion, I'll use "something" in this context to refer to anything at all, and I'll use "some material thing" in this context to refer to any material thing. Our two questions are why there is something rather than nothing, and why there are some material things rather than no material things.

The force of the "rather than" clauses in our questions also needs to be addressed. The explanation of why Laurie ordered chocolate cake for dessert rather than nothing might be different from the explanation of why Laurie ordered chocolate cake for dessert rather than strawberry ice cream; she ordered chocolate cake rather than nothing because she was still hungry, but she ordered chocolate cake rather than strawberry ice cream because she is allergic to strawberries.[1] Similarly, the explanation of why there is something rather than nothing, or of why there are some material things rather than no material things, might be different from the explanation of why there are *these particular* things, or *these particular* material things, rather than different ones. We are interested only in why there are some things *rather than nothing* and in why there are some material things *rather than no material things*; a full explanation of these contrastive facts might give us no insight at all into why the things that

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[1]For discussions of contrastive explanation, see Dretske 1972, Garfinkel 1981, Lipton 1990, Lipton 1991a, Lipton 1991b, Lipton 1993, Ruben 1987, and van Fraassen 1980.

do exist are these particular ones, rather than different ones. When we explain why A rather than B is true, I'll refer to A as the "explanatory fact" and B as the "explanatory foil."

This essay is about the Probabilistic Explanation of why there is something rather than nothing and of why there are some material things rather than none. The basic idea of the Probabilistic Explanation is that there is some legitimate sense in which there are "more ways" for there to be something than for there to be nothing, and hence that it was more likely that the Universe would contain something rather than nothing. Of course, we'll develop and critically discuss the Probabilistic Explanation below. But first, we should get some preliminaries out of the way.

First, a lot of writers on explanation focus on causal explanation, and some writers can be reasonably interpreted to have argued that all or most explanation is causal in nature. Some philosophers think that, even if there are some non-causal explanations, all explanation of *events* is causal.[2] I don't know whether the coming-to-exist of something, or the coming-to-exist of material things, is an event in the sense that these philosophers have in mind. But I think that the Probabilistic Explanation is best regarded as an example of a non-causal explanation of some fact or state of affairs; thus, if the coming-to-exist of something and the coming-to-exist of material things are events, then the Probabilistic Explanation is inconsistent with views according to which all event-explanation is causal.

Second, some people might balk at the overtly probabilistic nature of the Probabilistic Explanation; they might argue that a genuine explanation of a fact or event must show why the fact or event *had* to occur, not just why it was *likely* to occur. But, quite independent of any considerations specifically to do with the Probabilistic Explanation, it is widely agreed that at least some legitimate explanations are probabilistic in nature.[3] When a coin that is heavily but not perfectly biased in favor of heads lands heads, we can't point to any considerations in virtue of which the coin was *guaranteed* to land heads—there are none, since the coin *wasn't* guaranteed to land heads—but it still seems as though the heavy heads-bias of the coin explains the fact that it landed heads.[4] If you prefer an indeterministic case, change the coin into a quantum particle, and suppose that the particle is in a state (call it S) in virtue of which it's very likely—but not guaranteed—to emerge from the left aperture of the box that it has just entered. Again, when the particle does emerge from the left aperture, that fact seems to be explained by the fact that the particle was in state S when it entered the box, even though that fact merely probabilifies the explanandum. So, if there is a problem with the explanatory strategy of the Probabilistic

[2] Lewis 1986, for instance, defends this view.

[3] The classic treatment of probabilistic explanation appears in Hempel 1965a. Other important treatments include Humphreys 1989, Mellor 1976, Railton 1978, Salmon 1970, and Strevens 2000.

[4] I think it's even clearer that the heavy heads-bias of the coin explains why it landed heads in a very high percentage of a large finite number of flips, though here too the heads-bias fails to guarantee the explanandum.

Explanation, I don't think that it is plausibly diagnosed by pointing to the fact that it appeals only to factors in virtue of which its explanandum was likely, rather than guaranteed.

2 The Intuition Behind the Probabilistic Explanation

Consider the following three cases:

> **Case 1**: DICE. Marc rolls a pair of dice and observes that the sum of the numbers on the two dice is 7, rather than 12. Here is a candidate explanation of that fact: there is only one way to roll a 12—the left die has to land on 6 and the right die also has to land on 6. But there are more ways (namely, six) to roll a 7—the left die could land on n for any $n \in \{1, 2, 3, 4, 5, 6\}$, and the right die could land on $7 - n$. So, any particular dice roll is more likely to yield a total of 7 than a total of 12, which explains why Marc's roll yielded a total of 7 rather than 12.

> **Case 2**: GAS. A gas is initially contained by a partition in a small corner of a box. The partition is removed, and the gas quickly spreads out to occupy the entire box, rather than staying contained in the small corner. Here is a candidate explanation of that fact: once the partition is removed, there are relatively few physically possible microstates of the gas that correspond to the gas remaining bunched up in the corner of the box, but there are (comparatively) far more physically possible microstates of the gas that correspond to the gas being approximately evenly dispersed throughout the box. So, once the partition is removed, any particular volume of gas is more likely to spread out than to stay bunched up, which explains why the gas in the box spread out rather than remaining bunched up.

> **Case 3**: BEACH. John decides to count all of the grains of sand on Daytona Beach.[5] After completing the count, he notices that the total is divisible by 8, but not by 7,296. Here is a candidate explanation of that fact: there are a lot more natural numbers that are evenly divisible by 8 than there are natural numbers that are evenly divisible by 7,296. So, it is more likely that any beach will have a number of grains of sand that is evenly divisible by 8 than a number that is evenly divisible by 7,296, which explains why Daytona Beach has a number of grains of sand that is evenly divisible by 8 rather than 7,296.

[5] Imagine that Daytona Beach has precise borders, so that there is no indeterminacy in whether a particular grain of sand is within its borders or not. This is of course quite implausible, but this idealization seems harmless in this context.

Each of the explanations above, I submit, has significant intuitive plausibility. By claiming this, I don't mean to be committing myself to the view that these explanations are exactly correct, or that they don't need to be precisified or developed in various ways; in fact, we'll be returning to these explanations below. But I hope that you agree that something in the general spirit of each of the above explanations is a very plausible candidate for explaining the relevant explanandum.

Now, consider:

> **Case 4**: SOMETHING. We look around and notice that there are some things, whereas there could have been none. Here is a candidate explanation of that fact: there are lots of possible ways for there to be some things—there could be exactly one proton, or there could be God and exactly one proton, or there could be two Gods and exactly one proton, or there could be two protons and one God, or there could be exactly 17 neutrons, etc. By contrast, there is only one way for there to be nothing—there are exactly zero protons, zero neutrons, zero electrons, zero people, zero tables, zero elephants, zero Gods, etc. So, the Universe was more likely to contain something that nothing, which explains why the Universe indeed contains something rather than nothing.

> **Case 5**: MATERIAL THINGS. We look around and notice that there are some material things, whereas there could have been none. Here is a candidate explanation of that fact: there are lots of possible ways for there to be some material things—there could be some protons, or some electrons, or some neutrons, or all three, etc. By contrast, there are comparatively fewer ways for there to be no material things—there would have to be no protons, or electrons, or neutrons, or any other kind of material object. So, the Universe was more likely to contain material things than none, which explains why the Universe indeed contains material things.

The idea behind the Probabilistic Explanation is that an explanation in the general spirit of the ones in SOMETHING and MATERIAL THINGS succeeds, just as in DICE, GAS, and BEACH. Notice that the explanations provided in SOMETHING and MATERIAL THINGS don't purport to explain why there are just *this* many material objects, or why there are *these* material objects rather than different ones; the explanations provided there are meant to explain only why there are some things rather than none. Similarly, the explanations in DICE, GAS, and BEACH endeavor only to explain why the relevant facts, *rather than their foils*, are true.

We should pause to note one difference between SOMETHING and MATERIAL THINGS. In SOMETHING, it is plausible that there is *only one* way for there to be nothing, since it seems as though we have fully specified what the Universe is like when we say that there is *absolutely nothing* in it.[6] By contrast, in MATERIAL THINGS, we haven't yet fully specified what the Universe is like simply by saying that there are no *material* things in it, since we've left unspecified whether there are immaterial things like Gods, numbers, properties, etc., (as well as how many of them there are, and which ones there are) and thus there are lots of ways for there to be no material objects (there can be no material objects and one God, no material objects and two Gods, etc.). Arguably, DICE is more like SOMETHING, since in both cases there is only one way for the explanatory foil to be true,[7] whereas GAS and BEACH are more like MATERIAL THINGS, since in those cases there are multiple ways for the explanatory foil to be true (even though it is intuitive that there are *even more* ways for the explanatory facts to be true). In the end, I don't think that this difference will matter, since the core of the Probabilistic Explanation applies to any case in which there are intuitively more ways for the explanatory fact to be true than for the explanatory foil to be true. But this will play a role in my discussion of van Inwagen's version of the Probabilistic Explanation in Section 4, so it is worth noting here.

Let's go back to BEACH. The explanation in BEACH appealed to the alleged fact that that "there are a lot more natural numbers that are evenly divisible by 8 than there are natural numbers that are evenly divisible by 7,296." But the standard definition of the cardinality of a set entails that two sets have the same cardinality if their members can be placed in one-to-one correspondence with each other,[8] and it is possible to place the set of all natural numbers that are evenly divisible by 8 into one-to-correspondence with the set of all natural numbers that are evenly divisible by 7,296. You simply place the members of each set in ascending order, and associate the nth member of the former set with the nth member of the latter set; thus, 8 gets associated with 7,296, 16 gets associated with 14,592, 24 gets associated with 21,888, etc. Thus, on the standard definition of the size of a set, the size of the set of natural numbers evenly divisible by 8 is the same as the size of the set of natural numbers evenly divisible by 7,296. So, in this sense, it's false that "there are a lot more natural numbers that are evenly divisible by 8 than there are natural numbers that are evenly divisible by 7,296."

Does this mean that the explanation in BEACH fails? The intuition behind this explanation is extraordinarily gripping, and I think we should be very hesitant to give up the claim that there is something explanatorily legitimate in

[6]Complications here might arise to do with which laws, or dispositions, or counterfactuals are true. On some views, specifying that there is *absolutely nothing* in the Universe still leaves open which laws, dispositions, or counterfactuals are true. By contrast, on "Humean" views such as David Lewis's, this isn't so. For reasons of space, I will have to ignore these complications here.

[7]I say "arguably," because it's not completely clear that there is only *one* way for the sum of the dice to be 12; after all, both dice could land 6 *and they land one inch from each other*, or both dice could land 6 *and they land two inches from each other*, etc. Perhaps this complication could be avoided if we constrained the system more tightly, so that there really was only one way for both of the dice to land 6. But, as will become clear below, I don't think that anything turns on this complication.

[8]See, e.g., Potter 2004, Chapters 4 and 9.

the ballpark. One natural thought here is that, even though the size of the set of natural numbers evenly divisible by 8 is the same as the size of the set of natural numbers evenly divisible by 7,296, we (and John) really know something more about beaches than just that they have *some* natural number or other of grains of sand; in particular, we know that every beach on Earth has fewer than some large finite number—10^{20}, say—of grains of sand. And, the cardinality of the set of all natural numbers *that are less than* 10^{20} and are divisible by 8 is certainly not the same as the cardinality of the set of all natural numbers *that are less than* 10^{20} and are divisible by 7,296; the former set is many times larger than the latter. So, given that Daytona Beach has some number of grains of sand *that is less than* 10^{20}, it really is more likely that the number of grains of sand it has is evenly divisible by 8 rather than 7,296, since there really are more natural numbers less than 10^{20} that are evenly divisible by 8 than by 7,296.

The above all seems correct, but I don't think that the fact that we (and John) know that the number of grains of sand on Daytona Beach is less than 10^{20} (or any other finite number) plays an essential role in vindicating the explanation in Beach. The reason for this is that an analogous explanation succeeds even in cases where we do *not* know that the relevant set of possibilities is finite.

Consider the following case:

> **Case 6**: Dart. Keith is about to throw an infinitely sharp dart at a dartboard. Though he is guaranteed not to miss the dartboard entirely, Keith has no control over where the dart hits on the dartboard. Once the dart lands, he is going to draw a line-segment from the point where it lands to the exact center of the bullseye. This line will form an angle with a vertical line-segment that has already been drawn, beginning at the center of the bullseye and extending vertically upwards. (The angle will be less than 180° if the dart lands on the right side of the dartboard, and will be greater than 180° if it lands on the left side of the dartboard.) Keith will then measure the angle (in degrees) that the two lines form.[9] Keith throws the dart and measures the angle, and notices that the fifth decimal place of the angle is not 7. Here is a candidate explanation of that fact: there are more real numbers between 0 and 360 that have a digit other than 7 in their fifth decimal place than there are real numbers between 0 and 360 that have a 7 in their fifth decimal place. So, it is more likely that any particular dart (thrown by Keith) will form an angle that doesn't have a 7 in its fifth decimal place than that it will form an angle that does have a 7 in its fifth decimal place, which explains why the dart that Keith threw has a number other than 7 in its fifth decimal place, rather than a 7.

The explanation offered in Dart seems to be very much like the explanation offered in Beach. And the same criticism of the explanation in Beach we

[9]For the purposes of this case, it won't matter whether we say that a dart that lands exactly on the vertical line forms a 0° angle or a 360° angle. If the dart lands precisely on the center of the bullseye, we'll stipulate that the angle formed is 0°.

considered above could be legitimately raised against the explanation in Dart: the set of real numbers between 0 and 360 that have a 7 in their fifth decimal place can be placed in one-to-one correspondence with the set of real numbers between 0 and 360 that do not have a 7 in their fifth decimal place, so (on the standard definition of the size of a set) it is false that the former set is smaller than the latter set. But the response we considered in Beach—i.e., that there is some appropriate finite restriction of the relevant space in which it is strictly true that there are more elements that are instances of the fact-type than those that are instances of the foil-type—doesn't apply in Dart; in Dart, we have no further knowledge of the situation (analogous to the information that the number of grains of sand is less than 10^{20}) that can impose such a finite restriction.

Similar points apply to Gas. It is false that there are more spread-out microstates than there are bunched-up microstates; the elements of the two sets can be placed in one-to-one correspondence with each other. And there's no information that we have in virtue of which the set of possible microstates of the gas can be restricted to some finite set. Still, it seems, there is something in the general spirit of the explanations in Dart and Gas that succeed, and for roughly the same reasons that (something in the neighborhood of) the explanation in Beach succeeds. So, I think that finite restrictions of the relevant spaces in those two cases are red herrings.

The standard mathematical way of accounting for the intuition that one set can be in some sense "bigger" than another set even when they have the same cardinality is to appeal to *measure theory.* A measure is a function from certain subsets[10] of a given set X to the extended[11] non-negative real numbers, and it can be thought of as a generalization of the notion of length (or, in higher dimensions, area and volume); even though the points in a one-inch line can be placed in one-to-one correspondence with the points in a two-inch line (and hence the former set has the same cardinality as the latter set), the two-inch line can still have a *measure* that is twice as large as that of the one-inch line. Indeed, the standard Lebesgue measure has precisely this consequence.[12] So, by appealing to the Lebesgue measure, it seems that we might be able to vindicate the explanations in Dice, Gas, and Dart; the idea would be that the *measure* of the set of states in which the dice sum to 7 is greater than the *measure* of the set of states in which the dice sum to 12, the *measure* of the set of states in which the gas is spread out is greater than the*measure* of the set of states in which the gas is bunched up, and the *measure* of the set of states in which the dart forms an angle with a 7 in the fifth decimal place is greater than the *measure* of the state of states in which it doesn't. We can't *quite*

[10] The qualifier "certain" is required because, on the assumption of the Axiom of Choice, some measures are such that not all sets are measurable by that measure. Vitali 1905 first proved the existence of the Vitali set, which is not measurable by the standard Lebesgue measure.

[11] The "extended" non-negative real numbers are obtained from the non-negative real numbers by adding a single element: $+\infty$.

[12] See Tao 2011, section 1.2.

apply this analysis to Beach, since the Lebesgue measure can be defined only in spaces that can be represented as Euclidean n-dimensional *real-valued* spaces, and the space of possible numbers of grains of sand is natural-number-valued. The standard mathematical approach here is to appeal to something called an "asymptotic density," which yields the "proportion" of natural numbers up to n that have some property, in the limit as n approaches ∞.[13] Unsurprisingly, the asymptotic density of natural numbers divisible by 7,296 is lower (indeed: 912 times lower) than the asymptotic density of natural numbers divisible by 8. Asymptotic densities function much like measures for natural numbers; for a discussion of this analogy, see Buck 1946. In order to avoid these complications, I will focus on Dart rather than Beach below.

We will return to the Lebesgue measure in Section 4. But if it is right that an appropriate appeal to the Lebesgue measure can vindicate the explanations in Dice, Gas, and Dart, then it seems as though similar considerations may apply to Something and Material Things; in those cases, it's at least fairly plausible that the *measure* of the set of states in which something exists is larger than the *measure* of the set of states in which nothing exists. This is what I take to be the philosophical core of the Probabilistic Explanation.

3 Problem Cases

However, the explanations in Something and Material Things face a challenge: there are a number of cases that *seem* to be relevantly similar to those cases, and yet in which apparently analogous explanations fail. The question, then, is how to distinguish these cases from Dice, Gas, Beach, and Dart, and on which side of the distinction we ought to categorize Something and Material Things.

Here are a few such "problem" cases:

> **Case 7**: Restroom. You walk up to the airplane restroom, and the sign on the door is broken, so you are wondering whether or not it is occupied. You think to yourself, "There is only one way for the restroom to be unoccupied—namely, for nobody to be in the restroom. But there are lots and lots of ways for the restroom to be occupied—Dorit could be in there, or Bernie could be in there, or Mariska could be in there, or Doug and Susan could be in there, etc." So, you continue, it is more likely that this restroom is occupied than that it is unoccupied. You knock on the door and indeed hear a voice yell "There's someone in here!" You think to yourself, "That makes sense—the fact that there's someone in there is explained by the fact that there are so many more ways for the restroom to be occupied than there are ways for the restroom to be unoccupied.

> **Case 8**: Bomb. Dr. Evil has armed a universe-annihilating bomb and is threatening to detonate it unless his demands are met. The

[13] See Nathanson 2000 and Tenenbaum 1995 for discussions of asymptotic densities.

> police are pursuing him, but you are unsure of the status of either their pursuit or of any efforts to satisfy Dr. Evil's demands. You think to yourself, "There is only one way for the future to go if Dr. Evil detonates his bomb—namely, there will be eternal nothingness. But there are lots of ways for the future to go if Dr. Evil doesn't detonate his bomb—the Red Sox might win the World Series next year, or the Cubs might, or the Yankees might, etc." So, you continue, it is more likely that Dr. Evil will not detonate his bomb than that he will. In fact, Dr. Evil is apprehended later in the day, and his bomb is disarmed. You think to yourself, "That makes sense—the fact that Dr. Evil's bomb didn't detonate is explained by the fact that there are many more ways for the future to go if the bomb didn't detonate than if it did."
>
> **Case 9**: Strings. You hear two string theorists debating about string theory. One of them holds a theory on which spacetime has a total of 10 dimensions, whereas the other holds a theory on which spacetime has 26 dimensions. You think to yourself, "There are a lot more ways for spacetime to be arranged if spacetime has 26 dimensions than if it has 10 dimensions." So, you continue, it was more likely that spacetime would have 26 dimensions than that it would have 10 dimensions. Later, the scientific community comes to agree that the 26-dimension version of string theory is true. You think to yourself, "That makes sense—the fact that there are so many more ways for a 26-dimensional spacetime to be arranged than for a 10-dimensional spacetime to be arranged explains why spacetime is 26-dimensional rather than 10-dimensional."

I hope that you share my intuition that the explanations in Restroom, Bomb, and Strings are deeply problematic. There are, of course, some distinctions to be drawn among them. Bomb seems to be more like Dice and Something, where there is only one way for the explanatory foil to be true, while Strings seems to be more like Gas, Beach, and Material Things, where there are multiple ways for the explanatory foil to be true (though where it's intuitive that there are even more ways for the explanatory fact to be true). Restroom might seem to be like Bomb, Dice, and Something, since it might seem that there is only one way for the restroom to be unoccupied; however, just as the claim that there are no material objects leaves unspecified which immaterial objects there are, so too does the claim that the restroom is unoccupied (by humans) leave unspecified whether and how the restroom is occupied by non-human objects. Again, I don't think that this difference is the key to understanding the difference between the good explanations we've considered and the bad ones.

Moreover, it is worth noting that, if the explanations in Restroom and Strings were legitimate, that would seem to entail that it was *even more* likely that the restroom would have lots of people in it (after all, there are more ways for there to be lots of people in a restroom than for there to be only one), and that it was *even more* likely that spacetime would be 73-dimensional, or 473-dimensional, than that it would be 26-dimensional (after all, there are more ways for a 473-dimensional spacetime to be arranged than for a 26-dimensional spacetime to be arranged). Similarly, if the explanation of BOMB were legitimate, that would seem to entail that it is *even more* likely that the Universe will continue on for a very very long time without ever being annihilated by anything, since there are even more ways for a long-running Universe to develop than for a shorter-running Universe to develop. The analogous implication looks to be unproblematic in DICE, GAS, and BEACH; for example, it seems as though it *was* even more likely that the number of grains of sand on Daytona Beach would turn out to be divisible by 2 (say) than that it would be divisible by 8 (and even less likely that the number would turn out to be divisible by 2,491,237 than that it would be divisible by 7,296). But in RESTROOM, it was *not* more likely that more people would be in the restroom rather than fewer, and in STRINGS, it was *not* more likely that the Universe would turn out to be 473-dimensional rather than 26-dimensional.

4 Van Inwagen's Version of the Probabilistic Explanation

In his subtle and interesting paper "Why Is There Anything At All?,"[14] Peter van Inwagen offers a version of the Probabilistic Explanation.[15] van Inwagen's explanation has four premises:

1. There are some beings.
2. If there is more than one possible world, there are infinitely many.
3. There is at most one possible world in which there are no beings.
4. For any two possible worlds, the probability of their being actual is equal.[16]

Van Inwagen's version of the Probabilistic Explanation proceeds as follows:

> Now let *Spinozism* be the thesis that there is just one possible world.
> We proceed by cases.
> If Spinozism is true, then, by premise (1), it is a necessary truth that there are some beings, and the probability of there being no beings is 0. If Spinozism is false, then, by premise (2), logical space comprises infinitely many possible worlds. If logical space comprises infinitely many possible worlds, and if any two worlds are equiprobable—premise (4)—then the probability of every world is 0.

[14] van Inwagen 1996.
[15] Van Inwagen credits Robert Nozick (Nozick 1981, pp. 127–8) with having briefly presented a version of this argument.
[16] van Inwagen 1996, p. 99

> If a proposition is true in at most one world, and if the probability of every world is 0, then the probability of that proposition is 0. But then, by premise (3), the probability of there being no beings is 0. Hence, the probability of there being no beings is 0.[17]

According to van Inwagen, the fact that the probability of there being no beings is 0, then, explains why there are beings rather than no beings.

Van Inwagen is quite explicit that his explanatory goals are limited to the explanation of why there is something rather than nothing, and do not extend to the explanation of why there are material things rather than no material things: "The conclusion of the argument is not about the probability of there being no physical beings, but about the probability of there being no beings of any sort."[18] And it's clear that van Inwagen's argument as he presents it can be generalized only to cases in which the explanatory foil is true in only one possible world; this is true in SOMETHING, but false in MATERIAL THINGS.

Still, in order to accommodate explanations like those in GAS, BEACH, and DART (as well as DICE, perhaps), and in order to be able to assess the explanation in MATERIAL OBJECTS, it seems as though we need to extend our discussion beyond cases in which there is only one way for the explanatory foil to be true.

Van Inwagen's central premise (4)—the one that van Inwagen characterizes as "the one that people are going to want to dispute"[19]—is that each possible world has the same probability; on the assumption that there are infinitely many possible worlds, each possible world must therefore have probability 0. If that's right, then (again, assuming infinitely many possible worlds) any proposition that is true in only one possible world (such as the proposition that there are no beings) must have probability 0 too, and hence the negation of any such proposition must have probability 1. Presumably, van Inwagen would be happy to say that any proposition that is true in only a *finite* number of possible worlds also has probability 0 (since any finite sum of 0's is equal to 0), and hence that the negation of any such proposition has probability 1. But in order to extend our discussion to cases in which the explanatory foil is true in infinitely many cases, it seems as though we need to appeal to measure-theoretic strategy introduced in Section 2.

Why does van Inwagen accept premise (4)? He first defines the notion of a *maximal* state of a system: a state x is maximal if it is inconsistent with any state y such that x fails to entail y. Consider a system consisting only of two electrons, A and B, each of which can be in either of two states, spin-up or spin-down. The state x_1 of A and B being in the same spin-state is not maximal; x_1 neither entails nor is inconsistent with the state x_2 in which A and B are each in the spin-up state. But x_2 is maximal, since for each possible state y of the system, x_2 either entails y or is inconsistent with it; x_2 entails x_1, for example, and it is inconsistent with the state x_3 in which A and B are each

[17] van Inwagen 1996, p. 100.
[18] van Inwagen 1996, p. 100.
[19] van Inwagen 1996, p. 101.

in the spin-down state. Van Inwagen then defines a system to be *isolated* with respect to a certain set of its states when "no facts about objects external to the system could in any way have any influence on which of those states the system was in."[20]

Van Inwagen proposes that "for any system of objects (that has maximal states) the maximal states of the system should be regarded as equally probable, provided that the system is isolated."[21] Call this the MAXIMALITY CONSTRAINT. Since possible worlds are maximal states of Reality, and since Reality is isolated, van Inwagen concludes that each possible world must be equally probable. Moreover, according to van Inwagen, we can know *a priori* that each possible world is equally probable, since we can know *a priori* both that possible worlds are maximal states of Reality and that Reality is isolated (and, presumably, we can know the MAXIMALITY CONSTRAINT *a priori* as well); according to van Inwagen, "[w]e do seem to have some capacity for determining *a priori* that some states of some systems are of equal probability."[22]

Clearly, the MAXIMALITY CONSTRAINT will deliver us the result that the probability of there being no beings is 0, which is sufficient for van Inwagen's own explanatory purposes. But to extend our discussion to cases where there are infinitely many ways for the explanatory foil to be true, we need some analogous principle that allows us to say that that the measure of possible worlds in which the explanatory facts are true in GAS, BEACH, and DART is larger than the measure of possible worlds in which the explanatory foils are true. As discussed in section 2, the most natural way to do that is to appeal to a measure (like the Lebesgue measure) which assigns a higher measure to each explanatory fact than to its corresponding explanatory foil.

What is it about the Lebesgue measure in virtue of which it is relevantly analogous to van Inwagen's MAXIMALITY CONSTRAINT? The intuitive idea behind the MAXIMALITY CONSTRAINT seems to be that, when two propositions p and q are each "maximal" in that they are each true in exactly one possible world, then they must have the same probability (i.e., 0), even if the single possible world in which p is true is different from the single possible world in which q is true. In other words, the "identity" of the world we're considering is irrelevant to its probability; from the standpoint of probability, each maximal possible world is interchangeable with any other one. A natural way, I think, to extend this notion to propositions that are true in infinitely many possible worlds is to say that "identity" of an *interval* is similarly irrelevant to *its* probability, and thus that any consistent linear translation of an interval will yield an interval with the same probability. Thus, for instance, since the (infinite) set of possible worlds in which some particular gas-particle's horizontal location is somewhere in the interval between the left wall of the box and the center of the box can be translated into the (infinite) set of possible worlds in which that particle is somewhere in the interval between the center of the box and the right wall of the box, we conclude that the particle's *probability* of being located in the former

[20] van Inwagen 1996, p. 104.
[21] van Inwagen 1996, p. 104.
[22] van Inwagen 1996, p. 103.

interval is the same as its probability of being located in the latter interval. And, since the Lebesgue measure has the special property of being *translation-invariant*,[23] it has seemed particularly well-suited to grounding probabilities like the ones that appear in GAS.

The Lebesgue measure also has the special property of being *rotation-invariant*; just as with linear translations, any consistent *rotation* of one set will yield a set with the same Lebesgue measure as the original. In DART, for instance, consider the proposition p that the dart lands in the region corresponding to 20 points, and the proposition q that the dart lands in the region corresponding to 19 points. The former region can be rotated into the latter region; by rotating the whole dartboard 162° counterclockwise, the former region will exactly coincide with the latter region. Thus, the Lebesgue measure of the 20-point region is the same as the Lebesgue measure of 19-point region; and since we want to say that the *probability* that a dart will land in each region of the dartboard is identical, the Lebesgue measure again seems fairly well-suited for grounding probabilities in cases like DART.

Thus, though I want to be quite explicit in acknowledging that van Inwagen never endorses such a principle, it seems to me that van Inwagen's MAXIMALITY CONSTRAINT is similar in spirit and motivation to the principle that we ought to associate a proposition's probability with its Lebesgue measure in the relevant space. Call this principle LEBESGUEISM.

However, I have several reservations about the MAXIMALITY CONSTRAINT and LEBESGUEISM, as applied to the cases we've been considering.

The first problem we have already seen; to the extent that the MAXIMALITY CONSTRAINT and LEBESGUEISM vindicate the good explanations in DICE, GAS, BEACH, and DART, they seem to similarly vindicate the bad explanations in RESTROOM, BOMB, and STRINGS. After all, exactly analogous reasoning to that in DICE, GAS, BEACH seems to lead to the conclusion that the explanatory facts in RESTROOM, BOMB, and STRINGS are more probable than their explanatory foils, which (I'm assuming) is the wrong result. Just as the Lebesgue measure of the set of bunched-up states is lower than the Lebesgue measure of the set of spread-out states in GAS, so too is the Lebesgue measure of the set of unoccupied states lower than the Lebesgue measure of the set of occupied states in RESTROOM, and similarly for BOMB and STRINGS. (This is particularly apparent in BOMB because, just as in SOMETHING, the set of states in which the explanatory foil is true is a singleton, and the Lebesgue measure assigns a measure of 0 to each singleton set.)

Second, there are well-known paradoxical results that arise from the so-called Principle of Indifference, which seem also to extend to the unrestricted application of LEBESGUEISM. Van Fraassen's famous "cube factory" case[24] (and variations thereon[25]) illustrates the point nicely. If all we know about a "mystery square" is that it is no more than two feet wide, how likely is it that the square is less than one foot wide? If we think of the space of possible *widths* of the square,

[23]See, e.g., Hunter ms pp. 19–20 and Tao 2011 pp. 46–79 for a discussion.
[24]See van Fraassen 1989, Chapter 12.
[25]See, e.g., White 2010.

then LEBESGUEISM entails that the probability is $\frac{1}{2}$, since the Lebesgue measure of the interval (0,1) is half as large as the Lebesgue measure of the interval (0,2). But if we think of the space of possible *areas* of the square, then the probability is $\frac{1}{4}$; a square with a width of 1 foot has an area of one square-foot and a square with a width of 2 feet has an area of four square-feet, and the Lebesgue measure of the interval (0,1) is $\frac{1}{4}$ the size of the Lebesgue measure of the interval (0,4). The lesson usually drawn from these sorts of cases is that, since the same possibilities can be parametrized differently, resulting in different spaces over which the Lebesgue measure can be defined, we can't use the Lebesgue measure to define probabilities. But this, of course, is precisely what LEBESGUEISM tries to do.

Third, consider an isolated system in which a fair coin is repeatedly flipped until it lands tails, at which point the system self-destructs. There are various maximal states of the system: (1) the coin lands tails on the first flip, at which point the system self-destructs, (2) the coin lands heads on the first flip and tails on the second flip, at which point the system self-destructs, (3) the coin lands heads on the first two flips and tails on the third flip, at which point the system self-destructs, etc. Each of these states is maximal, but I don't see any reason to assign these states equal probability; it seems clear to me that the first state has probability $\frac{1}{2}$, that the second state has probability $\frac{1}{4}$, that the third state has probability $\frac{1}{8}$, and so on. This strikes me as a counterexample to the MAXIMALITY CONSTRAINT.

Fourth, a Carnapian worry: Carnap objected to the equal assignment of probability to each possible "state description" on the grounds that such an assignment would lead to the impossibility of "learning from experience";[26] I think that the MAXIMALITY CONSTRAINT has similar unacceptably skeptical epistemological consequences. For simplicity, consider an isolated system consisting of Ram and an animal in front of him. Ram is having an experience as of a zebra in front of him. But there being a zebra in front of Ram (in such-and-such a position and orientation) and there being a mule cleverly disguised to look like a zebra in front of Ram (in such and such a position and orientation) both seem to be maximal states of the isolated system; thus, the MAXIMALITY CONSTRAINT entails that they are equally probable. Since Ram's total evidence (namely, his experience as of a zebra in front of him) doesn't distinguish between these two maximal states of the system, it seems as though Ram should be equally confident that he's looking at a zebra as he is that he is looking at a cleverly disguised mule.[27] Moreover, this point seems to generalize to other

[26] See Carnap 1950. Carnap's objection was that Wittgenstein's confirmation function $c\dagger$ precludes "learning from experience" because it fails to incorporate relations of inductive relevance. Carnap offered an alternative confirmation function $c*$ that was designed to remedy this defect. For a clear discussion of Carnap, see Salmon 1967, p. 72.

[27] I'm making two assumptions here. First, I'm assuming something in the neighborhood of Lewis's Principal Principle (see Lewis 1980), which plausibly justifies the move from the claim that the zebra-hypothesis has the same objective chance as the cleverly-disguised-mule-hypothesis to the claim that Ram (who, I'm also supposing, lacks any "inadmissible" information) should "initially" be equally confident in each hypothesis. Second, I'm assuming the principle that, if a rational agent initially has the same confidence in two hypotheses, and if

skeptical hypotheses; we can always fill in the details of the skeptical state in order to make it maximal, in which case the MAXIMALITY CONSTRAINT will entail that that hypothesis is just as likely as the corresponding maximal anti-skeptical hypothesis according in which the subject has the same total evidence as in the skeptical state. So, it seems that me that the only hope of responding to skepticism is to say that some maximal anti-skeptical hypotheses are more probable than their corresponding maximal skeptical hypotheses, which requires denying the MAXIMALITY CONSTRAINT.[28]

5 The Lesson

The core lesson that I draw from the above is that we should reject van Inwagen's reliance on *a priori* considerations to calculate the relevant probabilities in cases like SOMETHING and MATERIAL THINGS. On my view, we have no general *a priori* grounds to think that any two maximal states of an isolated system (or, in particular, any two possible worlds) will have the same probability. Similarly, we have no *a priori* grounds to think that, just because two propositions are identified with sets of possibilities in some space that receive the same Lebesgue measure, those two propositions must be equiprobable.

Rather, at least in many cases—including some that we have been considering—our reasons for assigning probabilities to propositions are at least partly *a posteriori* in nature. In these cases, it is only when we have good *a posteriori* reasons to assign equal probabilities to each possible world—or, to assign equal probabilities to sets that receive the same measure in some suitable space—that we are justified in so doing. Of course, none of this is to deny that we can sometimes have good *a priori* grounds for particular probability assignments. I have good *a priori* grounds for believing that the proposition that $1+1 = 3$ is necessary false, and hence for assigning it a probability of 0; similarly, I have good *a priori* grounds for believing that the proposition that all dogs are dogs is necessarily true, and hence for assigning it a probability of 1. And we can also have *a priori* grounds for making comparative probability assignments; my *a priori* knowledge that the proposition that it will rain tomorrow is logically weaker than the proposition that it will either rain or snow tomorrow grounds my assigning a probability to the latter proposition that is no lower than the probability I assign to the former proposition.

In cases like DICE and GAS and DART, I think, we do have strong *a posteriori* grounds for thinking that the explanatory facts are likelier than the explanatory

his total evidence doesn't support one of these hypotheses over the other, then he should still be equally confident of the two hypotheses after collecting that total evidence. This second assumption is entailed by Conditionalization, but doesn't entail it.

[28] Of course, even if we do deny the MAXIMALITY CONSTRAINT, it is not as though our anti-skeptical work is done; we still need a story about *why* certain maximal anti-skeptical hypotheses are more probable than their skeptical cousins. This is not the place to develop that story, and there are several different strategies we might pursue; perhaps certain maximal states are more likely because they're simpler, or more unified, or more fit for explanation, or have some other epistemically desirable feature.

foils. Strevens 1998 develops the view that such judgments are often grounded by an appeal to "symmetries in the mechanism of the chance setup in question."[29] North develops a similar view in North 2010.[30] Strevens considers the case of a roulette wheel, which is quite similar in relevant respects to DICE and DART. To simplify a bit, Strevens supposes that ω—the angular speed with which the roulette wheel is initially spun—is the only initial condition of the setup that varies from spin to spin and that affects the probability that the spin will result in the ball landing on a "red" number. According to Strevens,

> As a consequence of the assumption of determinism, the laws of nature together with the mechanism of the wheel determine a function $U_E(\omega)$ which is equal to one just in case ω causes a red number to be obtained on the wheel, zero otherwise.…"Red" and "black" values of ω form rapidly alternating bands; neighboring bands are of approximately equal size.… The equal size of the black and red bands is a consequence of the physical symmetry of the wheel, in particular, of the fact that at any point in any spin, the wheel takes approximately equal time to rotate through a red segment as it does to rotate through a black segment. I will say that such a $U_E(\omega)$ is *microconstant* with ratio 0.5.[31]

In the roulette case, Strevens appropriately emphasizes the "microconstancy" of $U_E(\omega)$, since it is plausible in that case that the narrow "red" bands of $U_E(\omega)$ are of approximately equal size to their neighboring "black" bands. The analogous claim is plausible in DICE; there, too, the "laws of nature together with the mechanism" of the dice-setup induce a microconstant function which takes the initial conditions of the dice-roll (orientation, position, and velocity of each die, say) as inputs and yield outcomes (ordered pairs $\{n, m\}$, where $1 \leq n, m \leq 6$) as outputs. This microconstancy allows us to conclude that each $\{n, m\}$ is equally likely, which allows us to calculate the probability of any particular *sum* by adding up the probabilities of the $\{n, m\}$ pairs that produce that sum; the result, of course, is that a sum of 7 is much more likely than a sum of 12. Similar remarks apply to DART; in that case, the microconstancy of the relevant U_E function will allow us to conclude that "outcomes" involving an angle with a 7 in the fifth decimal place are equiprobable with outcomes involving any other number between 0 and 9 in the fifth decimal place, and hence that outcomes with a 7 in the fifth decimal place are more probable than outcomes with a non-7 in the fifth decimal place.

I don't think that microconstancy plays such a starring role in all such cases (nor, I should say, does Strevens commit himself to such a view). If we individuate the outcomes in a dart-throwing case by the region of the dartboard

[29] Strevens 1998, p. 238.

[30] Whereas Strevens's view appeals only to "microconstancy" (explained below) and smoothness of the distribution of initial conditions, North appeals to the *uniformity* of the distribution of initial conditions, which is a stronger constraint. However, this difference won't matter for our purposes here.

[31] Strevens 1998, p. 239.

that the dart hits (1 through 20 plus the bullseye), then I don't think that the relevant U_E function is *micro*constant, since relatively large changes in initial conditions won't affect the result (since the relevant regions of the dartboard are large and connected), and hence the "bands" corresponding to each outcome will be much larger. But this isn't important; perhaps knowledge of microconstancy is just one of many *a posteriori* grounds for assigning equal probabilities to distinct outcomes. What is important for my purposes is that the grounds are *a posteriori* in nature rather than *a priori*; the reason that we are justified in assigning equal probabilities to the relevant outcomes in DICE and DART is that we know empirically that that relevant laws and the relevant mechanisms together determine a function which assigns those probabilities.[32,33] Crucially, it is *not* merely because we are able to construct a mathematical space of outcomes and *define* a particular measure over that space which assigns equal measures to different regions. If *that* were all there was to it, there would be nothing to prevent the construction of a space of outcomes in DICE which treated the *sums* as the fundamental outcomes, and hence which licensed the conclusion that an outcome of 12 is equiprobable with an outcome of 7. (This is just another version of van Fraassen's "cube factory" problem from Section 4.)

Of course, none of this is to impugn either measure theory itself or its relevance to the cases we've been considering. But another way of putting the point of this section is that we need *empirical reasons* to identify a proposition's measure in some space with its probability of obtaining; we can't just construct the space in a mathematically legitimate way and place our faith in the Lebesgue measure. And it's not that there's any problem with the Lebesgue measure in particular; if we have good empirical reasons to identify the probability of a proposition with its Lebesgue measure in a particular space, then I'm all for the Lebesgue measure. We just can't close our eyes in our armchairs and hope.

The above story explains what goes wrong in RESTROOM and BOMB and STRINGS. In those cases, we lack any empirical reason to assign equal probabilities to the different outcomes—to the outcome in which both Doug and Susan are in the restroom and the outcome in which nobody is in the restroom, to the outcome in which Dr. Evil detonates the bomb and to the outcome in which he doesn't, or to some set of 10-dimensional states of the world and a set

[32] I think that very similar considerations apply to GAS as well, though a full discussion of that case would require a fuller treatment of statistical mechanics than space allows. See, e.g., Davey 2008, Albert 2000 Chapter 3, and Sklar 1993 Chapter 2.

[33] In DART, there might be some sense in which I've *stipulated* a function that assigns those probabilities; in the description of the case, I said that Keith "has no control over where the dart hits on the dartboard," and perhaps that amounts to the stipulation that the relevant outcomes in DART get assigned equal probabilities. Or, perhaps, there is some background *a posteriori* knowledge about the science of human throwing behavior that is required in order to conclude that someone with "no control" throws darts that are equally likely to land on any two regions of the dartboard that have equal Lebesgue measures. This issue is subtle and I can't pursue it thoroughly here, but I don't think that this distinction will matter for any of my purposes in this paper. After all, it seems obviously illegitimate to simply *stipulate* that the various possible maximal states of the universe are equally probable, and this is certainly *not* van Inwagen's strategy; his goal is rather to *argue* for the claim that *a priori* considerations ground the judgment that maximal states of any system are equiprobable.

of 26-dimensional states of the world which have the same Lebesgue measure. In fact, depending on the case, we often have good empirical reasons *not* do to that; we might have empirical knowledge, e.g., that the relevant restroom spends more time in its "unoccupied" state than in its "occupied" state, or that the restroom is far less likely to be occupied by multiple people than it is to be occupied by one person. The putative explanations in these cases attempt to accomplish purely *a priori* what can in fact be done only *a posteriori*; without this necessary *a posteriori* grounding, the explanations fail.

The big question for us, then, is whether we have the necessary *a posteriori* grounds to endorse the putative explanations in SOMETHING and MATERIAL THINGS—i.e., whether we have good *a posteriori* grounds to assign an equal probability to an empty universe as to a universe in which there are 17 neutrons (in SOMETHING), or to assign an equal probability to a universe with one God and no material objects as to a universe with one God and one (or two, or three, etc.) material objects (in MATERIAL THINGS). I think it's clear that we are in possession of nothing *remotely* like the grounds for doing this in SOMETHING or MATERIAL THINGS as we have in DICE, GAS, and DART. Unlike in DICE, GAS, and DART, we certainly have no clear idea of the laws or initial conditions that determine the space of possible outcomes in SOMETHING or MATERIAL THINGS (if the notions of law and initial condition even *make sense* in this context). Absent that, I don't think that there's any reason for optimism that SOMETHING and MATERIAL THINGS will turn out to be more like DICE, GAS, and DART than they are like RESTROOM, BOMB, and STRINGS. At the very least, the burden seems to be on the defender of SOMETHING and MATERIAL THINGS to provide us with grounds for thinking that the relevant propositions really are equally probable. As I've argued, van Inwagen hasn't succeeded in doing that, and I'm not aware of anyone else who has fared any better.

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