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abstract

Many epistemological problems can be solved by the objective Bayesian view that there are rationality constraints on priors i.e. inductive probabilities. But attempts to work out these constraints have run into such serious problems that many have rejected objective Bayesianism altogether. I argue that the epistemologist should borrow the metaphysician's concept of *naturalness* and assign higher priors to more *natural* hypotheses.

Naturalness as a Constraint on Priors

1. Introduction

Many epistemological problems can be solved by the objective Bayesian view that there are rationality constraints on priors i.e. inductive probabilities. But attempts to work out these constraints have run into such serious problems that many have rejected objective Bayesianism altogether. I'm going to argue that the epistemologist should borrow the metaphysician's concept of *naturalness*. Roughly, I'm going to argue that we should assign higher priors to more *natural* hypotheses. There is nothing especially original in this idea – it can be found in Quinton (1957) and was popularized by Lewis (1983, 1984) – but I don't know of any explicit defences of it, and the most detailed discussions reject the idea (Huemer 2009, Jenkins 2013, Hedden 2016).

Section 2 explains the concept of naturalness, section 3 explains the epistemological problems it might solve, section 4 discusses Carnap's answer, section 5 argues that using naturalness improves on Carnap's approach and section 6 argues that explanationism relies on natural properties. Then I discuss some ways of working through the details of the positive view: section 7 offers two paths from the naturalness of properties to the probabilities of hypotheses and section 8 discusses the Principle of Indifference. Section 9 concludes.

2. Naturalness

What is naturalness? I don't wish to be committed to anything but the core role for the concept of naturalness, and I take the core role to be what Schaffer (2004) calls Minimality¹:

Minimality: The [perfectly natural] properties serve as a minimal ontological base.

p.94

¹ Schaffer actually defends the weaker: '*primacy*: sparse properties serve as the ontological basis for linguistic truths.' p.100 But the stronger thesis is easier to work with, and I want to set aside Schaffer's objections to Minimality (based on onion universes).

So the perfectly natural properties are the metaphysically fundamental properties, those upon which everything supervenes. Plausible candidates would be the properties of fundamental physics. Thus the beauty of a painting supervenes on the properties of the quarks (or whatever the fundamental particles turn out to be) that constitute it².

Various possible roles for naturalness are discussed by Dorr and Hawthorne (2013). The only one we need to discuss³ is Empiricism:

Empiricism: Determining whether a property is perfectly natural is primarily a matter of a posteriori investigation⁴

It will be important for my view that there is a role for the a priori in determining whether a property is perfectly natural.⁵ Specifically, I assume:

A Priori: Given a set of properties instantiated in some world *w*, it is a priori which of the properties are perfectly natural in *w*.

Let me say a little to make this plausible. Consider a Newtonian world *w* which instantiates mass, momentum, tablehood etc. We don't need further information about *w* to ascertain which

² And the constituents of the observers will be part of the supervenience base for subjectivists about beauty.

³ I remain neutral on all the other principles they discuss except Supervenience (which is entailed by Minimalism): Everything supervenes on the perfectly natural properties.

⁴ This differs from their formulation of Empiricism. But they later say that 'The kinds of views we want Empiricism to rule out are those on which the task of determining whether a property is perfectly natural is primarily a matter of a priori reflection.' I've kept their term 'primarily' which makes the thesis a bit nebulous; it might be compatible with my 'A priori' below on some precisifications.

⁵ It has been forgotten that Lewis held that it is necessary which properties are natural: 'The name 'natural' is borrowed from the familiar term 'natural kind'...The name has proved to have a drawback: it suggests to some people that it is supposed to be nature that distinguishes the natural properties from the rest; and therefore that the distinction is a contingent matter, so that a property might be natural at one world but not at another. I do not mean to suggest any such thing. A property is natural or unnatural simpliciter, not relative to one or another world.' 1986 p.60-61

properties are perfectly natural in w – we can ascertain a priori that mass is perfectly natural, while momentum and tablehood are not. We don't need information about the details of w , nor do we need information about whether w is actual or merely possible.

To fill this out, we can generalize from the example of a Newtonian world. Imagine a wide variety of physics textbooks describing different possible worlds – finding that one has an 'actuality' stamp on the back is irrelevant to deciding which properties are natural in the world described by each textbook. As Hedden (2016) puts it:

'it is a priori which properties are possibly natural, and being possibly natural and actually instantiated is necessary and sufficient for being natural.' p.726

In case this seems odd, consider the task of assigning priors. We consider every maximally specific a priori possible world. A posteriori considerations – evidence – eliminates possible worlds, but eliminating possible worlds is not going to help with the task of ascertaining which properties are natural in a given world. So evidence doesn't tell us which properties are natural in a given world.⁶

A question remains about exactly *how* we ascertain which of the instantiated properties are natural. I think this question has not received enough attention and I hope to address it elsewhere. My point here is that this question need not be answered by empirical investigation.⁷

Another challenge to the view that we can know a priori which properties are natural comes from Kripke-style examples e.g. *my chemistry teacher's favourite property* refers to the property of having charge, which might be natural, but this cannot be known a priori.

⁶ A limitation of my approach is that the priors will be relative to a set of fundamental properties; my approach will not inform priors over worlds with entirely different fundamental properties e.g. a Newtonian vs a quantum world. This mirrors Carnap's restriction to assigning priors to languages. Carnap (1950) thought choice of language was settled by pragmatics. I don't follow him here; but, mirroring Carnap, this paper will not address how we should assign priors to worlds with entirely different fundamental properties.

⁷ So I can agree with Titelbaum (2010 p.484) that agents cannot determine *empirically* which properties are natural.

I propose to sidestep this complication by restricting the discussion to concepts that pick out properties in a *transparent* way where ‘transparent concepts come with an especially direct grip on the corresponding entities in the world’ (Chalmers 2012 p.372).⁸ Concepts like *electron* (transparent) give us a grip on the property of being an electron, and concepts like *my chemistry teacher’s favourite property* (opaque) do not. So I will assume that given a complete description of a possible world using transparent concepts, a rational agent would be able to work out a priori which properties of that world are natural.⁹ This allows me to be sloppy about the property/concept distinction.

The locus classicus for naturalness is Lewis (1983), where he argues that the concept plays a role in many philosophical debates. Interestingly, Lewis does not address the role of naturalness in *epistemology* in any detail in that paper, or anywhere else. He shows how the concept of naturalness illuminates topics in metaphysics and the philosophy of mind¹⁰, but epistemology enters only indirectly through his interpretivism. Lewis thinks that what it is to believe *p* is to be best interpreted as believing *p*. Assigning determinate beliefs requires numerous constraints on interpretation, among them:

principles of...charity...Such principles call for interpretations according to which the subject has attitudes that we would deem reasonable for one who has lived the life that he has lived...It is here that we need natural properties. The principles of charity will impute a bias toward believing that things are green rather than grue...In short, they will impute eligible content, where ineligibility consists in severe unnaturalness

⁸ See Goff (2011) for discussion and further references.

⁹ So ‘proposition’ or ‘hypothesis’ will mean ‘Fregean proposition composed of transparent concepts’. Carnap individuated hypotheses at the level of sentences, but analytically equivalent sentences get the same probability i.e. we should assign the same probability to ‘*p*’ as we do to ‘not not *p*’. So sentences are more fine-grained than we need. And Russellian propositions are too coarse-grained – we should not assign ‘Hesperus is red’ the same prior probability as ‘Phosphorus is red’. So Fregean propositions have the right level of granularity for credences.

¹⁰ Duplication, Supervenience, and Divergent Worlds; Materialism; Laws and Causation; The Content of Language and Thought

of the properties the subject supposedly believes...himself to have [i.e. unnaturalness of beliefs.¹¹] p.375

So the epistemological assumption that it is more reasonable to believe that all emeralds are green than grue is needed for his theory of mind, which in turn is needed for his theory of language.¹² But there is no defence of this epistemological assumption, leaving a gap at the base of the argument.

Setting aside Lewis, Hedden (2016) writes:

perhaps the most popular proposed solution to the Goodman's grue paradox...posits a distinction between natural properties and unnatural ones.... In general, hypotheses with natural properties received higher degrees of evidential support than hypotheses with unnatural properties. p.724

Yet this proposed solution has received very little discussion, and even less defence. I will do my best to defend it.

3. Induction and Priors

I'll assume the standard Bayesian model according to which agents have prior probability functions that are updated by conditionalization. Our question concerns whether there are rationality constraints on priors.¹³ I take constraints on priors to be a primitive posit; as such, they are motivated by the work they do.

¹¹ This surprising reference to properties the agent believes himself to have is presumably due to Lewis's (1979) theory that to believe a proposition is to self-ascribe a property.

¹² See Weatherson (2010), Schwarz (2014)

¹³ Maher (2006a, 2006b). Note that objective chance is another concept altogether that plays no role in this discussion.

In this section, I show how specific distributions of priors deal with the problem of induction, drawing on the Carnapian heritage of the view. In the following sections I engage with differing theories of *what it is* that privileges some hypotheses over others.

Start with the problem of induction. Suppose we have two emeralds, a and b, which can be green or blue. How should we assign priors? Suppose we first assign the four possibilities the same prior¹⁴:

$$w1: P(a \text{ is green} \ \& \ b \text{ is green}) = 1/4$$

$$w2: P(a \text{ is blue} \ \& \ b \text{ is green}) = 1/4$$

$$w3: P(a \text{ is green} \ \& \ b \text{ is blue}) = 1/4$$

$$w4: P(a \text{ is blue} \ \& \ b \text{ is blue}) = 1/4$$

It follows that:

$$P(a \text{ is green}) = 1/2$$

But what happens when we learn that b is green? Intuitively, the probability that a is green should rise. Call such a prior an *inductive prior*. The problem is that this is not an inductive prior – it turns out that on this distribution, $P(a \text{ is green} \mid b \text{ is green}) = P(a \text{ is green}) = 1/2$. We can work through what happens if we learn that b is green – just eliminate the bottom two rows and re-normalize (and we can drop reference to ‘b is green’ on the left hand side):

$$P(a \text{ is green} \mid b \text{ is green}) = 1/2$$

$$P(a \text{ is blue} \mid b \text{ is green}) = 1/2$$

¹⁴ Carnap’s (1952, p. 38) ‘cross’ measure; his ‘star’ measure is below. See Salmon 1967 for a helpful discussion.

The result is a failure to learn from experience.

What we need is a prior probability function such that: $P(a \text{ is green} \mid b \text{ is green}) > P(a \text{ is green})$.

We can generate such a probability function by assigning a higher prior to $P(a \text{ is green} \ \& \ b \text{ is green})$ than to $P(a \text{ is blue} \ \& \ b \text{ is green})$. That is, we favour the hypothesis that says that both emeralds are the same colour e.g.¹⁵:

$$w1: P(a \text{ is green} \ \& \ b \text{ is green}) = 1/3$$

$$w2: P(a \text{ is blue} \ \& \ b \text{ is green}) = 1/6$$

$$w3: P(a \text{ is green} \ \& \ b \text{ is blue}) = 1/6$$

$$w4: P(a \text{ is blue} \ \& \ b \text{ is blue}) = 1/3$$

Now what happens if we learn that b is green? We eliminate all but the top two possibilities, and re-normalize:

$$w1: P(a \text{ is green} \ \& \ b \text{ is green}) = 2/3$$

$$w2: P(a \text{ is blue} \ \& \ b \text{ is green}) = 1/3$$

On this model $P(a \text{ is green} \mid b \text{ is green}) = 2/3 > P(a \text{ is green}) = 1/2$, so this is an inductive prior. If this distribution of priors can be *justified* we will have solved the problem of induction.

In fact it is plausible that rational constraints on priors are the *only* way to solve the problem of induction.¹⁶ To see why, consider the empiricists who want to avoid any constraints on priors and who suggest that a preference for theories with some virtuous feature is a posteriori.¹⁷ For

¹⁵ In Carnap's terminology, we move from assigning the Principle of Indifference over the *state* description to assigning it over the *structure* description.

¹⁶ I can't give a full defence of this here. I argue elsewhere that analytic defences are a priori, and the pragmatic vindication is a sceptical position (Author a).

¹⁷ Salmon 1970: 85–86; 1985:13; 1990:186, Boyd 1973; 1981; 1984, Sober 1981, Laudan 1987, Psillos 1999 ch. 8. This is one strand of the naturalism associated with Quine.

concreteness, let's suppose the virtuous feature is simplicity. They argue that we should prefer simpler theories to the extent that such theories have turned out to be successful (accurate/true) in the past. But just because simpler theories have been successful in the past, why think they will be successful in the future? Answering this question requires an answer to the problem of induction. The empiricists have argued in a circle.

For example, if there are no constraints on priors then there is nothing to stop us assigning priors that generate the following conditional probability:

$$P(\text{Overly complex contemporary theory} \mid \text{Simpler theories have been successful in the past}) = \text{High}$$

Without constraints on priors there is nothing to block this sceptical, counter-inductive likelihood, according to which the success of simple theories in the past confirms current overly complex theories.

Let's now assume that there are rationality constraints on priors of the kind that produce the results above: the hypothesis that all emeralds are green has a higher rational prior than the hypothesis that all emeralds are grue. The question is: what feature of 'all emeralds are green' gives it this special privileged status? The request is for a grounding principle – in virtue of what does 'all emeralds are green' have a relatively high prior?

I can think of three plausible answers:

a) Epistemic fundamentality. Hypotheses that postulate uniformity with respect to epistemically fundamental concepts are privileged

b) Metaphysical fundamentality. Hypotheses that postulate uniformity with respect to metaphysically fundamental properties are privileged

c) Explanationism. Hypotheses that are good explanations are privileged.

It is worth emphasizing that these seem to be the only plausible answers; my criticisms of a) and c) are probably more convincing than any positive argument I can give for b), but I know of no alternative theories. I will use my criticism of (a) (section 4) as a spring board to my defence of (b) (section 5). Then I will argue against (c) (section 6).

4. Carnap's theory: Epistemic Fundamentality

Carnap initially tried to identify the privileged set of hypotheses on purely formal, *syntactic* grounds. For example, '*all emeralds are green*' is syntactically simpler than '*a is green and b is blue*'.¹⁸ Assigning a higher prior to syntactically simpler hypotheses helps motivate the following inductive distribution¹⁹:

$$w1: P(\text{all emeralds are green}) = 1/3$$

$$w2: P(a \text{ is blue} \ \& \ b \text{ is green}) = 1/6$$

$$w3: P(a \text{ is green} \ \& \ b \text{ is blue}) = 1/6$$

$$w4: P(\text{all emeralds are blue}) = 1/3$$

But Goodman (1955) showed that formal grounds aren't enough. The hypothesis '*a is blue & b is green*' can be abbreviated to '*all emeralds are grue*'.²⁰ Similarly, let '*all emeralds are green*' be written as '*a is bleen and b is grue*' and '*all emeralds are blue*' be written as '*a is grue and b is bleen*'. Assigning a higher prior to syntactically equally simple hypotheses *in the grue language* results in the counter-inductive distribution²¹:

¹⁸ A formal account of the distribution of priors would have kept the analogy between inductive logic and deductive logic, which is also formal.

¹⁹ In our toy models with two objects 'all' means 'both'

²⁰ For our purposes, a grue emerald is [green and discovered first] or [blue and discovered second]. A bleen emerald is [blue and discovered first] or [green and discovered second]. b is discovered first.

²¹ This distribution generates the result that $P(a \text{ is green} \mid b \text{ is green}) = 1/3 < P(a \text{ is green}) = 1/2$ i.e. $P(a \text{ is bleen} \mid b \text{ is grue}) = 1/3 < P(a \text{ is bleen}) = 1/2$.

w1: $P(a \text{ is bleen and } b \text{ is grue}) = 1/6$

w2: $P(\text{all emeralds are grue}) = 1/3$

w3: $P(\text{all emeralds are bleen}) = 1/3$

w4: $P(a \text{ is grue and } b \text{ is bleen}) = 1/6$

Carnap explicitly addressed the problem in a largely forgotten discussion. In 'Studies Inductive Logic vol. 1' (1971 p.70-73) he offers a detailed set of rules that has the effect of ruling out grue as an *admissible* concept, where admissible concepts are associated with sensory modalities. For example, a family of admissible concepts – colour concepts – would be associated with the visual field, a different family would be associated with auditory sensations, and so on. So the admissible concepts are those we would think of as *epistemically fundamental* - those at the base of our conceptual scheme, which cannot be defined in terms of other concepts. Grue is not epistemically fundamental, but green is.

The objection I want to make is that epistemic fundamentality is too subjective. Colour concepts are epistemically fundamental for humans, but other concepts may be epistemically fundamental for aliens. So using epistemically fundamental concepts introduces a strong element of subjectivity into our priors. Carnap endorsed this subjectivity, but our aim is to defend *objective* constraints on priors, which cannot depend on contingent features of our physiology.

A Carnapian might reply that they have objectivity enough. They do not have *interpersonal* constraints, which apply to all agents; they have *intrapersonal* constraints, which are fixed for each agent, but may differ across agents.²² Intrapersonal constraints allow that my constraints may not be the same as your constraints. Specifically, each agent's constraints depend on their fundamental epistemic concepts.

²² Kelly 2013 section 3

One virtue of this Carnapian position is that it entails that most humans share the same constraints because they share the same sensory organs, and so the same epistemically fundamental concepts. This explains the pressure we feel to resolve disagreements, a pressure which is usually taken to support interpersonal constraints. Instead, it can support intrapersonal constraints given the contingent fact that most humans have the same sensory organs.

I have no knock-down objection to this Carnapian position, but it seems to lead to some implausibility. First, it requires that we have a priori access to which concepts are epistemically fundamental. And it seems that we have no such access – for example, we cannot learn a priori that we can see in colour rather than only seeing black and white. We have to open our eyes and have experiences to discover that we can see colours, and thus discover what our epistemically fundamental concepts are. Waiving that problem, this position implies that if our epistemically fundamental concepts changed, our priors should change. To make this vivid, imagine two agents with no experiences discussing what their priors should be. (Perhaps two fetuses communicate telepathically in the womb.) Initially they have the same sensory organs, and so agree about what their priors should be. Then one of them has their eyes enhanced, giving them an extra receptor which allows them to see infrared. According to the current theory, they should change their priors. But why should this change to their eyes change their priors about what the world is like?

We don't really need agents with no experiences to make the point. Imagine that you suddenly grow infrared receptors. According to the current theory, this should alter your priors. This case is more complicated because you already have a posteriori beliefs – should your past evidence be reassessed in the light of your new epistemically fundamental concepts? It's hard to see what this operation would look like.

But the problem is not that the Carnapian is committed to a complicated operation on credences. The problem is that changes in epistemically fundamental concepts do not seem to be the right kind of thing to generate a change in priors. Our priors should not be sensitive to contingent features of our physiology.

5. Naturalness: Metaphysical Fundamentality

My suggestion is that we retain that hypotheses are privileged by fundamentality, but understood as *metaphysical* fundamentality rather than *epistemic* fundamentality. This solves the problem above – what is metaphysically fundamental does not vary with the physiology of agents. Metaphysical fundamentality has the intrapersonal objectivity we need.

Why think that hypotheses are privileged by metaphysical fundamentality? I take this to be primitive. Specifically, what I take to be primitive are particular grounding principles – those connecting prior credence functions privileging metaphysically fundamental properties and rationality. And it is plausible that there are no explanations of grounding principles. As Shamik Dasgupta writes:

For suppose (just to take a toy example) that it is essential to knowledge that someone knows only if she truly and justifiably believes. And suppose someone asks what explains this (in the metaphysical sense). In virtue of what (the question is) is it part of what knowledge is that someone knows only if she truly and justifiably believes? It is difficult to know how to respond. One is tempted to say that this is just what knowledge is...but of course this is what we were asked to explain! In saying this one is most naturally heard not as trying to explain this fact about knowledge in any serious sense but rather as deflecting the demand for explanation.

Or suppose that it is essential to water that it is a substance composed of H₂O, and suppose someone asks what explains this (in the metaphysical sense)...In virtue of what is it part of what water is that it is composed of H₂O? It is again hard to know what to say other than that is just what water is! And in saying this one is again most naturally heard as sidestepping the question rather than giving it a serious answer.

(Dasgupta 2016 p.386)

Dasgupta never quite says it, but the implication is clear: there are no explanations of grounding principles. Applied to our case, the issue is whether some prior credence function (grounding property) is rational (grounded property). Suppose some prior credence function, *C*, assigns a relatively high prior to hypotheses that postulate uniformity with respect to metaphysically fundamental properties (in the right way²³). The analogous claim to those above is that *it is essential to rationality that if an agent has prior credence function C then they are rational*. In virtue of what is it part of what it is to be rational that if an agent has prior credence function *C* then they are rational? I think that this has no answer, just like the examples above.

Someone might object that this case is more controversial than the claims about knowledge and water. So how do we make judgments about *contentious* primitive principles? The standard method is to appeal to examples, where our intuitions are clearest. Compare the methodology of ethics. How do ethicists argue for or against, say, 'pleasure is good'? The standard approach is not to argue from more fundamental principles; the standard approach is to describe a case and argue that their preferred principles deliver the correct verdict. For example, a problem for 'pleasure is good' is the case where pleasure is maximized by creating a vast number of people whose lives are just about worth living. Our judgment that this is not a good world drives us to reject or modify 'pleasure is good'.²⁴

I suggest the same approach in epistemology. As in ethics, we have grounding principles connecting the descriptive with the normative.²⁵ Having a credence function is a descriptive property; being rational is a normative property. Our judgments are clearest about cases, and we can use our judgments about cases to derive our principles. So let's consider a case which has been discussed in the literature.

²³ A credence function might assign 100% to hypotheses which postulate uniformity with respect to metaphysically fundamental properties, but this would not assign a high prior in the right way. Obviously what the right way is is a matter for further investigation.

²⁴ Derek Parfit (e.g. 2011) is a leading exponent of this approach.

²⁵ I argue in [Author, forthcoming] that the principles will need some kind of 'that's all' clause.

In the debate between Jerry Fodor (1974, 1997) and Jaegwon Kim (1993) about whether there are autonomous higher level laws of nature, Kim introduces the example of jade. Both sides agree that being jade is a disjunctive property, consisting of being jadeite or being nephrite. In our terms, jade is metaphysically disjunctive – it consists of two different minerals which share relatively few metaphysically fundamental properties. And we can assume that being jade is a relatively *epistemically* fundamental concept – instances of jade all look the same, feel the same etc.

Kim argues that being jade is not *projectable* – in our terms, being jade should not have a relatively high prior. Kim infers from jade being non-projectable to jade being non-lawlike, and concludes there are no higher level laws.

Fodor thinks there are higher level laws. The point I want to make concerns what Fodor *doesn't* do. He doesn't argue that jade *is* projectable on the grounds that jade is relatively epistemically fundamental. He doesn't even mention the idea in passing. Furthermore, I don't know of any anti-reductionist who argues for the projectability of epistemically fundamental but metaphysically disjunctive properties. Yet this is exactly what the Carnapian would do – and it would support the popular view that there are higher level laws. I think this is significant because it shows that when we have a concrete case, where intuitions are clearest, there is no temptation to project epistemically fundamental concepts.

This example has a couple of complications. One is that being jade is logically entailed by being jadeite (or by being nephrite), so being jade always has a higher probability. But we can avoid this by using cross-cutting examples e.g. imagine jadeite causes different responses in us in some circumstances, so there are instances of jadeite that are not jade. A further complication is the talk of *relative* fundamentality, which I don't want to use.

We can avoid all such complications by putting the point a bit more abstractly. Compare the following two properties:

appearing y to agents of type h

having fundamental property p

Suppose some F has both properties. Should this better support that all F appear y to h or that all F are p? I say the latter, and I take this to follow from the nature of rationality. We can get this result if we assign higher priors to hypotheses that postulate uniformity with respect to metaphysically fundamental properties than to hypotheses that postulate uniformity with respect to epistemically fundamental concepts.²⁶

This completes my positive case for the view that hypotheses are privileged by metaphysical fundamentality. A competing answer is that the privileged sets are those that are most *explanatory*. I will argue in the next section that appeals to explanation are incomplete or implicitly rely on naturalness.

6. The Incompleteness of Explanationism

Huemer (2009) and Hedden (2016) independently argue that we should favour hypotheses that provide the best *explanation* for our evidence. Call this explanationism²⁷. To know which explanation is *best*, we first have to know what makes an explanation *good*. Call the features that make an explanation good the explanatory virtues. I will argue that plausible accounts of the explanatory virtues require naturalness.

²⁶ Some people might still be puzzled by the connection between naturalness and epistemology. Why are natural propositions epistemically privileged? How do we connect a metaphysical claim about naturalness with an epistemic claim about justification? e.g. Jenkins (2013) says the view that some propositions have justification in virtue of some intrinsic features 'is at risk of sounding like a claim to the effect that some property of propositions magnetizes justification 'by magic'.' p.106 But this is not an objection specific to naturalness. The same problem applies to whatever concept we appeal to. For example, if we appeal to syntactic simplicity, the question will be: why are syntactically simple propositions epistemically privileged? I think these are special cases of the problem of the truth-connection for justification internalism (Poston (2018 3.a.)).

²⁷ See White (2005) for a similar account. White focusses on urgency and stability, which seem to me to be empirical virtues. But this doesn't matter here, as it is widely agreed that simplicity is a virtue, and my argument is that appeals to simplicity reduce to appeals to naturalness.

There are two factors contributing to the goodness of an explanation – how well the hypothesis predicts the data (empirical virtues) and the intrinsic qualities (theoretical virtues) of the hypothesis, such as simplicity. Einstein makes clear the contrast:

The first point of view...is concerned with...confirmation...by the available empirical facts. The second point of view is not concerned with the relation of the material of observation but with the premises of the theory itself, with what may briefly be characterized as the 'naturalness' or 'logical simplicity' of the premises... The second point of view may briefly be characterized as concerning itself with the 'inner perfection' of a theory, whereas the first point of view refers to the 'external confirmation'. (Einstein 1949 Autobiographical Notes, in Schilpp p. 21-22)

The first factor / point of view won't help us. We need a priori constraints, so constraints based on evidence are beside the point. Indeed, the problem cases arise where the hypotheses predict the evidence equally well, and so have equally good empirical virtues e.g. green vs. grue.

Let's move on to the second factor: theoretical virtues. Popular candidates for theoretical virtues include coherence, scope, abstraction, generality, unification and simplicity.²⁸ The appeal to explanatoriness therefore seems to be a place-holder for a long list of purported virtues, and has little content unless we have some substantive grip on what these virtues amount to. My objection focusses on simplicity, which is widely agreed to be a theoretical virtue. Hedden (2016) writes:

I won't attempt to give an analysis of explanatory goodness. Indeed, I doubt whether such an analysis is possible. But as a first pass, the most basic explanatory virtues, the features that make a potential explanation a good one, include the extent to which the potential explanation is simple... p.735

²⁸ Kuhn (1977)

But the concept of simplicity can be filled out in incompatible ways. If simple hypotheses are those which are syntactically simple, then Hedden faces the grue objection. If simple hypotheses are those with fundamental concepts, Hedden is defending Carnap's (1971) theory. If simple hypotheses are those which refer to metaphysically simple properties, then Hedden appeals to naturalness. I think the latter is the best way of filling out Hedden's suggestion, so we end up appealing to naturalness. The more general point is that explanationism requires a substantive conception of simplicity.²⁹

Let's move on to Huemer's defence of explanationism. Huemer argues that we should 'assign equal probabilities at *the most explanatorily basic level*' p.354-5. He relies on examples to demonstrate how he understands 'most explanatorily basic level'. I will argue that his account relies on a concept of naturalness.

What does Huemer mean by 'explanatorily most basic level'? The following example, I think, makes the best case for his position, and also shows how natural properties get into the picture.

Example 4. You are informed that a conscious brain has recently been artificially created...The brain has been put in one of the 4 million possible states recognized by modern brain science. Assume that mental states supervene on physical states, and that 100,000 of the 4 million possible brain states realize overall painful mental states, 50,000 realize pleasurable mental states, and the remainder realize hedonically neutral mental states... What is the probability, on this information, that the brain is in pain?

Solution #1: The brain is either in a painful state, in a pleasurable state, or in a hedonically neutral state. Applying the Principle of Indifference, each of these alternatives has a probability of 1/3.

²⁹ This is a problem for views that place explanation at the heart of epistemology e.g. Poston (2014).

Solution #2: Each of the possible brain states is equally probable. Since 100,000 of those states realize pain, the probability that the brain is in pain is $100,000/4,000,000 = 0.025$.

... Solution 1 is intuitively wrong. One should not assign $1/3$ probability to the brain's being in pain, because the brain's hedonic state is determined by its (*explanatorily prior*) physical state, and only 0.025 of the possible physical states give rise to pain. (p. 356 *Italics added*)

Huemer's appeal to explanation seems to be an appeal to *metaphysical explanation*. Where causal explanations involve antecedent conditions (base) and laws of nature³⁰ (link), metaphysical explanations involve relatively fundamental states (base) and grounding principles (link).³¹ Metaphysical explanations move us groundwards to more natural properties. So Huemer's use of the concept of explanatory priority relies on the concept of naturalness.³² To sum up, I have argued that Hedden's and Huemer's attempts to base prior distributions on explanation are either incomplete or implicitly rely on naturalness. I think the same applies to other attempts, but Hedden and Huemer are the most detailed.

In fact Huemer goes further than I want to in saying we should 'assign equal probabilities at the most explanatorily basic level' p.354-5. The appeal to equal probabilities requires a Principle of

³⁰ Or some weaker generalization.

³¹ See Schaffer (forthcoming)

³² Hedden (2016) objects that naturalness is not relevant to justification. '[A]ppeals to naturalness fall short of what is required to ground an objective evidential support relation. Consider cases of non-enumerative induction (sometimes called 'abduction'). Seeing that the sky is filled with dark clouds, I conclude that it will rain shortly. How is naturalness supposed to be relevant here? The property of being such that it will rain isn't obviously any more natural than the property of being such that it won't rain.' p. 371 In response, Hedden seems to be assuming that when faced with a choice between hypotheses, we must always favour the most natural. But on my account, naturalness is only directly relevant to priors – once priors have been fixed, we update based on the evidence we receive. In this example, our evidence presumably includes not just that the sky is filled with dark clouds, but the memory that dark clouds usually preceded rain in the past. So we need to apply a principle of induction to conclude that it will probably rain shortly, and we saw above that inductive distributions can be generated by assigning a higher prior to natural hypotheses.

Indifference. This is one answer to the question of how we move from naturalness of properties to priors of hypotheses. Let's now turn to this question.

7. From Natural Properties to Plausible Hypotheses

Naturalness is a feature of *properties* but priors are assigned to *hypotheses*. So how exactly does the naturalness of the properties referred to in a hypothesis inform the prior of the hypothesis?³³ The issue can be sharply presented with the following sceptical challenge³⁴:

(w1) All emeralds are grue if observed before t, and otherwise bleen.

(w2) All emeralds are green if observed before t, and otherwise blue.

Assume for ease of exposition that green and blue are perfectly natural properties. w2 (green, then blue) is described using perfectly natural properties and w1 (both green) using non-perfectly natural properties, where each description is equally syntactically simple. So why doesn't w2 get the higher prior? I'll first offer an answer based on the syntactic simplicity of eligible descriptions (7.1) and then one based on a Principle of Indifference (7.2). I will remain neutral between these answers.

7.1. Syntactic simplicity of eligible descriptions

We can take our cue from Lewis's suggestion for finding the laws in his Best System Account. On this account a regularity is a law iff it is a theorem of the best system, where the best system is the set of true sentences which best balances informativeness and simplicity.³⁵ But obtaining an objective measure of simplicity is threatened by gerrymandering using grue-type predicates:

³³ See Davidson 1966.

³⁴ Thanks to a referee for this example.

³⁵ 'Take all deductive systems whose theorems are true. Some are simpler, better systematized than others. Some are stronger, more informative, than others. These virtues compete: an uninformative system can be very simple, an unsystematized compendium of miscellaneous information can be very informative. The best system is the one that strikes as good a balance as truth will allow between simplicity and strength.' Lewis [1994: p.478.]

Different ways to express the same content, using different vocabulary, will differ in simplicity...Given system S, let F be a predicate that applies to all and only things at worlds where S holds. Take F as primitive, and axiomatise S (or an equivalent thereof) by the single axiom $\forall xFx$. If utter simplicity is so easily attained, the ideal theory may as well be as strong as possible. Simplicity and strength needn't be traded off. Then the ideal theory will include...all truths, and a fortiori all regularities. Then, after all, every regularity will be a law. That must be wrong. 1983 p.367

Lewis's solution appeals to naturalness:

The remedy, of course, is not to tolerate such a perverse choice of primitive vocabulary. We should ask how candidate systems compare in simplicity when each is formulated in the simplest eligible way; or, if we count different formulations as different systems, we should dismiss the ineligible ones from candidacy. An appropriate standard of eligibility [is] not far to seek: let the primitive vocabulary that appears in the axioms refer only to perfectly natural properties. 1983 p.367-8

We can apply a similar strategy to assigning credences: describe each hypothesis using perfectly natural properties and assign a score based on the syntactic simplicity of this eligible description. So w_1 gets the higher prior in virtue of being describable in syntactically simpler terms using perfectly natural properties. Analytically equivalent sentences get the same probability, so other ways of describing w_1 inherit the high prior.

Let's apply this to the sceptical challenge, in which we describe w_2 (green then blue) using natural properties and w_1 (both green) using non-natural properties:

(w1) All emeralds are grue if observed before t, and otherwise bleen.

(w2) All emeralds are green if observed before t, and otherwise blue.

My response is that w1 is not eligibly described, due to the unnaturalness of grue and bleen. The eligible description of w1 is 'all emeralds are green'. And this is syntactically simpler than the eligible description of w2: 'All emeralds are green if observed before t, and otherwise blue'. Assigning priors in proportion to syntactic simplicity when described in eligible terms, we can get the desired inductive distribution:

w1: $P(\text{All green}) = 1/3$

w2: $P(\text{a is blue \& b is green}) = 1/6$

w3: $P(\text{a is green \& b is blue}) = 1/6$

w4: $P(\text{All blue}) = 1/3$

7.2 Indifference

I mentioned above that Huemer suggests we assign equal probabilities at the most metaphysically fundamental level (in our terminology). A nice feature of this is that it accounts for the anti-sceptical advantages of universals, or other anti-Humean governing conceptions of laws. Let me sketch Huemer's argument, and then compare it to using the syntactic simplicity of eligible descriptions.

Suppose we have some objective non-Humean chance mechanism e.g. universals, which explains why emeralds have the colour they do. Then the laws will be explanatorily prior to events, and according to Huemer we should assign a Principle of Indifference over the possible laws. These laws might include:

Each emerald has a 100% chance of being green

Each emerald has a 50% chance of being green and 50% chance of being blue

Each emerald has a 100% chance of being blue.³⁶

Then we assign them equal probability:

$P(\text{Each emerald has a 100\% chance of being green}) = 1/3$

$P(\text{Each emerald has a 50\% chance of being green and 50\% chance of being blue}) = 1/3$

$P(\text{Each emerald has a 100\% chance of being blue}) = 1/3$

Applying a further Principle of Indifference to the two ways that two emeralds can be 50% green and 50% blue, we have the inductive distribution³⁷:

$P(w1) = 1/3$

$P(w2) = 1/6$

$P(w3) = 1/6$

$P(w4) = 1/3$

Thus, non-Humeanism about laws plus the Principle of Indifference justify an inductive distribution.

On the other hand, suppose with the Humean that events are explanatorily basic (and laws are nothing but summaries of events). Then assigning equal probabilities at the most explanatorily basic level results in:

$P(w1) = 1/4$

³⁶ Notice a further role for naturalness is to rule out laws such as 'all emeralds are grue'.

³⁷ Complication: If each emerald has a 50% chance of being green or being blue, we might end up with both being green (or both being blue). Whereas if emeralds have a 100% chance of being green (or blue) then both will definitely be green (or blue). So the net probability of one being green and one being blue is less than 1/3. This would mean a greater imbalance between the uniform $w1$ and $w4$ compared to the non-uniform $w2$ and $w3$, which would result in an even bigger preference for uniform possibilities. So on these assumptions the non-Humean has a stronger preference for uniform possibilities than the Humean.

$$P(w_2) = 1/4$$

$$P(w_3) = 1/4$$

$$P(w_4) = 1/4$$

This returns us to the undesirable non-inductive prior. Huemer concludes that ‘This is one reason for preferring non-Humean theories of causation and laws, since they yield the intuitively correct sort of probability distributions.’ p.360-1

I like this argument. I think it is the best argument for positing universals or other unHumean whatnots³⁸. They don’t solve the problem of induction by showing that it is *necessary* that the future resembles the past³⁹; they solve the problem of induction by explaining why w_1 has a higher prior than w_2 .

But I don’t think it’s the *only* way to arrive at this distribution of priors. The approach I suggested above demonstrates how Humeans can avoid scepticism. Rather than assigning equal probability to the most explanatorily basic possibilities, we assign higher priors to possibilities which can be syntactically simply expressed using perfectly natural properties. So w_1 gets a higher prior than w_2 because w_1 can be syntactically simply described with perfectly natural properties. So we arrive at the same distribution of priors, but for different reasons.

Notice that proponents of a Principle of Indifference are committed to the view that the features which ground the division of possibilities to which the Principle of Indifference is applied are the *only* epistemically relevant features – otherwise these other epistemically relevant features would disrupt the equal assignment of priors. Thus, Huemer’s appeal to the Principle of Indifference implies that he thinks naturalness (or what is ‘explanatorily basic’ in his terms) is the only feature relevant to priors. I have not argued for anything this strong - a score based on the syntactic simplicity of eligible descriptions can be weighed against scores for other theoretical virtues. But I am inclined towards this

³⁸ Lewis 1994 p.484

³⁹ See Beebe (2011).

strong view. So before concluding I offer a brief discussion of how the well-known challenges to the Principle of Indifference interact with the appeal to fundamentality.

8. Principle of Indifference

Carnap attempted to assign a Principle of Indifference across the privileged distribution of hypotheses, according to which each hypothesis gets the same probability. A problem is that there did not seem to be a unique privileged way to divide up the hypotheses. The point was famously demonstrated with van Fraassen's (1989) cube factory. I will change it to a square factory for simplicity.

Suppose you are told that a factory makes squares that have sides of length between 1 and 2 metres, and so have areas between 1 and 4m^2 . If we apply a Principle of Indifference over lengths, credence is 50% that a randomly selected square has length greater than 1.5 meters (half way between 1m and 2m); if we apply a Principle of Indifference over area, credence is 50% that a randomly selected square has area greater than 2.5 square metres (half way between 1m^2 and 4m^2). And these distributions are incompatible; a square with 1.5m sides has an area of 2.25m^2 , not 2.5m^2 . So should we apply a Principle of Indifference over length or area? The challenge is that there does not seem to be a principled way to answer that question.

First, can Carnap's theory using *epistemically* fundamental concepts solve the problem? Carnap would need either the concept of length to be more epistemically fundamental than the concept of area, or vice versa. Neither option is obviously best; equally, I see no reason why an answer could not be defended. As a first pass, our concept of area seems to be based on our concept of length, which indicates that the concept of length is epistemically fundamental. So I'm not sure the square factory is the fatal blow to Carnap's theory that it has been taken to be.

Can *metaphysically* fundamental properties solve the problem? We first need to modify the example. Being a factory is a very high level property, which requires being built by agents with certain intentions. What we expect factories to do depends on what we expect about the intentions of agents,

and about the process of manufacturing things such as squares. Our theory only assigns priors to metaphysically fundamental properties.

Is there a similar problem that does apply to our view? Suppose we zoom in on the region of the a priori credence function in which the world consists only of squares that have sides of length between 1 and 2 metres, and so have areas between 1 and 4m².

The question for us is whether length or area is metaphysically fundamental. Does length ground area or area ground length? I think it is plausible to argue that length grounds area. We can put this in terms of *dependence*: the area seems to depend on the length, in a way that the length does not depend on the area. And we can put it in terms of *explanation*: we can explain the area in terms of the length in a way that we cannot explain the length in terms of the area. We should expect these features if area is grounded in length, so it is plausible that we should apply a Principle of Indifference over length.

But all this is far from certain. An alternative response would involve denying that a Principle of Indifference should be applied. Perhaps only weaker constraints on priors apply. For example, a range of priors within a maximum and minimum range might be rational, leaving room for rational disagreement.⁴⁰ And in fact this conciliatory position was Carnap's mature view:

I think there need not be a controversy between the objectivist point of view and the subjectivist or personalist point of view. Both have a legitimate place in the context of our work, that is, the construction of a set of rules for determining probability values with respect to possible evidence. At each step in the construction, a choice is to be made; the choice is not completely free but is restricted by certain boundaries.

Basically, there is merely a difference in attitude or emphasis between the subjectivist

⁴⁰ Similarly, Sider (2011) writes: 'So selecting the right language doesn't, on its own, solve the problem of formulating principles of indifference. But without an appropriate language, we cannot even get started on a solution' p.39. The exact relation between my approach and Sider's, I leave for further work. Sider's Ontologese looks to be different to both metaphysically fundamental properties and epistemically fundamental concepts, and I find Schaffer's (ms) criticism of Sider's approach convincing.

tendency to emphasize the existing freedom of choice, and the objectivist tendency to stress the existence of limitations. (In Jeffrey, 1980, 119)

9. Conclusion

I have argued that we should posit constraints on priors, and that these constraints should be guided by natural properties. I have made an attempt to work through the motivations and consequences of this view. Sometimes, a theory is widely accepted until people try to state it precisely, at which point it is seen to be less plausible than was thought. Perhaps that will happen in this case. I hope not; I think this account is the best in the area, and that the benefits are worth the costs. But there are substantial costs and benefits to this account, and I hope to have made a start in laying them out.⁴¹

⁴¹ I am grateful to David Chalmers and Jonathan Schaffer, to two referees for *Mind* who gave me two rounds of feedback, and to the Editors of *Mind* for comments on the final draft.

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