A causal theory of chance?

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A Theory of Physical Probability
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1 Introduction

In common with most other important philosophical topics, no settled consensus has emerged regarding the correct understanding of probability. Views that take probabilities to be relative frequencies, or degrees of belief, or irreducible chancy properties of systems all remain viable, but none is without serious problems. One division that remains resilient is that between subjectivist and objectivist views of probability. Subjectivist views locate the facts that support true probability ascriptions within epistemic agents; objectivist views locate those facts out 'in the world'.

Richard Johns' *A Theory of Physical Probability* [1] is a welcome further contribution to this literature. Johns presents a novel approach, the "causal theory of chance", which purports to give an objectivist account of physical probability, or chance. But as we shall see, he does so in a way that blurs the boundaries between objectivist and subjectivist views.

The book has two main parts. The first part (Chapters 2–4) develops a sustained account of Johns' own view of chance. The second part (Chapters 5–7) applies the view to some outstanding problems in understanding probability in classical statistical mechanics and quantum mechanics. Johns' approach is bold, and his choice of topics to cover is nothing if not ambitious. In the second part alone he proposes accounts of the direction of time (§5.7), the measurement problem and the incompleteness of quantum mechanics (§§7.2–7.3), and the fundamental connection between physical facts and states of knowledge (§7.3.4). Despite the interest of the intriguing claims Johns defends in these chapters, I will concentrate on the positive account of physical probability in the first part. Unfortunately we shall find sufficient there to trouble us.

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[1] All otherwise unattributed references are to this book. Some notation has been altered.

2 The Causal Theory of Chance

The task Johns sets himself is to provide an interpretation of probability ascriptions in scientific theories that gives those ascriptions an objective ground in the physical properties of the systems those theories describe. Moreover, to be an adequate explication of the concept of probability, the resulting interpretation should show how this physical probability can constrain rational credence, can be uncovered by examining frequency data, and be defined in the single case. He claims, quite correctly, that no existing interpretation satisfies all these requirements, and proceeds to give his own account.

He dubs his view the *causal theory of chance*, and maintains that "the chance of an event is the degree to which it is determined by its cause" (p. 4). From this characterisation it is immediate that Johns must give us an account of determination and causation, and an account of partial determination.

2.1 Causation and Determination

In fact, Johns gives no analysis of causation, but is content with a quasi-Aristotelian notion of an *efficient cause*: "an efficient cause brings about, or produces, its effect" (p. 54), and "supports the real existence of the effect" (p. 58). Causation cannot be analysed, says Johns, because (he argues) causation is essentially a relation between actual existent events, and cannot be captured by a logical relation, which can only hold between abstract representations of actual existents. Johns thinks this is a very general problem: any existent entity has some 'concreteness' which outstrips the content of facts involving those entities, and hence outstrips the capacity of the understanding (§3.3.5). Even setting aside the mysterious role of 'concreteness', I find this argument puzzling at best. I don't see how it counts against any of the extant proposals we have for analysing causation. For instance, a naive counterfactual analysis of '*a* causes *b*' might go as follows: (i) *a* and *b* actually occur; and (ii) the proposition true just when *b* occurs counterfactually depends on the proposition true just when *a* occurs (Lewis, 1973). This analysis holds between actual events, yet whether there is causation or not depends on the logical properties of propositions involving those events. There doesn't seem to be any tension here. Furthermore, any account of causation like Johns' that restricts itself to actual events will have trouble with the fact that causal claims support counterfactual claims.

On the other hand, Johns has no problem giving an analysis of *determination*: the proposition C determines the proposition E just if, once we assume the natural laws $\mathcal{L}$, C entails E.

Johns has a very particular concept in mind when he speaks of laws—what he calls a *dynamical nature* (§3.2.2). He introduces this through a discussion of the Lagrangian formulation of Newtonian mechanics, particularly how this formulation emphasises the role of an internal parameter of the system (the lagrangian) in determining the trajectory of the parts, rather than emphasising external gravitational forces. Johns then claims that "the lagrangian of a system **X**. . . may be viewed as a representation of **X**'s dynamical nature"

(p. 67). This is supposed to be an intrinsic property that regulates the "natural motion" of the system, once the background conditions $bc_{\mathbf{X}}$ are specified.

However, contemporary physics is skeptical of teleological notions, and even if a system can be described *as if* it had some internal constraint on its natural motion, that doesn't establish that there is such a constraint forcibly guiding the system along a certain path. This is particularly relevant in this case, since the one instance he provides where such a constraint can appear to occur, namely the lagrangian of classical systems, has no analogue in stochastic systems. Without such an entity governing stochastic systems, his account of proability must remain incomplete. His response to this is simply to state that "it is one of the main theoretical claims of this book that *every* system has a generalized lagrangian" (p. 68). By 'theoretical claim' one can only understand Johns to mean 'metaphysical posit', and I think we can be rightfully skeptical of this kind of baptism *in absentia* of some physical property as the teleological ground of dynamical laws. I take this to be an instance of what van Fraassen (1989, pp. 38–9) calls "the identification problem": without an account of just how the dynamical nature is related to familiar physical properties, the account of laws is empty.

2.2 Partial Determination and Logical Probability

Johns proceeds to argue that we can have causation without determination, and though he proposes an extremely curious argument (§3.3.5), I take it that almost all contemporary accounts of causation are compatible with this possibility.[2] Where he does diverge from the mainstream is in maintaining that nevertheless causes determine their effects to a certain *degree*, by which he means that causes *partially entail* their effects.

In Chapter 2, Johns gives an account of this partial entailment relation as a species of *logical probability*. Ever since philosophers became convinced of the failure of Carnap's programme (1962), purely a priori determination of empirical probabilities has been widely regarded as a fantasy, so it is interesting to examine how Johns proposes to resurrect the notion.[3] He begins by looking at the nature of logic, and argues that the correct view of logic is that of Gärdenfors (1988, esp. ch. 6): logic is the study of the epistemic dynamics of idealised cognitive agents. The content of an epistemic input is a function that describes how that input alters the epistemic state of the agent, and each such function is identified with a proposition. Gärdenfors shows how these function-propositions have a group theoretic structure that is isomorphic to the intuitionistic propositional calculus. Gärdenfors sees the construction as showing how to model entailment without an ontology of possible worlds, utilising rather less controversial belief states.

Johns has an altogether more radical take on his very similar construction: he thinks one can construct states of affairs and possible worlds out of the contents of belief state changes. He

[2] Historically, of course, the identification of causation with determination was widespread (Norton, 2003, §2).

[3] For a recent attempt to partially resurrect Carnap's project see Fitelson (forthcoming).

therefore requires that the idealised epistemic states in question be more 'objective' than idealised human states would be. He posits the existence of

> a perfect, infinite intellect, a mind of unlimited capacity that infallibly draws all and only valid inferences. This mind is an embodiment of all logical truth. I assume that the Gedanken of this being are (or are indistinguishable from) states of affairs themselves. . . For this reason, I will treat states of affairs as components of epistemic states, and definable from epistemic states, rather than as separate entities. (p. 20–1)

Resisting the urge to stare incredulously, I will point out that if we are to follow Gärdenfors' construction, there need to be many possible epistemic states of this infinite mind, enough to distinguish all the possible propositions. This "infinite intellect" is not therefore unique—there is one abstract entity for each maximal state of affairs (though sometimes it seems that Johns means to claim that this actual world is just the epistemic state of the one actual infinite intellect.) Note also that any a priori truth (true in any epistemic state) will turn out a logical truth on this account: but we might baulk at "I am here now" (Kaplan, 1989).

Johns then proceeds to give an account of the internal structure of these ideal epistemic states, and adapts the Ramsey-de Finetti theorem to show that the structure is a subjective probability function.[4] This requires that the infinite intellect must possess not only epistemic states, but also desires and preferences. Johns' only argument for this claim is the rhetorical question "If this being has beliefs, then why not desires as well?" (p. 29). One reason why not is that, unlike epistemic states whose standard of correctness is the actual state of affairs, desire states are not commonly thought to be directed at any objectively correct standard. Therefore for any given epistemic state there is a plurality of compatible desire functions. If Johns wants a unique assignment, he needs something like a unique objectively determined assignment of utiles to any state of affairs. This is surely a chimera.

If we were to grant Johns this unique 'logical' preference ordering, he could use a variant Dutch-book argument to show that there is a belief-desire pair that can yield the correct 'logical' probability function Pr.[5] Johns introduces a nice characterisation of conditional probabilities in terms of relative probabilities (§2.5), and advocates the appealing view that conditional probability is the more basic notion.[6]

Johns obliquely recognises the problem of non-uniqueness of the logical probability function, and in §2.6 makes the claim that often logical probabilities will be interval-valued rather than perfectly precise. As best I can see, however, the intervals for every logically contingent proposition will be totally vague: just $[0, 1]$. If one imagines supervaluating over all the possible ideal epistemic/desire states, then since the epistemic content of a state

[4] Ramsey (1990); de Finetti (1964); Jeffrey (1983).

[5] He claims it is not a Dutch book argument: but the only way I can see to justify the constraints on the valuation function is that an agent who was *rational* wouldn't have a valuation function that violated those constraints—Lemma 2.4.4 in particular can only be justified by a rationality constraint that a proposition believed with certainty is worth the yield of any contract on it.

[6] See also Hájek (2003).

places no constraint on the desirabilities associated with it, there is nothing to limit the credence to a particular region of the unit interval given the preferences and desires. Of course we can fall back to the position where we simply stipulate a unique logical preference ordering. It is no surprise that if we assume this much we can get a substantial account of logical probability: it has all the advantages of theft over honest toil.

Johns also discusses (§2.7) the traditional companion of purely a priori probabilities, the Principle of Indifference (POI).[7] The POI states that equal probability should be assigned to equally possible cases. He proposes a new symmetry-based version of a POI: if in an epistemic state two mutually exclusive states of affairs are unable to "be singled out from" each other (Def. 2.7.8), they should be assigned equal probability. My best stab at understanding the metaphor of 'singling out' is that given the content of some epistemic state K, two distinct propositions A and B induce a shift to the same augmented epistemic state K^* and hence have no distinguishable content—though relative to another state K', those propositions would have different content. Naturally enough, this kind of symmetry is extremely difficult to achieve, and this supports Johns' contention that his POI is immune to the paradoxes that have plagued previous efforts. All of the paradoxical situations fail to be symmetrical in Johns' sense, and hence the POI cannot be applied to get conflicting results. This is a neat result.

2.3 Chance

We are now in a position to state Johns' own view. The chance $P_{\mathbf{X}}$ of an event A in a system $\mathbf{X}$ which has dynamical nature $\mathcal{L}_{\mathbf{X}}$ and background condition $bc_{\mathbf{X}}$ is (Def. 4.1.1):

$$P_{\mathbf{X}}(A) =_{\text{df}} \Pr(A|\mathcal{L}_{\mathbf{X}} \wedge bc_{\mathbf{X}}). \tag{1}$$

That is, the chance of an event is the degree to which the laws and the contingent background constraints entail the proposition that the event occurs. It is a *causal* theory because the concrete entities that the propositions $\mathcal{L}_{\mathbf{X}}$ and $bc_{\mathbf{X}}$ describe are supposed to be the efficient causes of the event that A describes, and that partially determine the event to the degree $P_{\mathbf{X}}(A)$—their status as causes justifies their inclusion in the conditioning events for the chance function. Though this is an objective account of physical chance, the reason for thinking that it blurs the line between subjective and objective views is clear: states of affairs like $\mathcal{L}_{\mathbf{X}}$ and $bc_{\mathbf{X}}$ are idealised epistemic entities for Johns, as is the logical probability function Pr. (Perhaps this would be better called a Berkeleyan or idealist theory of chance.)

I think Johns is right to explicitly include the system $\mathbf{X}$ in the consideration of the chances, rather than only the entire best theory of chances. There is no chance of any event simpliciter, but only relative to the particular system that event is taken to be embedded in. Though there remains a problem about interpreting our assertions of unconditional chance and our acting on unconditional credence, taking this position that conditional probability is basic solves a number of problems with chance (Hájek, forthcoming).

[7] For details on the problems with logical probability and POI see van Fraassen (1989, ch. 12).

The proposal is quite similar to at least one formulation of the Principal Principle (Lewis, 1980): that the chance of *A* is the reasonable credence one would have in *A* given the history of a world up until some time, and the theory of chance for that world. [8] Johns (§4.3) argues that his approach is superior in two ways: firstly, the logical probability function Pr replaces the 'reasonable initial credence'; and secondly the dynamical nature $\mathcal{L}_{\mathbf{X}}$ makes no mention of chances or modalities, unlike the 'complete theory of chance', and hence avoids the risk of circularity. However it seems to me that Johns does not avoid these difficulties. The appeal to logical probability doesn't yield a unique probability function if my arguments above are successful, and so doesn't remove any of the subjectivity or arbitrariness of the reasonable initial credence function. Moreover, the symmetry constraints Johns places on the ideal epistemic states are too weak to narrow the class of possible chance functions down substantially, and any stronger symmetry constraint looks to lead to paradox.

Again, if the dynamical nature $\mathcal{L}_{\mathbf{X}}$ is to mention no modal facts, then that makes $\mathcal{L}_{\mathbf{X}}$ a fact about the actual system **X**. But this makes it impossible to see how $\mathcal{L}_{\mathbf{X}}$ could support modal properties except as brute facts introduced as a metaphysical posit (Johns resists Lewis' demand that the correct theory of chance should be a Humean theory). To understand what chance is, it is not enough to know only that it constrains rational credence via the Principal Principle. Humean quantities (like frequencies) we have some independent means of accessing, but an appeal to $\mathcal{L}_{\mathbf{X}}$, in common with other metaphysical solutions to the problem of chance (like propensities), cannot explain why chance should have the role that it does. [9] Johns makes some attempt to address these worries in his discussion of direct and inverse inference (§4.6), but since his account presupposes the truth of the Principal Principle it cannot address this issue of empirical access to chances.

3 Conclusion

As must be obvious, I cannot agree with Johns' account of physical probability: I find the premises unacceptable. I suspect that, for the same reason, few others will find the view appealing. I have tried above to give several arguments that lead to what I consider to be deep problems for his view, but the book has other unappealing features.

Occasionally a deeper engagement with the relevant literature would have been desirable, despite the fact that Johns' primary concern is to propose a positive view. For example, the omission of Earman (1986) from the discussion of determinism (§§3.2–3.3) is quite striking, and leads to a number of confusions about determinism and prediction. [10]

This flaw is compounded by the extraordinarily broad scope of Johns' ambition, as often the argument proceeds at a very rapid pace and makes assumptions that have been quite

[8] Indeed, Johns argues that the Principal Principle (or as he calls it, Miller's Principle) is provable as a theorem (§4.4).

[9] See also Eagle 2004, esp. 401–2.

[10] The exclusively Fregean focus of the material on propositions in §2.1 is another example: one would have thought no contemporary discussion of 'Hesperus' and 'Phosphorus' could omit reference to Kripke (1980).

controversial in the literature. The discussions of model-theoretic accounts of entailment (p. 20), of the metaphysics of modality (§3.3.6) and of the problems of direct and inverse inference (§4.6) are particularly blatant examples, along with several issues I discussed in more detail above. When combined with occasional loose usage of important terms (e.g., 'maximal' used in two different senses on p. 22, and the persistent (deliberate?) confusion of states of affairs with descriptions of states of affairs throughout Chapters 3 and 4), the persuasiveness of the arguments is substantially impaired.

The book is novel, clearly written and technically able, and Johns proposes some very interesting ideas, but as a result of the foregoing problems I cannot recommend the book. The arguments proposed, while interesting, all too often depend on claims that careful readers will find it difficult to accept.

This is particularly unfortunate because many will find the broad outlines of the view very appealing. Johns' assessment of the demands that any acceptable theory of probability should meet is quite compelling. I agree that a view which recognises the fundamental importance of the modal aspect of probability and its dependence on acceptable physical theory can give the best account of these constraints on physical probability. I also concur in Johns' assessment that connecting chance with credence through principles of probability coordination like the Principal Principle is the best way to understand the empirical content of probabilistic theories, particularly in the single case. But similar existing accounts (Lewis, 1980; Levi, 1990) have less controversial foundations and make the case for the approach more effectively. It is a pity that Johns' book as a whole doesn't quite live up to the promise that parts of it so clearly display.

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