Conditional Probability from an Ontological Point of View

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Logic and metaphysics

There is quite a low probability that you will die shortly after reading this paper: within 20 minutes, for instance. Nevertheless, one might still grant that there is a high conditional probability that you will die shortly after reading this paper, if you jump out of a fifth-floor window, or if a tiger is released into the room. How do we know this, and what does it mean? Our answers depend on what we take to be the correct understanding of conditional probability. But it also depends on our philosophical understanding of probability, the logic of conditionals and on our wider metaphysical commitments.

Leibniz (1765) made the first attempt to find a way of computing the probability of conditional statements. His original interest was in law statements such as rights and liabilities, which he found to be conditional more often than absolute (Ishiguro 1990: 155). Someone is liable to a fine, for instance, *if* they are speeding. And someone has a right to inherit from their parents *if* the parents die first. Leibniz understood such hypothetical statements as the conditional assertion of the consequent upon the truth of the antecedent. It is this and similar pre-theoretical notions of conditional probability with which we are concerned here.

In this paper we consider conditional probability as a non-technical notion from an ontological perspective. This move is controversial for a number of reasons. First of all, not many think there is such a direct link between metaphysics and logic. We hope to show that there is. Second, one might think that conditionality and conditional probability are two entirely separate matters. We hope to show that they are not. Finally, the standard technical definition of conditional probability is often used as synonymous with conditional probability. We hope to show that this practice creates unnecessary confusion.

It is a premise of this paper that the notion of conditional probability has a wider meaning than the technical one. This wider meaning is what Leibniz was after, and is what makes conditional probability so important for our scientific and everyday reasoning. Arguably, our technical tools for probabilistic reasoning ought to match our intuitive and pre-theoretical notion of conditional probability.

There are two immediate obstacles. One concerns the logic of probability; the other concerns the logic of conditionals. While logic is often thought to be metaphysics-free, we will see that both the ratio analysis of conditional probability and the material conditional are particularly suited for a Humean metaphysics of discrete, distinct existences, where all events, facts or states of affairs are

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entirely unconnected. This metaphysics has its roots in the philosophy of David Hume (1739), who believed there were no powers or necessary connections in nature.

One essential feature of extensional logic is compositionality: where all molecular statements are derived from atomic ones. This means that if we know all the occurrent and non-occurrent events, facts or states of the world, this alone should suffice to derive all relations that hold between them: conditional and even causal ones included (Frege 1879: 134). We here argue that the ratio analysis of conditional probability, applied within extensional logic, implies a Humean ontology, and that the use of the corresponding RATIO scheme to calculate individual cases of conditional probability fails to produce plausible results in many intuitively clear cases.

From an anti-Humean perspective, the acceptance of this feature of extensional logic is unattractive, both ontologically and logically. If we are realists about powers, this should commit us to an irreducible and dispositional form of conditionality. In Mumford and Anjum (2011: sec. 8.10) it is argued that the attempt to analyse dispositions into something non-dispositional, through conditional analyses, gets it the wrong way round. Dispositions cannot be given a conditional analysis. Instead, conditionals should be given a dispositional analysis. On this view dispositions are the worldly truthmakers of conditionals. For each disposition we can derive countless true conditionals, in which the various types of stimulus conditions are expressed as antecedents and the manifestation of the disposition is expressed in the consequent: if this fragile glass is dropped, thrown, hit, heated, struck, etc., it breaks.

More needs to be said and a fully developed theory of dispositions and conditionals will not be offered here, though some lines for further development will be indicated. What will be shown, however, is that for a deeper understanding of conditionals we will need what John Heil (2003), in response to Quine (1953), calls an ontological point of view. Consider first the logic of conditionals.

The logic of conditionals

Understood as a material conditional, 'if p then q' is a (truth) function of the statements 'p' and 'q'. This means that we can calculate the truth-value of the conditional from the truth-values of its antecedent and consequent. The material conditional is defined as true whenever we have one of the following combinations of truth-values for the antecedent and the consequent: (TT), (FT) or (FF). A conditional would then be truth functionally defined as false only when the antecedent is true and the consequent is false (TF); otherwise true.

The truth-functional account of conditionals involves some well-known problems. Below are some of the results that seem counterintuitive if we take the material conditional to account for the truth conditions of 'if p then q':

1. $q \Rightarrow ((p \supset q) \& (\neg p \supset q))$
2. $\neg p \Rightarrow ((p \supset q) \& (p \supset \neg q))$
3. $(p \& q) \Rightarrow ((p \supset q) \& (q \supset p))$

The one that has received most attention is the second inference – often referred to as the problem of counterfactuals – i.e., that the conditional is truth-functionally defined as true whenever its antecedent is false. A common response is that although the material conditional might work as a logical representation of indicative conditionals, some further account is needed to account for conditionals with false antecedents (e.g. Stalnaker 1968 and Lewis 1973) or subjunctives (e.g. Adams 1975). This challenge has led to an extensive literature on counterfactuals in recent decades (see for instance Harper et al. 1981). We will not enter the debate over counterfactuals here, since the problem we seek to address is a more general one concerning the attempt to treat conditional statements as functions of their antecedents and consequents.

What is more relevant for our purpose, however, is that Lewis's theory of counterfactuals has an explicit metaphysical grounding in Humeanism. Lewis himself thus saw a relevant link between logic and metaphysics. Humean supervenience is the thesis that there is nothing but spatiotemporal arrangements of point-like intrinsic qualities and what supervene on these (Lewis 1986a: ix-x). As already mentioned, this fits well with the principle of compositionality in extensional logic, according to which the truth, necessity, probability, etc., of molecular propositions are inferred from the truth, necessity, probability, etc., of atomic propositions.

Unless we share Lewis's metaphysical commitments, we should resist his treatment of counterfactuals. On this theory, a counterfactual '$p \,\square\!\!\rightarrow q$' is true in the actual world if in the closest possible world where 'p' is true, 'q' is also true. This would commit us to the metaphysically rich theory of multiple worlds and inter-worldly modality in addition to the material conditional, which still holds within all possible worlds. As we can see in the following inferences (where $\square\!\!\rightarrow$ marks the counterfactual connective), there are some clear similarities between the material conditional and Lewis's counterfactuals.

1. If 'q' is true in all worlds, then '$p \,\square\!\!\rightarrow q$' is true
2. If 'p' is true in no worlds, then '$p \,\square\!\!\rightarrow q$' is true
3. If both 'p' and 'q' are true in all worlds, then both '$p \,\square\!\!\rightarrow q$' and '$q \,\square\!\!\rightarrow p$' are true

While much of the debate concerning conditionals is centred on counterfactuals and subjunctives, there is another debate that concerns assertability rather than truth conditions. This debate started when Adams (1975) offered a different solution to the apparent divergence between indicative and material conditionals: although the material conditional might work as a logical representation of a conditional's truth conditions, some further account is needed for its more pragmatic assertion conditions (Jackson 1987 and Grice 1989). The assertability of an indicative conditional is according to Adams (1975: 3) given by our conditional credence, or subjective belief, as determined by the ratio analysis of conditional probability. This is known as Adams' Thesis.

Adams' Thesis $P(\text{if } B \text{ then } A) = P(A|B) = P(A \,\&\, B) / P(B)$ (when $P(B) > 0$)

Adams' Thesis has been widely accepted in the debate on conditionals (see for instance Edgington 1987, 1995, Jackson 1987, 1991, Lewis 1976, 1986). This idea is interesting for our purpose because it assumes that conditional probability is somehow linked to conditionality as such. A relevant

question is still whether the ratio analysis is well suited for our conditional credence in the intuitive, non-technical sense. Consider next the logic of conditional probability.

The logic of conditional probability

Hájek (2003) argues that the plausibility of Adams' Thesis rests solely on the intuitive notion of conditional probability. This suggests that any counterintuitive result we get will be a result of the ratio analysis, and not the assumption that the assertability of a conditional is tightly linked to the probability of conditionals and the intuitive notions of conditional probability:

> Adams' Thesis is thought to sound right, and to accord with our intuitions about a wide range of cases. What sounds right and so accords, I suggest, is equating the assertability of the conditional to the corresponding conditional credence; it is the further equation of this conditional with a ratio of credences, then, that is the culprit. (Hájek 2003: 309)

According to the standard conception, conditional probability is given by RATIO. This analysis makes the conditional probability of *A* given *B* calculable from the unconditional probabilities of *A* and *B*:

RATIO $P(A|B) = P(A \& B) / P(B)$ (when $P(B) > 0$)

Hájek (2003) demonstrates some problems with taking RATIO as the definition of our intuitive notion of conditional probability. Often we have an immediate and clear intuition of the probability of *A* given *B* while no value can be given for $P(A|B)$. This problem occurs when the probabilities of (*A* & *B*) and (*B*) are zero, infinitesimal, vague, or undefined, in which cases no calculation of $P(A|B)$ is offered by the ratio analysis. From this he concludes that the ratio analysis is not an adequate analysis of conditional probability (Hájek 2003: 273) and that conditional probability must be taken as basic and primitive and not as something that can be analysed in terms of unconditional probabilities: 'I suggest that we reverse the traditional direction of analysis: regard conditional probability to be the primitive notion, and unconditional probability as the derivative notion'. (Hájek 2003: 315) We agree with Hájek on both these points.

Notwithstanding these issues, the question remains whether RATIO could still be used as a constraint over rational probability assignments to *A* given *B*, so that whenever $P(A \& B)$ and $P(B)$ are well-defined, the probability of *A* given *B* is precisely given by RATIO. Next we give additional support to Hájek's conclusion by presenting three counter-intuitive results even in cases where RATIO can be calculated.

First result

The first counter-intuitive result of RATIO occurs whenever the probability of *A* is 1. For such cases the probability of (*A*|*B*) will also be 1:

R1 $P(A) = 1 \Rightarrow P(A|B) = 1$

We can calculate this result from RATIO in the following way: since $P(A \& B) = P(B)$, we get that $P(A|B) = P(A \& B)/P(B) = P(B)/P(B)$, namely 1. Note that this is similar to result 1 above of the material conditional where a true consequent gives a true conditional, irrespectively of what the antecedent is taken to be.

As Hájek suggests in the quotation above, we should not conclude from this that Adams was wrong in assuming a link between the assertability of conditionals and our subjective belief in the consequent given the antecedent. What we should conclude is that the determinations of $P(A \& B)$ and $P(B)$ are not in themselves sufficient to calculate our credence in A given B. That is, we might take this result as an indication that the probability of A given B is not fully given by $P(A \& B)/P(B)$. If we can assign probability 1 to A, this is not in itself a reason for assigning probability 1 to A given B or A given C.

Someone might object to this that if A is certain, then it is certain given B, or whatever else for that matter. Lewis (1976: 307) offers an example in support of this: 'I'll probably flunk, and it doesn't matter whether I study; I'll flunk if I do and I'll flunk if I don't.' This example would however not be an instance of what we might normally think of as an indicative conditional, or what Lowe (1995:50) calls proper conditionals and Austin (1956: 209-10) refers to as ordinary causal conditionals. Typical for indicative conditionals, at least, is that they allow modus ponens, modus tollens and contraposition, which Lewis's conditionals do not. On the contrary, the consequent seems to be asserted unconditionally, i.e., irrespectively of whether the antecedent is true or not.

In Lewis's example there seems to be an implicit claim that there is no conditional or causal link between studying and flunking, or between not studying and flunking. Hence the studying and flunking are stated to be probabilistically independent. Such constructions are best understood as denials of a conditional relation between antecedent and consequent. A better formulation would be 'Even if I study, I'll still flunk' or 'It is not the case that if I study, I'll pass'. We should think of such statements as 'contra-conditionals', as they are characteristically used to deny that the antecedent is a sufficient or even relevant condition for an expected consequent. Contra-conditionals do not allow contraposition, modus ponens or modus tollens, and would therefore not be suitable candidates for indicative or causal conditionals. If Adams' Thesis fits such conditional constructions, we could take this as an indication of a logical discrepancy between the ratio analysis and conditional credence.

Second result

A second counter-intuitive result follows from RATIO when A and B are probabilistically independent, in which case the probability of $(A|B)$ will be equal to the probability of A:

R2 $(P(A \& B) = P(A) \cdot P(B)) \Rightarrow (P(A|B) = P(A))$

This result can be calculated as follows: since A and B are probabilistically independent, $P(A \& B) = P(A) \cdot P(B)$. Hence $P(A \& B)/P(B) = P(B) \cdot P(A)/P(B) = P(A)$. An example can illustrate this point. The properties of solubility and sweetness are not generally thought to be probabilistically dependent.

Sugar has both properties, but we do not think them related in any further way. Following the ratio analysis of conditional probability, however, if we assign high probability to 'Sugar is sweet', we should assign equally high probability to 'Sugar is sweet' given that 'Sugar is soluble'. By Adams' Thesis, our credence in the conditional 'If sugar is soluble, then it is sweet' should therefore also be high. But this seems to imply that the sweetness of sugar is somehow conditional upon its solubility.

An obvious objection to this would be to say that the conditional link itself is nothing more than what is indicated by the ratio analysis of conditional probability. As already argued, such a view may be attractive to Humeans, but not to anti-Humeans. The ratio analysis thus seems particularly well-suited for a Humean metaphysics, according to which there are no worldly connections between events. Much of our conditional reasoning, on the other hand, is premised on there being at least some type of connection that can ground our hypothetical reasoning. An anti-Humean might ground such connections in real dispositions, necessary laws or causation, none of which are part of the Humean ontology. It is then the worldly relations that enable us to judge the solubility of sugar and its sweetness to be probabilistically independent, even though they come together.

If we read conditional probabilities from the Humean mosaic, we have no ontological grounds to make such a distinction. As Lewis (1976) demonstrated, if the conditional (as characterized in Adams' Thesis) can function as a dual connective that is universally applicable, this implies that $P(A|B) = P(A)$ for all A and B. This means that all sentences and hence all facts are probabilistically independent. And if all facts are probabilistically independent, this means that the $P(A|B)$ is not affected by B having high or low probability. According to RATIO, however, $P(A|B)$ does not depend only on whether $P(A)$ and $P(B)$ are high or low; but on whether or not A and B are probabilistically dependent. Adams' Thesis estimates that the probability of A given B – or if B then A – is given by RATIO also when A and B have low probability (close to 0). But there are two possible scenarios for this, and RATIO gives us different answers for these: If A and B both have low probability, but are probabilistically *independent*, it follows that $P(A|B) = P(A)$, that is, close to 0. If A and B are both highly improbable but probabilistically *dependent*, then $P(A \& B)$ is close to $P(B)$ (as well as close to $P(A)$, since these probabilities concur), and $P(A|B)$ is close to 1. The main result of Lewis's deduction, however, is that all propositions expressed are probabilistically independent (Lewis 1976: 300): For all sentences A and B of the language $P(A|B) = P(A)$.

Consider a case where we know that Peter and Jane are spending the night together. It may be highly improbable that Peter is on the top of Mount Everest and also highly improbable that Jane is on the top of Mount Everest. But given that we know they are together, then the conditional probability is high of Peter being on Everest given that Jane is on Everest. This means that $P(A|B)$ being high *might* indicate a dependence between A and B, independently of the probabilities for (A) and (B). But it does not mean that $P(A)$ and $P(B)$ being high is *sufficient* for assigning high credence in A given B or in the conditional 'if B then A'.

Third result

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Regardless of the probabilistic relation between *A* and *B*, a third counter-intuitive result follows for every case in which the probability of (*A* & *B*) is high. In these cases, the probability of *A* given *B* is high, but so is the probability of *B* given *A*:

R3 $(P(A \,\&\, B) \sim 1) \Rightarrow ((P(A|B) \sim 1) \,\&\, (P(B|A) \sim 1))$

An example might illustrate why this is counterintuitive. The probability of the conjunction of 'The Sun will rise tomorrow' and 'Snow is white' is high. But this doesn't necessarily imply that the Sun rising tomorrow is conditional upon snow being white, or vice versa. Even if we could find no connection between the rising of the Sun and the colour of snow, RATIO calculates a high probability to the Sun rising tomorrow given that snow is white and snow being white given that the Sun rises tomorrow.

Assuming Adams' Thesis we then end up trivialising conditionals. For any pair of highly probable statements *A* and *B* we can form highly probable conditionals (If *A* then *B*) and (If *B* then *A*) (see the triviality proofs in Lewis 1976: 300ff). No assumption about a logical, conditional, or any modal link between *A* and *B* is needed for this inference beyond the criterion of high probability for both.

Summing up

These three results are related to our metaphysical concerns about treating the material conditional extensionally. As already mentioned, Lewis demonstrates that if we make the conditional a universally applicable dual connective (as implied by Adams' Thesis), all sentences are forced to be probabilistically independent. This might be harmless for a Humean. But for most anti-Humeans, this is an unexpected consequence of accepting the ratio analysis of conditional probability.

Some philosophers have assumed that we can keep the material conditional as explicating a conditional's truth conditions, and add Adams' Thesis (including the ratio analysis) to account for a conditional's assertion conditions (e.g. Jackson 1987 and Grice 1989). This move does not allow them to escape the counterintuitive first and third result of the material conditional, since these are then reproduced in the first and third results for conditional probability, as demonstrated above. The more serious consequence is however related to the second result of the material conditional, concerning counterfactuals. While the material conditional can give counterfactuals and subjunctives no meaningful exposition, the second result for conditional probability, combined with Lewis's demonstration of the converse result, implies that there are no conditional probabilities. This is because there are no conditionals in the intuitive, anti-Humean sense.

If we assume instead an anti-Humean metaphysics, we have reasons to take conditionals and conditionality as basic and primitive notions. Here we find some support in Hájek (2003). Rather than treating conditional probability as a function or ratio of unconditional probabilities, he suggests that conditional probability must be taken as a basic and primitive notion. Contrary to what is assumed in Adams' Thesis and the ratio analysis of conditional probability, he argues that all unconditional probabilities are derived from conditional probabilities.

The problem lies in the very attempt to analyze conditional probabilities in terms of unconditional probabilities at all. It seems that any other putative analysis that treated unconditional probability as more basic than conditional probability would meet a similar fate … On the other hand, given an unconditional probability, there is always a corresponding conditional probability lurking in the background. Your assignment of 1/2 to the coin landing heads superficially seems unconditional; but really it is conditional on tacit assumptions about the coin, the toss, the immediate environment, and so on. In fact, it is conditional on your total evidence. (Hájek 2003: 315)

We agree with Hájek that conditional probability is a primitive and irreducible notion. But this is mainly because we take conditionality as such to be primitive and irreducible. Any attempt to analyse the conditional into something unconditional would then fail.

The ontological point of view

The three counter-intuitive results we have presented here are symptoms of a failure within the theory to understand conditionals ontologically. Conditionals are capable of an ontological use primarily marked in the expression of a connection between the referents of the antecedent and consequent. What Lowe calls proper conditionals and Austin refers to as ordinary causal conditionals are conditionals in which the consequent in some way depends on the antecedent. These conditionals should therefore not be treated compositionally; rather, they should be taken as indivisible wholes. In other words, instead of treating the 'if... then...' as a two-place connective between distinct propositions, these conditionals should be treated as single, indivisible propositions. Admittedly, the neat logical properties when a conditional sentence is treated compositionally are lost; but those are the very properties that, in the case of proper conditionals, clash so obviously with the use to which we want the conditional sentences put.

Not all conditionals sentences or statements have to be read in the ontological way we are advocating. There are a number of conditional sentence constructions that do not express the kind of dependency we have in mind between antecedent and consequent. For instance, from a categorical statement such as 'All men are mortal', we can derive the classificatory conditional 'If a is a man, then a is mortal'. There are also what we might call identity conditionals (If this is water, it is H_2O), rhetorical conditionals (If that is Madonna, then I'm Bart Simpson) and logico-analytic conditionals (If today is Sunday, tomorrow is Monday). And we have also pointed out a class of contra-conditionals (If I win the lottery, I cannot afford this car), whose purpose is to deny any connection between antecedent and consequent. In Mumford and Anjum (2011: 159ff), these cases are called collectively non-causal uses of 'if'.

But by contrast with these classes, many other natural uses of 'if' clearly are designed to claim an ontological connection between the antecedent and consequent conditions, usually where this connection would be filled out in broadly causal or dispositional terms, either directly or indirectly. To give some standard examples: 'If you get hit by a train, you'll die', 'If ice is heated, it melts', 'If an iron bar is heated, it expands' are all cases where we want to draw a direct causal connection between antecedent and consequent. The connection could perfectly well be indirect, however. It

may be that 'If the barometer falls, it will rain' not because the falling barometer causes rain but, as is well-known, the antecedent and consequent conditions are connected by a common cause: a drop in air pressure. Conditionals should be understood ontologically, then, when there is some connection in the natural world that makes them true: some causal-dispositional connection or complex of such between the referents of the antecedent and consequent.

Common for all these causal conditionals is that they should be given an irreducibly dispositional reading. Getting hit by a train disposes towards one's death and heating ice disposes towards its melting. Characteristic of dispositional statements is that they invoke a modality that is more than contingency but short of necessity. There is a disposition towards a particular outcome, but one that could be counteracted (Mumford and Anjum 2011: ch. 8). There is always the possibility for any natural causal process that the outcome is prevented, and this allows us to draw a clear line between the ontological, causal conditionals and the more logical, non-causal ones, in the following way.

Causal conditionals have to be asserted only *ceteris paribus* because they admit exceptions in a way that the non-causal conditionals for the most part do not (contra-conditionals might also admit exceptions because they too rely on natural causal processes occurring or not). There are no exceptions to statements such as 'If *a* is a man, then *a* is mortal' or 'If today is Sunday, then tomorrow is Monday', for which additional *ceteris paribus* clauses would be inappropriate. There will be an inviolable constant conjunction between antecedent and consequent here. But contrary to Hume's account, which links causation to constant conjunction, we argue that constant conjunction indicates that any connection involved cannot be causal. In cases of causation, the effect can always be prevented by the addition of a further condition to the antecedent cause and this is evident in the way that our causal reasoning is non-monotonic. Hence, we may assent to the conditional that 'If I strike this match, it will light' but not to the conditional 'If I strike this match in a gale, it will light'.

It is thus paramount that we draw this distinction between the causal and non-causal uses of 'if'. Moreover, it seems unlikely that there will be a single theory of conditionals that accounts for them both. Lowe (2012), for instance, argues against Mumford and Anjum that one cannot use antecedent strengthening as a test of the necessity of a conditional. Antecedent strengthening would be a way of testing whether a conditional is subject to falsity under additive interference, and thus whether it is a causal conditional (or not and thus non-causal). But Lowe's argument in brief relies on the possibility of the additive interferer being something inconsistent with the prior antecedent conditions as they stand. The conditional then comes out true trivially on account of having an impossible antecedent.

However, if we consider the conditional ontologically, as pointing to a natural causal process, then of course no such conditional could come out true for this reason, assuming that contradictions are a logico-linguistic feature only and not found in nature. In other words, it would be impossible to rescue a causal conditional from falsity in the face of antecedent strengthening, by giving it an inconsistent antecedent, because such inconsistent circumstances are not things that can be brought about in reality. One could so rescue a non-causal conditional, but this is precisely because it is not taken ontologically, in the sense we have described. It is thus no accident that it can be

shown that it is particularly counterintuitive to apply RATIO to calculate conditional probabilities for propensities (see Humphreys 1985).

Dispositions as truthmakers of causal conditionals

There are many details that would remain to be outlined if this were to become a full theory of causal conditionals. While this is not the place to develop those details it should be clear that we take a dispositional theory of causal conditionals and of conditional probability to have some credibility. This has an important consequence. There is a long history of attempts at a conditional analysis of dispositions, the motivations for which are to be found in the preservation of a Humean metaphysic and philosophy of science (see Carnap 1936 for the instigation of this trend). Rather than offer a conditional analysis of dispositions, however, we have effectively offered a dispositional analysis of conditionality, at least as regards those conditionals we identify as ontological in import. This causal-dispositional connection, we have argued, is what best explains the connection to which we draw attention in making many of our conditional claims.

There is still some tidying to do. We have been keen to emphasize the diverse uses of conditionality, which we can now make explicit. There are different sorts of conditional *sentences* (i.e. linguistic expressions that can be used to express conditional statements), different sorts of conditional *statements* (that is, statements one uses conditional sentences to express), some of which are contra-conditionals (that is, elliptically expressed denials of a conditional relation between antecedent and consequent), some of which are rhetorical, i.e. only feigning a conditional relation, and then *proper conditional statements*, that actually state a conditional relation. Among the proper conditionals there are then those that are used to express a logical or classificatory relation between antecedent and consequent (e.g. 'if *x* is a man, *x* is mortal'), or an unconditional ontological principle (e.g. 'if *x* is influenced by a net zero moving force, *x* will continue in constant rectilinear motion or remain at rest'), or an unconditional mathematical relation (e.g., 'if *x* is a triangle, the sum of the interior angle will be equal to two right angles'), and, finally, ordinary causal conditionals, which will always be stated with a tacit *ceteris paribus* clause.

Conclusion

We began by pointing to a number of cases in which the ratio analysis of our intuitive notion of conditional probability fails, even where the probability of antecedent and consequent are well defined. A general diagnosis of these failures was that the probability of *A* given *B* was dependent on a connection between *A* and *B* that the analysis had failed to capture. In many cases where the unconditional probabilities are derived from underlying conditional ones, application of the RATIO method of calculation does not produce an unintuitive result but, we argued, it does in most cases where the probability of *A* is 1, where *A* and *B* are probabilistically independent and where the probability of (*A* & *B*) is high.

Since the use of RATIO often fails to give plausible results we need to recognise that there are cases where *A* and *B* are connected in some significant, ontological sense. Indeed, it is because of this

connection that the probability of *A* will be conditional on that of *B*. And when we look at conditional probability from an ontological point of view, it seems that our intuitions favour a non-Humean connection between antecedent and consequent that is best understood as a real causal connection and not merely the causation that is gained within the theory of Humean supervenience. At the very least, and no less significant, it is such a real connection that we wish to assert in making many of our conditional statements. Our linguistic behaviour thus betrays our anti-Humeanism.

The final and crucial move, we argue, is that we understand causal connection within a dispositional framework. This allows us to see the true difference between the purely logical and ontological uses of conditionals. If we understand the ontological connection to be a causal-dispositional one, then there is a very real difference between the way we understand causal uses of 'if' and non-causal uses. Causal uses will be defeasible under antecedent strengthening, showing that causation involves the dispositional modality, which permits exceptions under additive interference. Other uses of 'if' – the non-causal ones – do not have this feature.

Armed with an ontology of real dispositions or powers, the path is open for an account of conditional probability. This would not be based on frequentist interpretations of probability, as fits best with Humean supervenience, where the probability of an event supervenes on the frequency with which events of its type occur within the Humean mosaic. Rather, probabilities will be determined by the singular propensities that are determined by the dispositions of things (see Popper 1990, Mellor 1971 and more recently Suárez 2011). It would be such a propensity of a flammable match to light, for instance, conditional upon it being struck, that grounded the relevant conditional probability. This may require, for the reasons given above, amendment to some of the standard ways in which we understand conditional probability.

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