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Abstract: Carnap's motivations for introducing reduction sentences for disposition terms are easily thought of as purely scientific and logical. However, it is argued here that Carnap's account had primarily a metaphysical motivation. The commitment to extensional logic, which generates the problem of dispositions, has a basis in Humean metaphysics in which there is only a truth value and no modal value. The chief ontological commitment of the dispositionalists should be to the reality of the dispositional modal connection in nature, as opposed to the Humean metaphysic in which all is loose and separate. This means that the dispositionalist cannot express their most important claims using the standard apparatus of classical logic, nor any logic that builds upon the classical base. It also shows that we cannot use the standard logical apparatus for adjudicating rationally between these rival metaphysical systems as logic will inherently favour Humeanism. This illustrates the Aristotelian doctrine that metaphysics is First Philosophy.

1. Introduction: the spirits of Carnap and Hume

During the mid-Twentieth Century, dispositions were treated as philosophical objects of suspicion. Attempts were made to reduce or eliminate them away, the first serious effort of the modern age coming in the form of Carnap's (1936) reduction sentences. The spirit of Carnap lives on in the conditional analysis of dispositions, which retains adherents.

Carnap saw the importance of the dispositional idiom to science but also that there was something problematic about the modal connection between distinct existences that real dispositional properties would bring. Such a modal connection was unobservable and thus no legitimate part of empirical science. While Carnapian motivations could easily be mistaken as scientific and logical, however, we argue that the true source of this anti-dispositional philosophy has a deeply metaphysical motive that

the defenders of dispositions can tackle on purely metaphysical grounds.

We contend that there is a metaphysical bias towards Humeanism within extensional logic. This logic is perfectly suited for a metaphysics of discrete, distinct existences of the kind developed by Hume (1739, 1748), which is where the true roots of this approach to dispositions lie. All is loose and separate: there are no necessary connections in nature. No powers. And the philosophy of science that goes with this view of the world is one based on observation of events where scientific statements have only a truth-value but no modal value. Anti-Humeanism, in contrast, commits to connectedness through a real this-worldly dispositional modality. This should be the principal ontological commitment of any dispositionalism, we believe. Understood in this way, disposition ascriptions could never be properly captured within an extensional logic, therefore, and any conditional analysis of dispositions is doomed either to falsehood or circularity.

2. Metaphysics and logic

Many who use the apparatus of classical logic, and other logics that build upon it, may do so in the belief that it is an innocent tool: one that carries no metaphysical theory with it, for instance. Indeed, because this tool is considered entirely neutral, the use of a logical analysis might be brought to bear upon different metaphysical theories and systems as a reliable and authoritative way of adjudicating between them. Logic is a codification of reason, one might say, and as metaphysics has to be reasoned through, then all theories must be answerable to logic. Without our reasoning, how else can we choose the best metaphysics?

Within contemporary metaphysics, for example, there is an on-going debate between the neo-Humean metaphysics of discrete, distinct existences, where at best events might be conjoined but never connected, and the neo-Aristotelian metaphysics of real causal powers in which there are real-worldly connections between powers and their effects. Representative of the neo-Humean view is David Lewis (1986) whose metaphysics of causation (Lewis 1973a) depends upon conjunctions of events where in the closest possible world in which the first event did not occur, the second did not either (cf. Hume 1748: §VIII, 56). A number have been involved in developing the neo-Aristotelian rival, for instance Mellor (1974), Harré and Madden (1975), Mumford (1998), Molnar (2003) and Martin (2008). In terms of simple numbers of adherents among contemporary metaphysicians, it would seem as if the neo-Humeans currently have the upper hand (see Collins, Hall and Paul 2004), though few are as ready as Lewis himself to endorse the plurality of concrete other worlds in the position known as modal realism.

However, we do not accept that this battle between rival ontologies is always a fair fight. In particular, the classical logical framework, in which virtually every analytic philosopher is schooled, is one inherently suited to the Humean metaphysic. One might then speculate that in adopting such a logic, its users should indeed find neo-Humeanism more intuitive, despite containing many of what Hume himself, writing before the establishment of classical logic, thought of as counterintuitive aspects (1739: Bk I, Pt IV, §vii). A less speculative finding, if it is established that logic contains Humean commitments, is

that it clearly cannot be used as a neutral and fair tool in deciding between neo-Humeanism and neo-Aristotelianism. There are things that those who believe in real causal powers or dispositions simply cannot express within a classical framework, nor indeed in any logic that builds on a classical foundation, such as various systems of modal logic. Simply to modally strengthen classical logic will not do. There are some major assumptions at the very core of all classically-based systems that, if one believes in neo-Aristotelian causal powers, one should never accept.

Our aim, therefore, is to expose the metaphysical assumptions – neo-Humean assumptions – within the classical framework. This will require some historical work as we uncover the root commitments of the view. This work would count as confirmation of a further well-known Aristotelian claim: that metaphysics is First Philosophy, prior even to logic. And from that it would follow that one should first choose one's metaphysics and then choose one's logic, rather than the other way around.

3. Carnap, Dispositions and Science

Carnap is the pivotal figure in this debate due to his recognition of the importance of disposition terms but also his commitment to the extensional apparatus of classical logic. It is in Carnap that we find the clash between dispositions and logic, resulting – we would say inevitably – in a failed attempt to define the former in terms of the latter using the material conditional. Attempts at a conditional analysis of dispositions still continue (e.g. Gundersen 2002, Choi 2008).

Carnap realised that science is filled with dispositional vocabulary but also that the standard logical tools could not accommodate a modal connection between distinct existences. Such a modal connection was unobservable and thus not a part of empirical science (see Carnap 1936 and 1956), with Carnap's verificationism being brought to bear. This unobservability claim for dispositions, we have argued, is contestable (Mumford and Anjum 2011: ch. 9). The modal force of dispositions is arguably observable once we understand correctly our own roles as causal agents and patients, proprioceptively aware of the world. But the modal connection is not observable if one follows Hume's account of causation and volitional agency.

This is where we venture a historical hypothesis, though clearly one we cannot prove with any certainty. Carnap was taught by Frege at Jena and Frege, we know from the engaged discussion in the *Grundlagen* (Frege 1884), read J. S. Mill's (1843) *System of Logic*. Mill in turn was developing the empiricist programme of Hume (before that, Locke) and although Frege is critical of Mill in relation to the foundations of arithmetic, his own logic of *Begriffsschrift* (Frege 1879) is perfect for a general Humean outlook in which all is loose and separate. We thus have a hypothesis concerning key influences on Carnap. But we can also think of the lineage going forward in time from Carnap. Carnap's ideas spread, following his move to the United States, through his interactions with Quine (who had completed his PhD with the co-author of *Principia Mathematica*, A. N. Whitehead); and then from Quine to his sometime pupil Lewis. If all this is plausible, we have a line of influence connecting Hume to Lewis that moves crucially through Carnap. And Lewis, we ought to note, was willing to engage precisely in

Carnap's project of reducing disposition ascriptions away, with his revised conditional analysis (Lewis 1997).

The true source of this anti-dispositional philosophy – anti-dispositional insofar as the dispositional idiom ought to be reduced away – is really a deeply metaphysical motivation prior to the logic. Resistance to the modality of dispositions arises from a commitment to extensionalism: an entirely philosophical commitment, though one shared by prominent logical positivists. Extensional logic was adopted by logical positivists without acknowledgement of its metaphysical basis: and why should such a basis be considered by them, in any case, given their rejection of metaphysics on the same grounds given by Hume at the end of the *Enquiry* (Hume 1748: §12, 120)? Despite superficial appearances, Lewis's modal realist project is certainly within this tradition. There are no intra-world modalities, for Lewis; but a theory of modality is gained through the plurality of worlds and the inter-world similarity relation. Our version of Anti-Humeanism, in contrast, commits to connectedness through a real, this-worldly dispositional modality.

4. A backwards history of logic

We have made some broad-ranging claims already, the significance of which hardly needs emphasising. More detail should now be added if we are to have a persuasive case. We should start by explaining the commitments of the standard logic and then how dispositions have to be treated once such commitments are adopted. We will do this through a roughly backwards history of logic. This reverse-historical approach assists us in understanding the conceptual ordering of the key claims of classical logic.

First, what do we mean by extensionalism? Extensionalism would be the view that the language of an extensional logic is adequate to provide us with a 'canonical notation' sufficient for all the purposes of scientific discourse (the term 'canonical notation' is from Quine 1960: ch. 5 – a book dedicated to Rudolf Carnap). So what is extensional logic? To quote Ayer (1972: 44): 'An extensional system of logic can be characterised by the essential feature that replacement within it of one proposition by another which has the same truth-value always leaves the truth-value of the proposition in which replacement occurs unchanged.'

This is exactly the logic a Humean would want. If we restrict our considerations for the moment to classical propositional logic, then any proposition is capable only of truth or falsehood and nothing more. A proposition cannot have a modal value in addition, for instance. The business of science can then be exactly as Hume sees it in the *Treatise*. Our experience of the world tells us only what there is: not that something true is also necessary. And it is thus wholly appropriate within such a Humean framework that one can substitute any one truth for another and nothing should matter as to the truth of the whole within which that proposition occurs. The importance of this point will be clear when we come to the material conditional and its attempted use in defining or reducing disposition terms.

To get to that point, we should spell out some more of the logic. Next should be a notion of compositionality, understood here as a purely syntactic operation. Wittgenstein's 'elementary propositions' (1921: 4.21) are the simplest things that are either true or false. Complex propositions can be composed out of elementary propositions using connectives that are truth-functions of the elementary ones they connect (1921: 4.41). Hence, <the cat is black> is an elementary proposition because it is capable of truth and falsehood although no part of it is capable of truth or falsehood (here adopting Armstrong's (2004) use of angled brackets, <, >, to isolate propositions). The proposition <the cat is black and today is Sunday> is complex because it has components that are capable on their own of truth and falsehood – in this case two such components – which in the complex proposition are conjoined.

Crucially, Wittgenstein says that the composition of complex propositions is performed using propositions that are truth-functions of elementary propositions. Truth functionality is perhaps now taken for granted by many who are taught the standard logic; but it is an absolutely crucial feature for an anti-Humean to oppose. We should be sure, therefore, we understand exactly what it means. A striking account is provided by Russell, who uses the term 'molecular' proposition for a complex formed out of elementary propositions:

I call these things truth-functions of propositions, when the truth or falsehood of the molecular proposition depends only on the truth or falsehood of the propositions which enter into it. The same applies to 'p and q' and 'if p then q' and 'p is incompatible with q'. When I say 'p is incompatible with q' I simply mean to say that they are not both true. I do not mean any more. Those sorts of things are called truth-functions, and these molecular propositions ... are instances of truth-functions. If p is a proposition, the statement 'I believe p' does not depend for its truth or falsehood simply upon the truth or falsehood of p, since I believe some but not all true propositions and some but not all false propositions. (Russell 1918: 210)

Thus, the truth value of propositions p and q entirely determine the truth value of any molecular proposition that has only p and q as its elements and uses only truth-functional connectives. Classical propositional logic will take it as definitive of a proposition that it is that which is true or false, can only be true or false, and must be either true or false: so there are no undetermined truth values for anything that is really a proposition.

Now there is one truth-functional connective in particular that will concern us. This is because it is the connective that usually plays the major role in any attempted reductive account of a disposition term: namely the material conditional. Although we sometimes think of this connective in terms of Frege's *Begriffsschrift* of 1879, it is of course an ancient way of understanding a conditional that Frege reintroduced. Bochenski explains its ancient origin:

Philo (of Megara, c.300 BC) said that the connected (proposition) is true when it is not the case that it begins with the true and ends with the false. So according to him there are three ways in which a true connected (proposition) is obtained, only one in which it is false. For (1) if it begins with the true and ends with the true, it is true, e.g. 'if it is day, it is light'; (2) when it begins with the false and ends with the false, it is true, e.g. 'if the earth flies, the earth has wings'; (3) similarly too that which begins with the false and ends with the true, e.g. 'if the earth flies, the earth exists'. It is false only when beginning with true, it ends with false, e.g. 'if it is day, it is night'; since when it is day, the (proposition) 'it is day' is true – which was the antecedent; and the (proposition) 'it is night' is false, which was the consequent. (Bochenski 1961: 116)

If one simply began from a consideration of conditionals, it is not clear at all that the material conditional would be the account that suggested itself. So why should it be adopted? Peirce gives one reason:

The utility of this is that it puts us in possession of a rule, say that 'if A is true, B is true', ... The hypothetical proposition may thereby be falsified by a single state of things, but only one in which A is true and B is false. States of things in which A is false, as well as those in which B is true, cannot falsify it. (Peirce 1885: 218)

The material conditional is then defined as true unless falsified by having a true antecedent and false consequent. Of course, if one is creating a system of logic, as Frege was, this asset of the material conditional is a considerable advantage. The rival Diodorean conditional, for instance, 'is true when it begins with true and neither could nor can end with false.' (Bochenski 1961: 117-118) But this does not give us a rule for deciding the truth or falsehood of the whole based simply on the truth or falsehood of its antecedent and consequent components. Such simplicity is what truth-functionality in general gives us. Indeed the material implication can even be understood simply in terms of conjunction and negation, since $A \rightarrow B$ (where \rightarrow marks the material conditional) is equivalent to $\neg(A \ \& \ \neg B)$. The language is thus perfect for dealing with mere occurrence and non-occurrence. With the Diodorean conditional, one would have to know, in addition to the truth of the antecedent and consequent, whether the consequent, even if true, could be false: and nothing is said about the truth of conditionals whose antecedents are false.

But there is a further factor to consider. Simplicity alone is unlikely to have attracted Frege, nor anyone else, if it comes at considerable cost to the logical system: if the material conditional were so far removed from the world or our reasoning so as to render that logical system useless, by which we mean

without application. However, as we have already said, for a Humean, what more connection could one want in order to describe the world than the material conditional? As Hume had argued, to say that A causes B is to say nothing more than that A is always followed by B (they are constantly conjoined, contiguous and A is temporally prior to B). Notoriously, Hume argued that we absolutely could not say in addition that A necessitated B. A and B were conjoined but never connected. It is entirely adequate, therefore, for neo-Humeans to adopt the material conditional when making causal claims. That A causes B could plausibly then be understood according to the truth-table of the material conditional: that is, false only when A is true and B is false, true otherwise. In a little quoted passage, after setting out the conditions of the material conditional, Frege said exactly this: 'We can thus translate: "If something has the property X, then it also has the property P.", or "All X's are P's." This is how causal connections are expressed.' (Frege 1879: 134)

5. Dispositions and the material conditional

As already indicated, a realist about dispositions is someone who believes the world contains real causal powers, alleging the kind of connection-over-and-above-conjunction that Hume denied. A power brings about its manifestation when it is in appropriate conditions: it tends towards it, makes it happen. There would be, in this causally powerful world, strong modal connections between powers and their manifestations, hence it is not the case that all is loose and separate. A power or disposition bears a more than purely contingent connection to the manifestation it brings about.

Clearly such things are not part of the Humean's ontology. How, then, is an extensionalist to treat dispositions? One can hardly deny that we have and use freely a dispositional vocabulary. What is more, a scientific naturalism, such as logical positivism, cannot even deny that this dispositional vocabulary is used in science. Even in fundamental physics, we ascribe properties such as spin, charge and mass, which look dispositional in character. One possible response from an extensionalist is to say that we appeal to dispositions in current science only because such a science is not yet complete or ideal. Quine says, for instance: 'So, if I were trying to devise an ideal language for a finished theory of reality, or any part of it, I would make no place in it for the general dispositional idiom.' (Quine 1974: 11) This suggests an eliminative approach to our dispositional vocabulary, for instance: that the ideal language of reality would be free of disposition terms.

Another possible approach, however, is reductionist. One could try to reduce disposition terms to occurrent, non-disposition terms using only truth-functional connectives. If successful, such an account would be entirely acceptable to the extensionalist. Indeed, there is something quite important at stake here. The neo-Aristotelian claims that dispositions constitute an irreducible feature of reality: a feature that Hume's description of the world omits to its detriment. But, if the reduction goes through, it shows that the Humean can account for everything that the dispositionalist claims is additional. No modal connections would be needed; truth-functional connectives would alone have been adequate.

Carnap recognised, however, that contrary to the spirit of Frege's claim, quoted above, one cannot

define a disposition predicate with a simple extensional conditional analysis, using the material conditional. One cannot say that x has disposition D simply when it is that case that $Fx \rightarrow Gx$. Such a conditional is true whenever the antecedent is false. Something might then satisfy the definition for both soluble (S) and insoluble (I), if never tested, where $F_{x,t}$ means x is placed in liquid at t and $G_{x,t}$ means x dissolves at t :

$$(S): \quad \forall x \forall t (Dx \leftrightarrow (F_{x,t} \rightarrow G_{x,t}))$$

$$(I): \quad \forall x \forall t (\neg Dx \leftrightarrow (F_{x,t} \rightarrow \neg G_{x,t}))$$

Using the material conditional, it follows that anything not placed in liquid ($\neg Fx$) is merely in virtue of that fact soluble (Dx) but at the same time insoluble ($\neg Dx$). We might think of this as a paradox though of course it is a perfectly natural consequence of adopting the material conditional and is thus entirely acceptable to the consistent extensionalist.

Carnap thought that this was a problem, though. His response was to concede that dispositions cannot be defined in extensional terms but to argue that this did not matter as long as they could be reduced to a non-equivalent extensional sentence that was constructed out of observation sentences. 'Testability and Meaning' (Carnap 1936) is an attempt to integrate this project into the larger one of constructing a language for science based on observation. It attempts to show that 'all scientific terms could be introduced as disposition terms on the basis of observation terms either by explicit definition or by so-called reduction sentences, which constitute a kind of conditional definition' (Carnap 1956: 53).

The explicit definition is forgone and the *reduction sentence* replaces it. The reduction sentence for a disposition term is given as (1936: 440):

$$R. \quad \forall x \forall t (Q1(x,t) \rightarrow [Q3(x) \leftrightarrow Q2(x,t)])$$

where $Q3$ represents the disposition term. In the case of solubility the reduction sentence would be 'If any x is put into water at any time t , then, if x is soluble in water, x dissolves at the time t , and if x is not soluble in water, it does not' (1936: 440-1).

When Carnap goes into more detail, the reduction sentence R turns out to be a special case. As the unified science seeks to introduce a new disposition predicate, $Q3$, into the language, it does so through characterising the positive and negative test cases that form the truth-conditions for application of the predicate. Carnap gives these test cases as:

$$R1. \quad Q1 \rightarrow (Q2 \rightarrow Q3)$$

and

$$R2. \quad Q4 \rightarrow (Q5 \rightarrow \neg Q3),$$

where $Q1$ and $Q4$ are the antecedent experimental conditions for the test and $Q2$ and $Q5$ are possible results which would confirm or disconfirm the presence of the disposition. We can see that ' $Q1 \ \& \ Q2$ ' is a sufficient condition for application of the predicate $Q3$, while ' $\neg(Q4 \ \& \ Q5)$ ' is a necessary condition for $Q3$. Together, $R1$ and $R2$ are the 'reduction pair' for $Q3$. We are told that 'By the statement of $R1$ and $R2$ "Q3" is reduced in a certain sense to those four predicates' (1936: 441).

The case of R was a special one. This is called the 'bilateral reduction sentence' and is simplified to (1936: 442):

$$Rb. \quad Q1 \rightarrow (Q3 \leftrightarrow Q2)$$

which occurs when $Q1$ and $Q4$, and $Q2$ and $\neg Q5$, of a reduction pair, coincide. Hence the same test can be used for both confirmation and disconfirmation of the disposition's presence and only one reduction sentence is needed to reduce the meaning of $Q3$.

The problem with the material conditional is that whenever an antecedent is false, that is, whenever the test conditions are left unfulfilled, the material conditional is true and the disposition can be ascribed. Reduction sentences do not fully eliminate this difficulty however; rather they side-step it with the clause that whenever an antecedent is not true for any time t , in untested cases, then it is meaningless to ascribe the disposition. The presence of the disposition is neither affirmed nor denied, rather, the predication of such a disposition is deemed meaningless because it lacks any confirmed empirical content. Thus Carnap has to include the clause that $R1$ and $R2$ constitute the reduction pair for $Q3$ provided it is not the case that ' $[(Q1 \ \& \ Q2) \vee (Q4 \ \& \ Q5)]$ is not valid [i.e., true]'; that is, provided at least one test case has been confirmed. Similarly, the bilateral reduction sentence Rb reduces the meaning of $Q3$ provided that ' $\forall x (\neg Q1(x))$ is not valid [true]'. This leaves a large area of indeterminacy, for the reduction of $Q3$ is conditional upon the realisation, at some time, of the antecedent test conditions of the reduction sentence. Because the meaningfulness of the term is conditional upon the truth of the antecedent test conditions, the reduction sentences are also known as 'conditional definitions'.

But does this entail that it is meaningless to call this vase fragile or this cube of sugar soluble because they have never been tested? Just when and how many times does the testing for the disposition need

to be conducted for the reduction sentence to be confirmed? Carnap is not wholly clear on this. Consider again the quantified version of the bilateral reduction sentence R. The disposition predicate 'Q3' is non-relative to a time t , hence one test of the reduction sentence at time t_1 will, if Q2 is also realised at time t_1 , confirm the truth of Q3 for all times. We must say therefore, that a confirming instance is insufficient to confirm the truth of 'Q3(x)', rather it suffices only for the confirmation of 'Q3(x,t)'. This apparently adds further to the area of indeterminacy of Q3, for we must say that the reduction sentence is not only indeterminate when a test is never made, but now it is also indeterminate whenever the disposition is not currently being tested because we have no verification of its behaviour in between tests. Carnap realised there was this problem and made concessions in an attempt to answer it (e.g. Carnap 1936: 445). We will not follow the point further, however, except to say that we do not think he made the problem go away.

Carnap's reduction sentences are ultimately inadequate to fully grasp the meaning of a disposition term. A simple material conditional ' $P \rightarrow Q$ ' will not do the job and Carnap's reduction sentence does little better, we have claimed.

The inadequacies of the material conditional seem to be the cause. If we restrict our consideration again to propositional logic, we can see that there are many other counterintuitive results. Based mainly on a list of theorems assembled by C. I. Lewis (1918), we offer some natural readings that illustrate the problem:

$$1. \quad \neg P \rightarrow (P \rightarrow Q)$$

If x is not put in water, it follows that if x is put in water, it dissolves.

$$2. \quad Q \rightarrow (P \rightarrow Q)$$

If x breaks, it follows that if x is exposed to light, it breaks.

$$3. \quad \neg(P \rightarrow Q) \rightarrow P$$

If it is not the case that if the match is in water it dissolves, it follows that the match is in water.

$$4. \quad \neg(P \rightarrow Q) \rightarrow \neg Q$$

If it is not the case that if x is exposed to light then it breaks, it follows that it is not the case that x

breaks.

$$5. \quad \neg(P \rightarrow Q) \rightarrow (P \rightarrow \neg Q)$$

If it is not the case that if x is exposed to light it breaks, it follows that if x is exposed to light, it does not break.

$$6. \quad \neg(P \rightarrow Q) \rightarrow (\neg P \rightarrow Q)$$

If it is not the case that if x is exposed to light it breaks, it follows that if x is not exposed to light then it breaks.

$$7. \quad (P \ \& \ Q) \rightarrow ((P \rightarrow Q) \ \& \ (Q \rightarrow P))$$

If x weighs 10 kilos and dissolves, it follows that if x weighs 10 kilos it dissolves, and if x dissolves it weighs 10 kilos.

$$8. \quad (\neg P \ \& \ \neg Q) \rightarrow ((P \rightarrow Q) \ \& \ (Q \rightarrow P))$$

If it is not the case that x weighs 10 kilos and not the case that x dissolves, it follows that if x weighs 10 kilos it dissolves, and if x dissolves it weighs 10 kilos.

$$9. \quad (P \rightarrow Q) \vee (Q \rightarrow P)$$

It is either the case that if x is immersed in water it breaks, or that if x breaks it is immersed in water.

$$10. \quad (P \rightarrow Q) \rightarrow ((P \ \& \ R) \rightarrow Q)$$

If it is the case that if a match is struck it lights, it follows that if a match is struck and there is a gale blowing, it lights.

While conditionals with false antecedents have received much attention since David Lewis's (1973) work on counterfactuals, the Humean assumption is best revealed, we suggest, in (7) above: where two true

propositions make a true material conditional going from either one to the other. This means that a conjunction suffices to derive a material conditional in either direction between any two truths. We take this to be a trivialisation of conditionals, suggesting that we cannot really have the material conditional in mind when we assert a conditional 'if P then Q'. The mere fact that from any pair of truths, we can infer a material conditional in each direction, tells us that this is a Humean way of understanding a conditional.

One might object against this putative trivialisation that in a Humean metaphysic there really is nothing more a conditional could assert than that it is not the case that the antecedent is true and the consequent false: 'not(P and not-Q)'. Similarly, causation can mean nothing more than what we know of it, according to Hume's analysis, which is constant conjunction, temporal priority and contiguity. We have no knowledge of any necessary or other modal connection between cause and effect. Constant conjunction just means that whenever C occurs, E occurs (where each C is before and spatially next to an E). Given the lack of connection in the Hume-world, then there is nothing more that causation could mean than that when C is the case, E is the case (plus the other two conditions, henceforth assumed). To be explicit: there is no necessary or other modal connection to be taken into account between C and E. Hence, there is no distinction to be drawn between 'accidental' and 'genuinely causal' constant conjunctions, for example: a distinction that many critics of Hume have tried to assume (e.g. Armstrong 1983: ch. 2). Further, no conclusion is to be rationally drawn about those cases in which C is not the case.

6. Strengthening and weakening

It might yet be argued that we shouldn't blame logic for any of this. Logic is what we make it. Shouldn't we simply add some further strength to classical logic so that it allows us to express truths about a richer world such as ours: one richer than a Hume world? We are certainly at liberty to develop a logic that allows us to express what we think should be expressed. The problem is, however, that for anyone serious about the ontology of real causal powers, anything that includes the classical base will contain its flaws. One cannot simply bolt on to Frege's logic additional components that would satisfy powers metaphysics. The two would be fundamentally at odds. Thus, any extended logic that retains the classical base will see the same counterintuitive results resurface that the dispositionalist rejects. We show this for the sample cases of first-order predicate logic, modal logic, and the logic of probability.

Predicate logic is the most familiar extension of propositional logic. For more complex arguments, such as Aristotle's syllogisms, we need this first-order logic to uncover the argument's structure. So is it that we have made it only seem as if classical logic could not express dispositionalist claims because we restricted it to its simplest form? Would the possibility of quantification give us a stronger link between antecedent and consequent? It seems not. From any universally quantified conjunction we can derive a universally quantified conditional in any direction (11); if everything is G, then if something were F it would be G (12), and if nothing were F, then if anything were F it would be G (13). Because predicate

logic retains the truth-functional connectives, we get correspondingly counterintuitive results, as far as anti-Humeans are concerned: just quantified versions of them. Hence:

$$11. \quad (\forall x)(Fx \ \& \ Gx) \Rightarrow ((\forall x)(Fx \rightarrow Gx) \ \& \ (\forall x)(Gx \rightarrow Fx))$$

$$12. \quad (\forall x)(Gx) \Rightarrow (\forall x)(Fx \rightarrow Gx)$$

$$13. \quad (\neg \exists)(Fx) \Rightarrow (\forall x)(Fx \rightarrow Gx)$$

Perhaps it might be said that modality is the real issue and this is what needs to be added to classical logic. Once one does that, one might say it shows that there was nothing inherently Humean about the classical base. It is simply that one needs to find the right form for anti-Humeans. We can give the realist about powers a modally strengthened logic and then let them get on and express their claims about dispositions using it. Unfortunately, this does not work out with any of the best developed modal logics, given that they have all retained the classical base of the usual truth-functional connectives (such as the systems described in Hughes and Cresswell 1996).

Introducing modal strengthening does not secure the conditional connection between antecedent and consequent that the neo-Aristotelian wants. Instead we get consequences that look very much like the material conditional, but with necessity replacing truth. A necessary conjunction, for instance, will give a necessary conditional in any direction (16). Other results also follow that the dispositionalist would see no reason to accept, hence:

$$14. \quad \Box Q \Rightarrow \Box(P \rightarrow Q)$$

$$15. \quad \neg \Diamond P \Rightarrow \Box(P \rightarrow Q)$$

$$16. \quad \Box(P \ \& \ Q) \Rightarrow \Box(P \rightarrow Q) \ \& \ \Box(Q \rightarrow P)$$

$$17. \quad \Box(\neg P \ \& \ \neg Q) \Rightarrow \Box(P \rightarrow Q) \ \& \ \Box(Q \rightarrow P)$$

Now why would such a modal logic be developed in the first place? An answer seems to be that if one adds modal operators to standard truth-functional logic, it still remains possible to have an entirely extensional interpretation of modality, as the work of David Lewis (1986) ably demonstrates. $\Box Q$ need not, as a dispositionalist might at first have expected, mean that there is some worldly necessity to Q , in addition to its truth. Rather, Lewis shows that this can be accounted for entirely in terms of truth alone – but truth in all worlds, which can be thought of as a kind of hyper-extensionalism.

The final adaptation of classical logic that we want to rule unacceptable to the dispositionalist concerns the extensional treatment of probability. Again, a probabilistic logic might be one that the dispositionalist could think of as potentially useful. Dispositions tend towards certain outcomes so one might be persuaded to think that this is a matter of making them more probable. We have tried a modal strengthening of logic, without satisfaction, so perhaps this sort of modal weakening will work better.

Adams (1975: 3) proposed that our conditional credence is given by the ratio analysis of conditional probability. With this ratio analysis, the probability of a conditional 'if A, then B' is identical with the probability of 'A & B' divided by the probability of A:

$$\text{Adams' Thesis: } \Pr(\text{If A then B}) = \Pr(B|A) = \Pr(A \& B) / \Pr(A)$$

But this alternative also generates similar results to the material conditional. From any pair of statements that are highly probable, we can derive conditionals in either direction which are highly probable (20) and there are other counterintuitive results too:

18. $P(B) = 1 \Rightarrow P(B|A) = 1$
19. $(P(A \& B) = P(A) \cdot P(B)) \Rightarrow P(B|A) = P(B)$
20. $(P(A \& B) = \sim 1) \Rightarrow ((P(A|B) = \sim 1) \& P(A|B)) = \sim 1)$

7. Conditionals and Deviant causal chains

The Humean assumptions within the logical treatment of dispositions run deep. But perhaps they are deeper than even many dispositionalists realise. We wish now to push this point even further. It is not just the interpreting of 'if P then Q' as a material conditional that shows a broadly Humean metaphysics at play, but explicating dispositions in conditional terms at all is arguably an ill-advised move for a dispositionalist.

While those developing a realist theory of dispositions are likely immediately to see that the material conditional is not up to the job, they could think that some suitably realist, alternative theory of conditionals would be all that's needed. Perhaps one could keep the conditionals and merely take real dispositions, rather than the Lewisian plurality of worlds, to be their truthmakers (e.g. Bird 2007: ch. 3). Or perhaps one could have a robustly anti-Humean account of the conditionals. One could then say that a realist view requires a real causal-modal connection between antecedent and consequent. The antecedent names the stimulus and the consequent names the response, in the usual way.

Such a permissive view in respect of a conditional account of dispositions, we suggest, plays into the hands of the Humeans. It still accepts the Humean framing of the approach to dispositions. What, for instance, if the consequent is true because there is a deviant causal chain leading to it from the antecedent condition?

A basic conditional account tells us that *x* is fragile where if it is dropped, it breaks. We have now granted, for purposes of argument, that this conditional can be as strong as one likes modally and concern a real causal connection between antecedent and consequent. We say that this still is not adequate because the antecedent conditions could cause the consequent through a deviant causal route and, where it does so, it is not necessarily the case that *x* is fragile. An object being dropped, for instance, might cause someone to smash it with a heavy sledgehammer. The object broke after being dropped, and being dropped was causally connected to it breaking, according to the case we have constructed. But such an object may or may not be fragile. The truth of the conditional is alone unable to determine which.

One might then try to produce a conditional that rules out this kind of possibility. Indeed, the debate around the conditional analysis of disposition ascriptions has brought ever more elaborate analyses. Lewis's revised conditional analysis is one such but see also Choi (2008).

What the possibility of deviant causal chains within true conditionals shows is that it is not enough to count as a manifestation of a disposition merely that the typical consequent manifestation occurs and its occurrence was caused by the typical antecedent stimulus. The true dispositionalist can explain why. A disposition is for a certain natural causal process towards an outcome or manifestation that can, unless interrupted, result in the consequent response which is the end point of that process. The stimulus and response, captured by the antecedent and consequent of a conditional, are only the start and end of a process. But the disposition has to be for the whole process. It matters, for it to be a real disposition, how the causation gets from one to the other. It has to be via this natural route. In the case of fragility, it has to be via a process in which small cracks appear on impact, leading gradually to bigger cracks and eventually breaks. Being smashed by a sledgehammer, even if this were to be a causal result of being dropped, still does not count as a manifestation of fragility because it is not the disposition that is doing the work, taking its natural course. What is being invoked is a distinct natural kind of process from A to B (see for instance Ellis 2001: 162-4), not simply that A is causally responsible for B.

The metaphysical view that accompanies the conditional analysis is one of discrete (cause and effect) events standing in a certain relation. It is a metaphysics of discrete stages. Instead, the dispositionalist understands the world in terms of continuous processes, running their course unless interrupted. It is possible to get causally from the same stimulus to the same response via more than one process. But on a conditional analysis of dispositions, these two or more cases would come out as the same disposition. For a realist, they would be different dispositions and thus such a realist should never be satisfied with a conditional analysis, even a strengthened one. It plays into the clutching hands of Humean metaphysics.

8. The irreducibly intensional connection

At the risk of overdetermining the case against reductive accounts of dispositions, there is one further important argument that shows how the dispositionalist needs to express something that cannot be expressed in standard logic, with its extensionalist commitments.

It is a mark of dispositions that they can fail to manifest, even when stimulated in the usual way. This is because all natural causal processes are susceptible to prevention and interference (see Bird's 1998 antidote cases and Mumford and Anjum 2011: ch. 3). No matter how much content one builds into the antecedent of a supposed causal conditional, it is always possible to add something more that prevents the manifestation.

Hence, where F is the typical stimulus for the Disposition D, and G is the typical manifestation:

$$(CA): \quad \forall x (Dx \leftrightarrow (Fx \rightarrow Gx))$$

is false because there could be a further factor ϕ which prevented the manifestation G even under stimulus F:

$$(CAE): \quad \forall x (Dx \rightarrow \diamond \exists \phi ((Fx \ \& \ \phi x) \rightarrow \neg Gx))$$

A way of avoiding this problem intuitively is to say that conditionals such as those in (CA) are to be *ceteris paribus* qualified. But what sense can the *ceteris paribus* qualification have that is neither circular nor still subject to counterexample? If the *ceteris paribus* clause points to some set of conditions under which the manifestation occurs, there might still be further factors added to those conditions that prevent the manifestation, for instance.

We have argued (Mumford and Anjum 2011: ch. 8) that there is an irreducible dispositional modality. Dispositions do not necessitate their manifestations but their connection to them is nevertheless more than purely contingent. It is more than the mere conjunction that Hume claims. When the conditions are right – when they meet their mutual manifestation partners – dispositions will tend, and no more than tend, to produce their effects.

No extensional connective can express this irreducible dispositional modality that ought to be the central commitment of a causal powers metaphysic: a commitment inexpressible in standard logic. Now perhaps one could say that a conditional analysis of dispositions is still possible as long as a connective is used that does indeed carry this dispositional force. The conditional could use a connective, which we

will indicate by an arbitrary symbol ' $D \rightarrow$ ', that involves the dispositional modality: for instance that Fx disposes towards Gx ? But this is to concede that the extensional definition of Dx does not work because the value of ' $Fx D \rightarrow Gx$ ' is not simply a function of the truth of Fx and Gx .

If one were to say that this explained the meaning of a ceteris paribus clause, for instance, then clearly it would be no use in a conditional analysis. Such an analysis would have to deploy the very notion – dispositionality – that the analysis was intended to analyse. Instead, then, we could offer a dispositional analysis of conditionals. The fragility of a glass makes it true that if it is thrown at a wall, dropped on a tiled floor, etc., it will tend to break. The truth or falsity of these various antecedents is itself irrelevant for the truth of the conditional as a whole. And in all cases there will be possible conditions under which the glass would not break, which means that the modality has to be of tendency only.

9. Conclusion

The classical logic that employs only extensional connectives is not a neutral or innocent tool of reasoning. It is an apparatus that coheres perfectly with a Humean theory of reality in which all is loose and separate, conjoined but never connected. Those who follow a neo-Aristotelian, causal realist and dispositionalist line, ought not to think it harmless to their metaphysics to use such a logic. It almost certainly would undermine their claims to express them in this way.

We saw that there are some extensionalists, such as Carnap, who see that the dispositional idiom cannot be ignored by anyone claiming to have a naturalistic approach. Some account of disposition terms was owed us. Carnap and others have failed to fulfil this obligation, which itself is indicative of the point we have argued. The realist about dispositions cannot express their claims within the standard logical framework. They should therefore be prepared to overthrow it. Our conjecture is that part of the continuing appeal of an otherwise counterintuitive Humean philosophy of nature is that it coheres so well with the logic on which we have now all been brought up. Logic should be our slave. In at least some instances, however, it may have made a slave of us.

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