Is There A Monist Theory of Causal and Non-Causal Explanations?

The Counterfactual Theory of Scientific Explanation

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Abstract. The goal of this paper is to develop a counterfactual theory of explanation (for short, CTE). The CTE provides a monist framework for causal and non-causal explanations, according to which both causal and non-causal explanations are explanatory by virtue of revealing counterfactual dependencies between the explanandum and the explanans. I argue that the CTE is applicable to two paradigmatic examples of non-causal explanations: Euler's explanation and renormalization group explanations of universality.

1. Introduction

Since the mid-2000s, a consensus (or the closest one gets to a consensus in philosophy) has emerged in the literature on the scientific explanations, according to which there are causal and non-causal scientific explanations. I call this claim the 'liberal consensus'. The liberal consensus has two sources: first, it rests on well-known examples of causal explanations in the natural and social sciences, including detailed mechanistic explanations, especially in the life sciences (Bechtel and Richardson 1993; Machamer et al. 2000), and less detailed 'higher-level' or 'macro' causal explanations (Cartwright 1989; Woodward 2003). Second, the liberal consensus also gains support from compelling examples of non-causal explanations. Such examples include different kinds of ‘purely’ or ‘distinctively’ mathematical explanations such as graph-theoretic (Pincock 2012; Lange 2013a), topological (Huneman 2010; Lange 2013a), geometric (Lange 2013a), and statistical explanations (Lipton 2004; Lange 2013b). Other kinds of non-causal explanations, especially in physics, include explanations based on symmetry principles and conservation laws (Lange 2011), kinematics (Saatsi forthcoming), renormalization group theory (Batterman 2000; Reutlinger 2014), dimensional analysis (Lange 2009), and inter-theoretic relations (Batterman 2002; Weatherall 2011).

The liberal consensus is not an innocent assumption, because the currently dominating accounts of scientific explanation are causal accounts. According to causal accounts, there is a tight conceptual connection between explaining and identifying or representing causes (see, among many others, Salmon 1984; Cartwright 1989; Machamer et al. 2000; Woodward 2003; Strevens 2008). The common core of seminal causal accounts of explanation can be expressed as follows: to explain some phenomenon P just is to identify the (type or token level) causes of P. The liberal consensus is a direct challenge to causal accounts, because causal accounts of explanation – prima facie – cannot accommodate non-causal explanations and, hence, causal accounts do not provide a general account of all scientific explanations (as van Fraassen [1980: 123]; Achinstein [1983: 230-243]; Lipton [2004: 32] already noted).[1]

This dialectic situation leaves us with the task to come up with a theoretical response to the liberal consensus. In this paper, I will defend one possible (and particularly attractive) strategy for dealing with the liberal consensus: *monism* – more precisely, I will defend one specific monist approach to explanation, a counterfactual theory of explanation. I take *monism* to be the view that there is one single philosophical account capturing both causal and non-causal explanations. A monist holds that causal and non-causal explanations share a feature that makes them explanatory. Hempel’s covering-law account is an instructive historical example for illustrating monism. Hempel argued that

[1] If causal accounts are taken to be general accounts of scientific explanation, then the existence of non-causal explanations is a direct challenge. If causal accounts are not taken to be general accounts, then the existence of non-causal explanations rather calls for a complementing account of non-causal explanations.

causal and non-causal explanations are explanatory by virtue of having one single feature in common: nomic expectability (Hempel 1965: 352). In the case of causal explanations, one expects the explanandum to occur on the basis on causal covering laws (laws of succession) and initial conditions; in the non-causal case, one's expectations are based on non-causal covering laws (laws of coexistence) and initial conditions. However, due to well-known problems of the covering-law account (Salmon 1989: 46-50), Hempel's monism is not a viable option for dealing with the liberal consensus.

My goal in this paper is to explore a monist account that does not collapse into Hempel's untenable version of monism. I claim that a *counterfactual theory of explanation* is a promising candidate for playing this role (building on and elaborating recent work by Frisch 1998; Bokulich 2008; Saatsi and Pexton 2013; Reutlinger 2013). However, I do not want to argue for full-fledged monism, i.e. the claim that the counterfactual theory captures *all* kinds of non-causal explanations (including the ones listed above). My goal in this paper is more modest: I will argue that the counterfactual theory can be successfully applied to two paradigmatic examples of non-causal explanations, which I take to be representative of a larger class of non-causal explanations: Euler's explanation and the renormalization group explanation of universality.[2]

The plan of the paper is as follows: in section 2, I introduce the counterfactual theory. In section 3, I argue that the counterfactual theory can be successfully applied to Euler's explanation and renormalization group explanations of universality.

[2] One alternative option for dealing with the liberal consensus is the view that seemingly non-causal explanations can ultimately be understood as causal explanations. Lewis (1986) and Skow (2014) have presented the most compelling attempt to spell out this strategy. Lewis and Skow rely on the notion of providing information about the causal history of the explanandum. Their notion of 'causal information' is significantly broader than the notion of 'identifying causes of the explanandum' figuring in the causal accounts I have referred to earlier. For instance, Lewis and Skow hold that one explains causally by merely excluding a possible causal history of some explanandum E, or by stating that E has no cause at all – while other causal accounts would not classify this sort of information as causally explanatory. I cannot enter a discussion of Lewis' and Skow's accounts here. Suffice it to say that I suspect that the notion of causal information is ultimately unhelpful because it is too broad.

2. The Counterfactual Theory

Is there a monist alternative to Hempel's troubled monism? It is fruitful to take a suggestion of Peter Lipton's as a stepping-stone for developing such a monist account. Having presented several examples of non-causal explanations, Lipton outlines a monist strategy for dealing with (what I call) the liberal consensus: "One reaction to this would be to attempt to expand the notion of causation to some broader notion of 'determination' that would encompass the non-causal cases […]." (Lipton 2004: 32) However, Lipton is skeptical as to whether one can prevent such a "broader notion of determination" from collapsing into Hempelian monism:

> This approach has merit, but it will be difficult to come up with such a notion that we understand even as well as causation, without falling into the relation of deductive determination, which will expose the model to many of the objections to the deductive-nomological model. (Lipton 2004: 32)

I think Lipton was too hasty in dismissing the merit of explicating "some broader notion of 'determination' that would encompass the non-causal cases" (ibid.), because such a philosophical project need not necessarily rely on the covering-law account and a "relation of deductive determination" (ibid.).

Following Lipton's original suggestion, my claim is that Lipton's envisioned broader notion of determination is the notion of the counterfactual dependence (of the explanandum on the explanans), as captured by counterfactual theories of explanation (for short, CTE). Perhaps the most influential version of the CTE[3] is James Woodward's:

> An explanation ought to be such that it enables us to see what sort of difference it would have made for the explanandum if the factors cited in the explanans had been different in various possible ways. (Woodward 2003: 11)

[3] I adopt Woodward's terminology in calling it a counterfactual theory.

> Explanation is a matter of exhibiting systematic patterns of counterfactual dependence. (Woodward 2003: 191)

The CTE is appealing from a monist perspective for two reasons: first, Woodward's (2003: §5.3, §5.8) CTE avoids the notorious problems of the covering-law account (see below for a qualification of this claim). Second, although Woodward's version of the CTE – and the underlying interventionist theory of causation – is mainly intended to fit causal explanations, the core idea of the CTE provides a natural way for specifying Lipton's "broader notion of determination". As Woodward suggests himself (but does not elaborate):

> [T]he common element in many forms of explanation, both causal and non-causal, is that they must answer what-if-things-had-been-different questions. (Woodward 2003: 221).

Answering "what-if-things-had-been-different questions" amounts to revealing (or exhibiting) – in Woodward's words – what sort of difference it would have made for the explanandum if the factors cited in the explanans had been different in various possible ways. The monist proposal, according to the CTE, is that causal and non-causal explanations are explanatory by virtue of exhibiting how the explanandum counterfactually depends on the explanans (Woodward 2003: 13). Or, put it in Lipton's terms, the notion of counterfactual dependence is the broader notion of determination that one "expands" from causal explanations such that it encompasses the non-causal explanations. This CTE-based monism has been explored by Frisch (1998), Bokulich (2008), Saatsi and Pexton (2013), Saatsi (forthcoming), and Reutlinger (2013). My goal is to further elaborate and advance the CTE and to apply it to two novel examples of non-causal explanations that proponents of the CTE have not yet addressed.

I will start with reconstructing the CTE in a way that emphasizes the "common element" (Woodward 2003: 221) of causal and non-causal explanations – this common element, I conjecture, is not essentially tied to an interventionist approach to causation (I will return to this issue below). In this reconstruction I largely follow Woodward's (2003: 203) and Woodward and

Hitchcock's (2003: 6, 18) exposition of the CTE. As a first step, the structure of an explanation has two parts: first, a statement E about the explanandum phenomenon; second, an explanans consisting of generalizations $G_1, \ldots, G_m$ and auxiliary statements $S_1, \ldots, S_n$. Auxiliary statements often are statements about initial or boundary conditions specifying the state of the explanandum system (as Hitchcock and Woodward highlight those statements typically assert that variables take a certain value). But the auxiliary statements may also comprise other kinds of statements useful for explanations (for instance, Nagelian bridge laws, symmetry assumptions, limit theorems, and other modeling assumptions). According to the CTE, the relationship between the explanans and the explanandum is *explanatory* iff the following conditions are all satisfied:

1. *Veridicality condition:* $G_1, \ldots, G_m, S_1, \ldots, S_n$, and E are (approximately) true.
2. *Implication condition:* $G_1, \ldots, G_m$ and $S_1, \ldots, S_n$ logically entail E or a conditional probability $P(E|S_1, \ldots, S_n)$ – where the conditional probability need not be 'high' in contrast to Hempel's covering-law account.
3. *Dependency condition:* $G_1, \ldots, G_m$ support at least one counterfactual of the form: had $S_1, \ldots, S_n$ been different than they actually are (in at least one way deemed possible in the light of the generalizations), then E or the conditional probability of E would have been different as well.[4]

The CTE provides a monist framework for causal and non-causal explanations – both kinds of explanation are explanatory because they reveal counterfactual dependencies between the explanandum and the explanans.

Let me add two further remarks in order to sharpen the CTE:

First, one may distinguish between causal and non-causal explanations within the CTE framework as follows: non-causal explanations are explanatory by virtue of exhibiting non-causal counterfactual dependencies; causal

[4] I assume that a generalization supports counterfactuals only if the generalization is non-accidentally true or lawful. (Note that I use a broad notion of laws that includes non-strict ceteris paribus laws, such as Woodward and Hitckcock's own invariance account). However, my aim here is not to defend a particular view of laws. I want to suggest instead that the CTE is neutral with respect to alternative theories of non-accidental truth or lawhood, I which take to be a strength of the CTE.

explanations are explanatory by virtue of exhibiting causal counterfactual dependencies. Although I consider the causal/non-causal distinction as a primitive for present concerns, I have argued for a positive account of how one might draw the distinction (Farr and Reutlinger 2013; Reutlinger 2013). Following Bertrand Russell (1912/13) and present-day Neo-Russellians, I propose that causal relations are characterized by criteria such as asymmetry, time-asymmetry, distinctness of the relata, metaphysical contingency, and so on. These 'Russellian' criteria may also be useful for identifying what makes an explanation causal, or respectively, non-causal in the CTE framework: causal explanations reveal counterfactual dependencies instantiating all of the Russellian criteria, while non-causal explanations exhibit counterfactual dependencies not instantiating all of the Russellian criteria. However, the success of the CTE does not depend on my particular proposal for drawing the causal/non-causal line.

Second, the dependency condition can, to a certain extent, be disentangled from an interventionist (or, more generally, causal) interpretation. In the context of causal explanations, Woodward interprets the dependency condition of the CTE in terms of interventionist counterfactuals whose antecedents state "if there were a possible intervention on the initial or boundary conditions". Woodward's critics have recently argued that interventionist counterfactuals are inherently problematic and ultimately dispensable for understanding causation and causal explanation (see Strevens 2007, 2008; Reutlinger 2013). Since I want to sidestep this debate, I simply do not assume that the counterfactuals mentioned in the dependency condition need to be understood as interventionist counterfactuals. Woodward himself voices another prima facie convincing reason for not requiring that *all* explanatory counterfactuals have the form of interventionist counterfactuals: "When a theory or derivation answers a what-if-things-had-been different question but we cannot interpret this as an answer to a question about what would happen under an intervention, we may have a non-causal explanation of some sort." (2003: 221) Based on these two reasons, I assume, in the dependency condition, that the CTE should generally rely on non-interventionist counterfactuals of the form "if S_1, …, S_n had been different than they actually are (in at least one way deemed possible in the light of the generalizations), then E or the conditional probability of E would have been different as well".[5] There is a positive analogy to Woodward's causal CTE regarding the existentially quantified form of the counterfactuals: the qualification 'in at least one way deemed possible in the light of the generalizations' is analogous to the interventionist requirement that there be *some* possible intervention on the antecedent variable that leads to a change in the consequent variable; it is *not* required that *all* possible interventions have such an effect.

I anticipate a potential worry at this point. One may wonder whether the non-causal version of the CTE avoids the problems of the covering-law account. I assume here that the causal version of the CTE successfully solves these problems. I can only sketch how the non-causal version of the CTE responds to these problems. (a) To avoid counterexamples such as the birth-control pills scenario (Salmon 1989: 50), the non-causal CTE distinguishes between explanatorily relevant and irrelevant factors as follows: a factor is relevant if the explanandum counterfactually depends on it (dependency condition), otherwise it is an irrelevant factor. (b) To deal with the syphilis-paresis scenario (Salmon 1989: 49), the non-causal CTE allows for low probability explanations (implication condition). Finally, having the notorious flagpole-shadow scenario in mind (Salmon 1989: 47), one may wonder whether the CTE accounts for the explanatory asymmetry in the case of non-causal explanations. This is one of the deepest puzzles of the current philosophy of explanation – not merely affecting the CTE – and it is an open research question as to how one can capture the explanatory asymmetry in the non-causal cases. It is even possible that non-causal explanations do not generally display such an asymmetry. This complex question will have to be addressed in another paper (for one recent attempts to make progress on the issue, see Lange 2011).

[5] Reutlinger (2013) provide an in-depth discussion of non-interventionist counterfactuals and their semantics.

3. Applying the Counterfactual Theory

I will now argue for the claim that the CTE applies to two paradigmatic examples of non-causal explanations. I will first apply the CTE to Euler's explanation (Section 3.1), and, then, to renormalization group explanations of universality (section 3.2).

3.1 Euler's Explanation

Let me start with an intuitively simple but powerful non-causal explanation (see Pincock 2012: 51-53; Lange 2013a: 489). In 1736, Königsberg had four parts of town and seven bridges connecting these parts. Interestingly, no one ever succeeded in the attempt to cross all of the bridges exactly once. This surprising fact calls for an explanation. The mathematician Leonhard Euler provided an explanation. Euler's explanation starts with representing relevant aspects of Königsberg's geography with a graph. A simplified geographical map of Königsberg in 1736 represents only the four parts of town (the two islands A and B, and the two riverbanks C and D) and the seven bridges (part A is connected to 5 bridges, parts B, C and D are each connected to 3 bridges). This simplified geography of Königsberg can also be represented by a graph, in which the nodes represent the parts of town A-D and the edges represent the bridges.

Given this graph-theoretical representation, Euler defines an Euler path as a path through a graph G that includes each edge in G exactly once. Euler uses the notion of an Euler path to reformulate the explanandum in terms of the question: why has everyone failed to traverse Königsberg on an Euler path? His answer to this why-question has two components:

1. *Euler's theorem:* there is an Euler path through a graph G iff G is an Eulerian graph. Euler proved that a graph G is Eularian iff (i) all the nodes in G are connected to an even number of edges, or (ii) exactly two nodes in G (one of which we take as our starting point) are connected to an odd number of edges (Pincock 2012: 51).
2. *Contingent fact:* The actual bridges and parts of Königsberg are *not* isomorphic to an Eulerian graph, because conditions (i) and (ii) in the definition of an Eulerian graph are not satisfied: no part of town

(corresponding to the nodes) is connected to an even number of bridges (corresponding to the edges), violating condition (i); and more than two parts of town (corresponding to the nodes) are connected to an odd number of bridges (corresponding to the edges), violating condition (ii).. Königsberg *could have been* isomorphic to an Eulerian graph in 1736, but as a matter of *contingent* fact it was not.

Therefore, Euler concludes, there is no Euler path through the actual Königsberg. This explains why nobody ever succeeded in crossing all of the bridges of Königsberg exactly once.

Does the CTE capture Euler's explanation? Euler's explanation has the *structure* demanded by the CTE: the explanans consists of Euler's theorem (a mathematical and intuitively non-causal generalization) and the statement that all parts are actually connected to an odd number of bridges. The explanandum phenomenon is that everyone has failed to cross the city on an Euler path. Moreover, all three *conditions* that the CTE imposes on the relation between explanans and explanandum are satisfied:

1. The *veridicality condition* holds because (a) Euler's theorem, (b) the statement about the 'contingent fact' that each part of Königsberg is actually connected to an odd number of bridges, and (c) the explanandum statement are all true.
2. The *implication condition* is met, since Euler's theorem together with the statement about the 'contingent fact' entail the explanandum statement.
3. The *dependency condition* is satisfied, because Euler's theorem supports the counterfactual "if all parts of Königsberg were connected to an *even* number of bridges, or if exactly two parts of town were connected to an *odd* number of bridges, then people would not have failed to cross all of the bridges exactly once".

Therefore, I conclude that the CTE applies to Euler's explanation.

3.2 Renormalization Group Explanations

So-called renormalization group (RG, for short) explanations constitute another, technically more sophisticated, kind of non-causal explanation (see Batterman 2000, 2002).[6] RG explanations are intended to provide understanding of why microscopically different physical systems display the same macro-behavior when undergoing phase-transitions. For instance, near the critical temperature, the phenomenology of transitions of a fluid from a liquid to a vaporous phase, or of a metal from a magnetic to a demagnetized phase is (in some respects) the same, although liquids and metals are significantly different on the micro-level. This 'sameness' or – to use a more technical term – 'universality' of the macro-behavior is characterized by a critical exponent that takes the same value for microscopically very different systems (Batterman 2000: 125-126). How do physicists explain the remarkable fact that there is universal macro-behavior?

It is useful to understand the workings of RG explanations as consisting of three key explanatory elements: (1) Hamiltonians, (2) RG transformations, and (3) the flow of Hamiltonians. There is a fourth element – the laws of statistical mechanics, including the partition function – which I will leave in the background, for sake of brevity (Norton 2012: 227; see Wilson 1983). The exposition of these elements will be non-technical because the paper is concerned with a non-technical question (see Batterman [2000: 137-144]; for a more detailed exposition see Fisher 1982, 1998; and Wilson 1983).

1. *Hamiltonians:* The Hamiltonian is a function characterizing, among other things, the energy of the interactions between the components of the system. One characteristic of the Hamiltonian of a physical system undergoing phase transition (say, a heating pot of water undergoing a transition from a liquid to a gaseous phase) is that each component of such a system does not merely interact with its nearby neighbors but is also correlated with distant components; in fact, the correlation length diverges (and becomes infinite). Adopting Batterman's terminology, I call this complicated Hamiltonian of a system undergoing a phase transition the "initial" or "original" Hamiltonian.
2. *Renormalization group transformations:* Keeping track of the interactions

[6] I argue for the non-causal character of RG explanations in Reutlinger (2014).

and correlations between all the components of a system undergoing a phase transition is – given the large number of components and the diverging correlation length – practically impossible. So-called renormalization group transformations (henceforth, RG transformations) deal with this intractability by redefining the characteristic length, at which the interactions among the components of the system at issue are described. Repeatedly applying RG transformations amounts to a re-description of the system, say fluid F, on larger and larger length scales (while preserving the mathematical form of the original Hamiltonian). The transformed Hamiltonian describes a system (and the interactions between its components) with less degrees of freedom than the original Hamiltonian. In sum, the RG transformation is a mathematically sophisticated coarse-graining procedure eliminating micro-details that are irrelevant for the explanation of universality.

3. *The flow of Hamiltonians:* Suppose we start with the original Hamiltonian H of a fluid F undergoing a phase transition. Then, one repeatedly applies the RG transformation and obtains other more 'coarse-grained' Hamiltonians. Interestingly, these different Hamiltonians "flow" into a fixed point in the space of possible Hamiltonians, which describes a specific behavior characterized by a critical exponent (Batterman 2000: 143). Now suppose there is another fluid F* and its behavior (during phase transition) is described by the initial Hamiltonian H*. Repeatedly applying the RG transformation to H* generates other, more 'coarse-grained' Hamiltonians. If the Hamiltonians representing fluid F* and fluid F turn out to "flow" to the same fixed point, then their behavior, when undergoing phase transition, is characterized by the same critical exponent (Fisher 1982: 85; Batterman 2000: 143).

In sum, the three elements of an RG explanation allow us to determine whether systems with different original Hamiltonians belong to the same "universality class" and are characterized by the same critical exponent (Fisher 1982: 87). Two systems belong to the same universality class, if reiterating RG transformations reveals that both systems "flow" to the same fixed point.

Now the decisive question is whether the CTE applies to RG explanations. First, RG explanations exhibit the required *structure*. The explanandum phenomenon is the occurrence of universal macro-behavior. The explanans of an RG explanation consists of the system-specific Hamiltonians describing the energy state of the physical systems in question – and, strictly speaking, the laws of statistical mechanics (the fourth element in the background); RG transformations and the flow of Hamiltonians are central auxiliary assumptions in the explanans (see Section 2).

Second, the *conditions* that the CTE requires to hold are also satisfied:

1. The *veridicality condition* is satisfied, because the explanandum statement (that there is universal behavior) and the explanans can – at least for present purposes – be considered as being (approximately) true. Due to space limits, I cannot discuss the role of idealizations (especially, limit theorems) in RG explanations posing a potential threat to the truth of the explanans. However, there are interpretations of the idealizations in question that are consistent with the veridicality condition (see Strevens 2008; Norton 2012).
2. The *implication condition* holds, since the RG explanans entails that many physical systems with different original Hamiltonians display the same macro-behavior.
3. The *dependency conditions* is met, because the RG explanans supports *some* counterfactuals of the form:

   > "There is a physically possible Hamiltonian H* such that: if (1) a physical system had the original Hamiltonian H* (instead of its actual original Hamiltonian H), if (2) H* were subject to repeated RG transformations, and if (3) we determined the resulting flow of the Hamiltonians to a fixed point, then a system with original H* would be in a different universality class than a system with original Hamiltonian H".

   Let me elaborate why I believe some counterfactuals of this form are true in the light of RG theory. To avoid misunderstandings, a counterfactual of this form *is not* true for *every* physically possible (original) Hamiltonian, because the main accomplishment of RG explanations is to show that many systems with different original Hamiltonians belong to the *same* universality class. However, the dependency condition of the CTE does not require that the explanandum depend on *all* possible changes in the intitial conditions. Instead the condition merely requires that the explanandum counterfactually depend on *some* possible changes in the explanans. The latter claim receives support from RG theory, which (also) shows that and why some systems with different original Hamiltonians do *not* exhibit the same macro-behavior and in fact belong to *different* universality classes (Wilson 1983). As Batterman (2000: 127) points out, RG explanations reveal that belonging to a particular universality class *depends* on features such as the symmetry properties of the order parameter and the spatial dimensionality of the physical system. Hence, if systems with H* and H – figuring in the counterfactual above – differ with respect to those features, then the counterfactual at issue seems to be true, according to RG theory.

Therefore, the CTE successfully captures RG explanations.

4. Conclusion

A 'liberal consensus' has emerged in the recent philosophy of scientific explanation: there are causal and non-causal explanations. In order to deal with the liberal consensus, I have argued for the counterfactual theory of explanation (the CTE). According to the CTE, causal and non-causal explanations are explanatory by virtue of revealing counterfactual dependencies between the explanandum and the explanans. I have argued that the CTE is applicable to two paradigms of non-causal explanations: Euler's explanation and renormalization group explanations of universality. For this reason, I believe that the CTE is a promising monist approach that deserves more attention and discussion.

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