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SYMPOSIA PAPER

Non-causal Explanations of Social and Biological Networks

Daniel Kostić[1,2] and Christopher Pincock[3]

[1]Institute of Philosophy and Sociology, Polish Academy of Sciences: Polska Akademia Nauk, Warsaw, Poland, [2]Donders Centre for Neuroscience, Radboud University, Nijmegen, Netherlands and [3]Department of Philosophy, The Ohio State University, Columbus, USA
Corresponding author: Daniel Kostić; Email: daniel.kostic@gmail.com

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Abstract

One argument that all explanations are causal explanations is that no extant analysis of non-causal explanations can respect mandatory restrictions on explanation. After articulating two such restrictions, Asymmetry and Directionality, we consider how they work with respect to an explanation from network theory that applies to both social and brain networks. We argue that there are two viable ways to make sense of this explanation. One approach is broadly ontic, while another is pragmatic.

1. Introduction

Are there non-causal scientific explanations? Many philosophers say "no" (Kuorikoski 2021). In this paper we consider what could be called the directionality challenge to non-causal explanation: any attempt to develop an account of non-causal explanation inevitably violates mandatory restrictions on explanation (Craver and Povich 2017). We argue that this challenge fails. There are in fact two promising ways to provide a positive account of how non-causal explanations work that respect all reasonable restrictions.

In section 2 we formulate this challenge by considering two restrictions on explanation that we call asymmetry and directionality. Here we draw on some recent work that illustrates the difference between these restrictions and how they are best formulated (Kostić and Khalifa 2021; Pincock 2023). Section 3 then considers how these restrictions may be violated in an explanation that is used in both sociology and neuroscience. This explanation links two properties of networks using a mathematically necessary biconditional. With this example in mind, section 4 develops an ontic response to the directionality challenge, while section 5 proposes a pragmatic response. These responses may ultimately be compatible, but we postpone further consideration of these relations for future work.

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2. The directionality challenge

In (Craver and Povich 2017) the authors challenge Lange's account of "distinctively mathematical" scientific explanation (Lange 2013; 2017; 2018). They contrast a traditional "asymmetry" worry directed at covering law accounts of explanation with their "directionality" worry: mathematical "equations have no intrinsic left-right directions; rather, these must be imposed from the outside" (Craver and Povich 2017, 33). They go on to argue that Lange's account allows in all cases for various contrapositive versions of genuine explanations that we should not accept as genuine. For example, if it is a genuine explanation to say that the bridges of Königsberg *cannot* be crossed exactly once on a tour of the city because the bridges *fail* to have a specific network structure, then it should also be a genuine explanation to say that the bridges of some other city *have* that network structure because they *can* be crossed exactly once on a tour (Craver and Povich 2017, 34). The directionality challenge is thus to endorse some non-causal explanations without invariably endorsing their reversals.

Despite distinguishing between asymmetry and directionality, Craver and Povich have yet to clarify what restrictions they have in mind. This challenge was independently taken up by (Kostić and Khalifa 2021) and (Pincock 2023) as part of their more systematic investigations into these matters. One formulation of asymmetry that is suggested by these discussions is:

> Asymmetry: for some explanatory relevance relation R, it is not generally the case that if A(c) is part of an explanation of B(c) via R, then B(c) is part of an explanation of A(c) via R.

"A(c)" and "B(c)" are whole claims about some explanatory target c. The general motivation for Asymmetry is that it cannot generally be the case that whenever A(c) contributes to an explanation of B(c) in some way that B(c) also contributes to an explanation of A(c) in that very way. For example, if A(c) indicates a cause of B(c), then it is not generally the case that B(c) indicates a cause of A(c).[1] The classic challenge to the covering-law model of explanation in terms of the height of a flagpole and the length of its shadow can be taken to involve arguing that the covering-law model violates Asymmetry. The prima facie challenge to non-causal explanations that emphasize mathematical equations or biconditionals is to clarify how Asymmetry is respected.

Craver and Povich develop a separate challenge that involves contrapositive reversals of genuine explanations. To regiment this challenge, we need some plausible restriction on explanations that includes these sorts of cases. Here is one proposal, again drawing on the work of (Kostić and Khalifa 2021) and (Pincock 2023):

> Directionality: for some explanatory relevance relation R, it is not generally the case that if A(c) is part of an explanation of B(c) via R, then not-B(d) is part of an explanation of not-A(d) via R.

[1] This can of course occur in some cases for specific reasons, e.g., feedback loops.

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As with Asymmetry, "A(c)" and "B(c)" are claims about some target c. "not-B(d)" and "not-A(d)" are claims about some other target d that ascribe to d the negation of the properties B and A. In the bridges case, the original explanation says that the bridges cannot be crossed (B(c)) because they lack a specific network structure (A(c)). Craver and Povich point out that the mathematical claim involved has a biconditional structure, and so appears to also license their "reversed" explanation: in a case where a city's bridges do have that specific network structure (not-A(d)), then this apparently can be explained by appeal to the fact that the bridges can be crossed exactly once on this tour of the city (not-B(d)). The second challenge for an account of non-causal explanation is to clarify how Directionality is respected.

Once Asymmetry and Directionality are presented in these terms, it becomes clear that they are two independent restrictions on explanation that require two different kinds of response. The pragmatic account that we sketch in section 5 illustrates a way to respect Asymmetry without respecting Directionality. This highlights the independence of the two restrictions. In the next section we discuss two case studies that provide details that help to embed our arguments in the actual scientific practice.

3. Efficient communication in social and brain networks

In the classic "six degrees of separation" experiment conducted by Milgram in the 1960s, subjects in the United States were given an envelope addressed to someone that they did not know (Milgram 1967). They were asked to try to get the envelope to its destination by forwarding it to someone that they knew on a first name basis. Milgram tracked how many intermediaries a successfully delivered letter went through and found that the average number of intermediaries was much less than he expected. Milgram argued that these findings were evidence that the social network among Americans at that time connected every American to every other American by a path that had, on average, a length of six. Later investigators argued that these social networks have what has been called a "small world" structure (Watts and Strogatz 1998). A small-world network involves each node being connected to many of its spatially near neighbors, with a smaller number of additional longer-range connections. Since their initial discovery in human social networks, small-world networks have been found in a wide range of natural and artificial systems, including the human brain and electrical power grids (Schnettler 2009).

In 2000 the computer scientist Kleinberg asked a more specific question about small-world networks: how can information be effectively sent across such a network on the assumption that information is routed just using the locations of the nodes that some sending node is connected to? Kleinberg showed that only some small-world networks permit the efficient sending of information when this additional constraint is imposed (Kleinberg 2000a; 2000b; Easley and Kleinberg 2010, chap. 20). He called these networks "algorithmic small-world networks" as the information is sent in an especially simple way: when a node X is tasked with sending information to a node Y, and X is not directly connected to Y, then X sends its information to a node Z that is, among its direct connections, closest to Y. For this to occur, X must somehow direct information in a way that accords with this algorithm. The specific mechanism

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that realizes this algorithm need not be known in order to identify what network structure would permit the algorithm to work.[2]

Kleinberg proved that information could be sent efficiently just in case the long-range connections in the network fit a specific statistical pattern. For a two-dimensional spatial network, the long-range connections fit a sequence of independent, random assignments such that the probability that u is connected to v is proportional to $d(u, v)^{-2}$, where d(u, v) is the distance between u and v. We will abbreviate this feature by saying that a small-world network whose long-range connections meet this restriction has the Kleinberg property. So, Kleinberg showed that:

> For any small world network n, n permits the efficient sending of information by an algorithm just in case n has the Kleinberg property.

Many small-world networks will fail to have the Kleinberg property as their long-range connections will not match this special kind of spatial distribution. For example, if the long-range connections are assigned between random nodes, independently of their distance, then the network will not have the Kleinberg property, and so it will not permit the efficient sending of information by an algorithm.

Kleinberg argued that we cannot explain Milgram's findings just by saying that this social network is a small-world network. For it is only a special kind of small-world network that permits what Milgram observed. So, Kleinberg insists that a reason why Americans are capable of sending these letters efficiently is that this social network has the Kleinberg property. As he puts the point, "Why should arbitrary pairs of strangers be able to *find* short chains of acquaintances that link them together? . . . It is natural to ask what properties a social network must possess in order for it to exhibit such cues, and enable its members to find short chains through it" (Kleinberg 2000b, 164). The cues turn out to be encoded in the statistical distribution of the long-range connections that we are calling the Kleinberg property.

The same kind of issue has been raised in neuroscience in relation to what is sometimes called the navigation problem. The brain and its parts can be treated as a network at various scales, from the regions of the brain and their links down to the scale of individual neurons and their synaptic links (the so-called "connectome"). A brain network is navigable (or efficiently navigable) just in case information that is transmitted according to a specific navigation strategy is reliably received. The navigation strategy that Seguin and collaborators (Seguin, Van Den Heuvel, and Zalesky 2018) consider employs the very same algorithm that was investigated by Kleinberg: "Navigation is a network communication strategy that routes information based on the distance between network nodes ([citing Kleinberg 2000b]) . . .

[2] For the algorithm to work, it must lead to information being transmitted efficiently through the network in the following sense: there is constant α, independent of the number of nodes n in the network, where the expected delivery time of a message is $\alpha (\log n)^2$. Furthermore, if the routing algorithm summarized above leads to messages being sent in this efficient way, then no other algorithm that exploits this limited information about the network can send messages any more efficiently, i.e., with a lower expected delivery time. See (Kleinberg 2000b, 165–66) and (Easley and Kleinberg 2010, 631–42) for a sketch of the proof.

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[by] progressing to the next node that is closest in distance to the desired target" (Seguin et al. 2018, 6297). They do not specify the mechanism through which nodes follow this algorithm, but instead set this as a problem for future research. Instead, Seguin et al. provide evidence that the human brain (and some non-human mammalian brains) are navigable in their sense. Their argument involves detailed investigations into how various sorts of brain scans should look were the brain to be navigable as opposed to some competing models of information transmission in the brain (Seguin et al. 2018, 6301).[3]

Let us take for granted that these brain networks are navigable. It should be clear that one explanation of this feature of brain networks will involve the very same Kleinberg property that we discussed above. As Seguin et al. put the point "Navigation depends on network nodes possessing information about the relative spatial positioning between their direct neighbors and a target node" (Seguin et al. 2018, 6301).[4] For this information to lead to efficient signaling, the network must have the right structure: "Successful navigation depends on certain topological properties such as small-worldness ([citing Kleinberg 2000b]) and a combination of high clustering and heterogeneous degree distribution (24), all of which are found in the brain networks of several species (9)" (Seguin et al. 2018, 6297). We take this talk of dependence to be explanatory: one reason why brain networks are navigable (a capacity) is that they are small-world networks with the Kleinberg property.

In summary, then, there are at least two cases where practitioners appeal to a mathematically necessary biconditional in order to explain the presence of a property of a real-world network. Here is a schematic presentation of that biconditional:

> M. For any small-world network n, n permits the efficient sending of information by an algorithm (E(n)) just in case n has the Kleinberg property (K(n)).[5]

And here is a schematic summary of the two explanations endorsed by Kleinberg and Seguin et al., respectively:

> E1. The social network of Americans s permits the efficient sending of information by an algorithm (E(s)) because s is a small-world network and s has the Kleinberg property (K(s)).
>
> E2. A human brain network b permits the efficient sending of information by an algorithm (E(b)) because b is a small world-network and b has the Kleinberg property (K(b)).

[3] One alternative is that nodes are able to send information along the shortest path, no matter how the network is structured. Seguin et al. reject this algorithm as too demanding as it would require nodes to "know" the entire structure of the network they are a part of. Seguin et al. also reject the diffusion model of transmission that involves nodes "broadcasting" information to all other nodes they are connected to.

[4] More generally, a network having a given structure does not guarantee that messages can be sent efficiently through that network. There must be some mechanism through which nodes transmit the information in line with that algorithm. This is consistent with the structure of the network being an explanation of the network's capacities.

[5] This result is similar to other cases emphasized by Woodward and Ross, where the structure of a network helps to settle the possibilities for interactions among the nodes of the network. See (Woodward 2018; 2022; Ross 2023) for more discussion.

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4. An Ontic Proposal

What is it about (M) that leads to (E1) and (E2) but not additional purported explanations that would clash with our Asymmetry and Directionality restrictions from section 2? Recall Craver and Povich's worry that "equations have no intrinsic left-right directions; rather, these must be imposed from the outside" (Craver and Povich 2017, 33). If we cannot appeal to causal relations, then what other factors can we appeal to? It might seem like a generalized counterfactual condition could work. But if we are dealing with a mathematically necessary equation or biconditional like (M) then both the "left-right" conditional and the "right-left" conditional will have the same level of necessity, namely mathematical necessity. This means that counterfactuals are too plentiful to privilege the one conditional over another.

One approach that we consider builds on a broadly ontic account of explanation: it is something about the systems that settles that only one of these candidate explanations is genuine. This factor must go beyond the fact that the requisite properties are present or absent. So, if we are sympathetic to a broadly ontic approach to explanation, we must bring in additional features of the target systems, beyond just the fact that they exhibit the relevant properties.

One initial point is that the properties connected by mathematically necessary biconditionals like (M) are often distinct properties: some networks have E without having K. For example, if every node is directly connected to every other node, then each message can be sent in one step, but the long-range connections fail to fit the statistical distribution required by K. Given that the properties are distinct, the basic ontic assumption is that there is something about the network that leads to one property explaining the other, and not vice versa. In the social network case, let us suppose that there is some process through which social networks form: people meet each other, move around, stay in touch and maintain some of their friendships. As a result, the social network s comes to be both a small-world network and to have the Kleinberg property (K(s)). And it is in virtue of it having the Kleinberg property that s has the property of permitting efficient communication (E(s)).

By contrast, consider another network t that develops a small-world structure, but in a way that fails to exhibit the Kleinberg property (not-K(t)). This could occur if the small-world structure indicated the social relations between the workers of a corporation. If the members of this corporation were moved around the world according to some plan for corporate innovation, this process could lead to long-range connections that failed to fit the statistical distribution required by the Kleinberg property. One unforeseen consequence of this corporate innovation would then be that the network no longer permits efficient communication (not-E(t)). So, for t, it is in virtue of not having the Kleinberg property that t lacks the property of permitting efficient communication (not-E(t)).

On this ontic proposal, then, the processes through which networks come to have properties settle what can explain what.[6] If these processes for s and t are as we have sketched them, then we get both (E1) and

[6] This proposal could be fruitfully compared to the heuristics Woodward identifies for settling the direction of non-causal explanations in (Woodward 2022). We have to leave this comparison to future work.

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(E1') t lacks the property of permitting efficient communication (not-E(t)) because t is a small world network and t lacks the Kleinberg property (not-K(t)).

No other explanations would then be legitimate. In particular, no violations of Asymmetry or Directionality are endorsed by this account of non-causal explanation. The order is set by the processes through which the systems acquire these properties, and for the systems specified, each system either has E because it has K or it lacks E because it lacks K. There is a kind of explanatory classification of these systems that makes either K or not-K responsible for either E or not-E. On the ontic proposal, similar points hold for the brain networks b and c.

The processes assumed here are causal processes. One objection to this suggestion is that a causal process is not apt to privilege a property like K over a property like E. It might seem that any causal process that makes a small world network with K is also going to make a small world network with E. And if that's the case, it seems that no such causal process can privilege K over E.

Our response to this objection is that explanatory relevance is not transitive in the way this objection seems to presuppose: even when A explains B and B explains C, it does not follow that A explains C or that the appeal to B is superfluous. We see this for contrastive causal explanations, where transitivity is widely acknowledged to fail. Despite the differences between the processes in the social and brain network cases, the factors that sustain these networks over time and that influence their growth and development are tied up with K rather than E. In the social network case, the key factor is how people move around the United States for purposes like education and employment, and how this tends to generate long-range connections that exhibit a specific sort of spatial distribution K. Nothing about this process directly involves E, efficient communication. In the brain network case, the details of the process are of course unknown. But the working assumption is that there are factors that influence brain connectivity as the brain develops. For example, more frequently accessed connections tend to grow stronger, while less frequently accessed connections tend to grow weaker. Over time, this will contribute to a brain network that has long-range spatial connections that satisfy K. So, as a result, this brain network will also exhibit E. Again, K arguably has explanatory priority over E given the processes that create and sustain the network.[7]

5. A Pragmatic Proposal

A second proposal for handling these cases is much more pragmatic and contextual. On this way of approaching explanation, a genuine explanation is an answer to a why-question, where genuine answers are identified in terms of contextual factors. Here we focus on the specific pragmatic proposal for non-causal explanations developed by Kostić (Kostić 2022; 2024). Kostić presents a theory of why-questions that helps to settle when a proposed explanation is genuine. In the cases we have focused on, the why-questions that drive the investigations focus on property E, efficient communication. For (E1) the corresponding why-question is: why, for social network

[7] It is certainly possible that researchers are mistaken in their assumptions about how these brain networks form. If they are mistaken, then this explanation would not be genuine. But this is the usual situation for an ontic approach: evidence that a proposed explanation is genuine could be misleading.

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s, does s permit the efficient sending of information by an algorithm (E(s))? This why-question arises in some specific context of inquiry. Kostić argues that a why-question arises in some context just in case it can be erotetically derived from a set of propositions that define that specific context of inquiry. An erotetic derivation obtains when these propositions settle that the question has an answer on some determinate list, but that the propositions do not entail any particular answer.[8]

To show how such derivation might work, we can employ Kostić's E-schema (Kostić 2024, 1083). The topic of investigation is the efficiency of the transmission of messages in a given network: "Why E(s)?" Further investigation could reveal that some small-world networks have features like K, while others do not. This suggests a contrast between small-world networks that have K and small-world networks that lack K. Kleinberg's work then establishes that this proposed answer is the genuine one: Why E(s) (rather than not-E(s)? Because K(s) (rather than not-K(s)): were s to have had not-K, then it would have had not-E.

With these preliminaries in hand, we are now in a position to clarify why, on the pragmatic view of explanatory relevance, asymmetry can be preserved even in the face of violations of directionality. Asymmetry is preserved because, within any given context of inquiry, a why-question involving some explanandum property E can be genuinely answered by appeal to an explanans property K, while a follow-up question about K cannot be answered in terms of E. This is because the propositions that define the context determine which questions can be erotetically derived and which answers count as legitimate. Once E has been explained by K, a further question about K requires a different kind of explanation, typically causal or historical, and cannot be answered simply by reversing the prior explanatory relation.

Directionality, by contrast, concerns relations across different systems or contexts. If it were the same system or the context—as in the case of asymmetry—it would be logically impossible to violate directionality in such non-causal explanations (Kostić and Khalifa 2021, 14163). Because the pragmatic approach treats explanatory relevance as context-dependent, it allows for different why-questions to arise in different contexts involving distinct systems or properties. In such cases, one might find that in context A, "Why E?" receives the genuine answer "Because K," while in context B, concerning a different system, the question "Why not-K?" receives the genuine answer "Because not-E." These are not contradictory, but rather reflect the fact that different explanatory contexts give rise to different why-questions and legitimate different answers. Had it been the same system—as in the case of asymmetry—such reversals would not be possible, as they would violate the structure of erotetic derivation.

This flexibility in handling directionality does not undermine the principled nature of the pragmatic account. On the contrary, it highlights an important distinction: while causal explanations typically respect both asymmetry and directionality, non-causal explanations are not bound by the same constraints. So long as asymmetry is preserved

[8] We can formulate the pragmatic explanatory relevance (**PER**) in the following way: (***PER***): *A set of propositions, that encapsulates a context of inquiry, determines explanatory relevance of an answer to a why-question just in case the inquiry context erotetically implies that why-question*. This restriction on explanatory relevance distinguishes Kostić's pragmatic approach (2024) from the much more permissive approach by van Fraassen (1980).

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within a given context, the pragmatic view allows for violations of directionality without inconsistency. Defenders of directionality may argue that violating it compromises asymmetry, but the pragmatic approach shows this need not be the case. Unless compelling reasons are provided to extend directionality to all forms of explanation, the pragmatic view should be considered a viable and principled alternative.

6. Conclusion

One argument that all explanations are causal explanations is that no extant analysis of non-causal explanations can respect mandatory principles like Asymmetry and Directionality. We have shown the limitations of this argument using two cases from scientific practice. There turn out to be at least two ways to make sense of these cases as involving a special sort of non-causal explanation. The ontic proposal we sketched takes these explanations to turn on a fine-grained distinction between properties, such that the presence of one property is explanatorily prior to another property. This indicated how one could have a kind of non-causal explanation that preserves both Asymmetry and Directionality. The pragmatic proposal we outlined demonstrates that, in certain cases of non-causal explanation, an erotetically regimented pragmatics of explanatory relevance preserves Asymmetry, even when Directionality is violated. Hence, it is not clear why Directionality is required for non-causal explanatory relevance relations.

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