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SYMPOSIA PAPER

Causal Constraints in the Life and Social Sciences

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Abstract

This paper examines constraints and their role in scientific explanation. Common views in the philosophical literature suggest that constraints are non-causal and that they provide non-causal explanations. While much of this work focuses on examples from physics, this paper explores constraints from other fields, including neuroscience, physiology, and the social sciences. I argue that these cases involve constraints that are causal and that provide a unique type of causal explanation. This paper clarifies what it means for a factor to be a constraint, when such constraints are causal, and how they figure in scientific explanation.

1. Introduction

In the philosophical literature, it is often claimed that scientific explanations need to meet particular standards, but also that explanation types can differ in various ways. A growing amount of work studies diverse types of explanation and explanatory practice (Woodward 2019; Ross 2023a). A recent example of this are analyses of "constraints," which are viewed as a unique explanatory factor that provides a distinct type of explanation. Constraint examples are numerous in science—we find parameter constraints in physics, developmental constraints in biology, anatomical constraints in neuroscience, and structural constraints in the social sciences. As their name suggests, constraints are often viewed as factors that limit, guide, or channel the behavior of some system, often explaining why various outcomes are more likely, while others are impossible or off limits.

An influential account of constraints and their role in explanation is provided by Lange (2018), who claims that they supply non-causal explanations. While Lange's account captures important features of constraints, it is primarily focused on constraint examples from the physical sciences. This paper builds on Lange's work by exploring constraints and constraint-based explanations in other scientific fields, including neuroscience, physiology, and the social sciences. These examples raise new questions for dominant philosophical accounts of constraints and their role in explanation. First, questions remain about how to define explanatory constraints, especially in ways that capture reasoning in the life and social sciences. Second, if explanatory constraints are always non-causal, why do scientists sometimes refer to them as causally responsible for outcomes and as targets that provide causal control? Finally, can philosophical work add clarity to scientific discussions of constraints? As scientists routinely state, the term "constraint" is often unclearly defined and inconsistently used.[1] Providing a clear and compelling definition of "constraint"—perhaps one with distinct subtypes or usages in different fields—is necessary for clear communication, effective theorizing, and progress in science and philosophy.

This paper addresses these questions by providing an analysis of explanatory constraints that applies to life and social science examples. I build on Lange's work by showing that his account captures important features of these examples, such as the "strength" of constraints and their ability to provide "impossibility explanations" (Lange 2018). However, my analysis differs from his by arguing that some constraints are causal and provide causal explanations. I provide an analysis that captures what makes an explanatory factor a constraint, what makes a constraint causal, and how causal constraints provide a unique form of explanation.

2. Lange on constraints

A key contributor to these philosophical discussions is Lange (2018), who provides an account of constraints and their role in explanation. Lange claims that explanations by constraint are common in science, that standard accounts of explanation fail to accommodate them, and that a compelling analysis of explanation by constraint should "do justice to scientific practice" (Lange 2018, 24).

In this literature, common constraint examples include the Königsberg bridge system, a mother attempting to divide 23 strawberries among 3 children, and various modal relations in physics (Lange 2018). In the Königsberg bridge case, the explanatory question is whether it is possible to walk a route that crosses each bridge exactly and only once. The topological structure of the bridges, as demonstrated by Euler, explains why such a path is impossible (Euler 1956).[2] According to Lange, this bridge structure constrains walking routes and, in so doing, it explains why such a path is impossible. In the second example, the explanatory question is whether a mother can divide 23 strawberries evenly among her 3 children (Lange 2018). Her attempts to do this are constrained by mathematical facts, which explain why she is unable to do this. In both cases, mathematical facts explain why such outcomes are impossible and they do so through a unique type of constraining relation.

[1] For example, while the notion of a "developmental constraint" has received significant attention in evolutionary biology, this "popularity has also bred confusion" as the term is often used in "distinctly different ways" (Gould 1989, 516). However, simply accommodating all possible definitions—such that all of biology is a result of constraints—is also problematic because then "the meaning of the word would vanish" (Stearns 1986, 35). For more on the "chaos of constraint terminology" see Antonovics and van Tienderen (1991).

[2] In particular, Euler proved that in order for there to be a path that crosses each bridge exactly and only once, there are two conditions that need to be met. When the bridge system is represented graphically, (1) all nodes should be connected to each other and (2) there should be either zero or two nodes of odd degree (Euler 1956; Ross 2020).

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Lange's account of explanation by constraint is motivated by these cases and it contains two main features. First, he suggests that (1) constraints explain in virtue of exhibiting a strong form of necessity, which makes the explanatory target inevitable. This necessity allows the constraint to explain why various outcomes strictly "couldn't" happen, or alternatively "that the explanandum *had* to be" (Lange 2018, 45). The inevitability of constraints relates to the fact that they explain targets that are either impossible or not—these cases lack the wiggle room of standard explanations, in which different possible states of the explanatory target are considered. For example, in the Königsberg bridge case it is impossible to walk a single path across all bridges and in the mother example it is impossible for her to evenly divide the strawberries. These differ from standard causal scenarios, which involve explaining why one outcome occurs instead of other possibilities. For example, genetic causes explain why a fruit fly has red eyes in contrast to other possible eye colors (red, black, white, etc.).[3]

Second, according to Lange, (2) constraints necessitate their outcomes in a way that is stronger than standard causal laws and, because of this, they provide non-causal explanations. This is consistent with the fact that the Königsberg bridge case and the mother–strawberry case are often interpreted as non-causal, mathematical explanations. The impossibility and stronger-than-causality features are emphasized in both of these cases as Lange states: "[t]he Königsberg bridges as so arranged were never crossed because they *couldn't* be crossed. Mother's strawberries were not distributed evenly among her children because they *couldn't* be … These necessities are stronger than the variety of necessity possessed by ordinary laws of nature, setting explanations like these apart from ordinary scientific explanations" (Lange 2018, 9).

Mathematical facts are just one type of explanatory constraint that Lange considers—he outlines a ranking or "pyramidal hierarchy" of other modal relations that figure in constraint-based explanations (Lange 2018, 80). Many of these other constraint examples come from the physical sciences and involve particular constraints that are "explanatorily prior" to others. As one example, the (i) law of energy conservation constrains both (ii) gravitational and (iii) electric interactions, and, in this manner, (i) explains why (ii) and (iii) have particular features and take the form they have (Lange 2018, 51).

Lange is firm in his stance that "explanations by constraint are not causal explanations" as they "work not by describing the world's causal relations" and they "do not reflect causal processes" (Lange 2018, 30). This is further supported by his claims that Woodward's interventionist account—arguably the most influential account of causal explanation in current literature—is unable to capture these constraint-based explanations (Woodward 2003). On Woodward's account, some property X is a cause of property Y if there are hypothetical changes to X that produce

[3] Why not view this fruit fly case as explaining why non-red eye colors are impossible, given the presence of the mentioned causal gene? This relates, in part, to the explanatory target in question—the fruit fly example includes the target "eye color" for which there are many possible outcomes. The bridge and strawberry cases are focused on one feature that is either possible or strictly impossible ("Eulerian path or not" and "even divisibility or not"), in contrast to a set of possible features, with one being produced and explained.

changes in Y in some set of background conditions (Woodward 2003). Lange argues that interventionism does not accommodate constraint-based explanations, because these explanations have "no obvious variables to be changed" (Lange 2018, 87–8). Lange suggests that they do not answer "what-if-things-had-been-different questions" because constraints are "fixed" and considering changes to them "reveals nothing" (Lange 2018, 87–8). Even if there are properties that can be represented as variables that change, when considering these changes the "argument simply goes nowhere" and "the proofs simply go nowhere" (Lange 2018, 87).

Lange offers a rich and detailed account of explanation by constraint. I agree with him that constraints are a unique explanatory factor and that they provide non-standard explanations. I also agree that constraints often explain impossibilities and that our account of them should "do justice to scientific practice" (Lange 2018, 24). However, I am going to argue that some constraints in the life and social sciences are causal and provide causal explanations. I explore these cases in the next section by examining cases from neuroscience, physiology, and the social sciences.

3. Constraints in the life and social sciences

This section considers constraint examples from neuroscience, physiology, and the social sciences: neural pathways, vascular pathways, and social structure, respectively. While scientists often refer to these factors as "constraints," this section considers what their features are and how they provide explanations and understanding.

3.1. Neuroscience: Neural pathways

As a first example, consider neural pathways in the brain and peripheral nervous system. In these areas, neural pathways include single axons, microcircuits, neural tracts, and higher-scale causal network connections, among others. These pathways constrain how signals and information flow through the nervous system. As scientists claim:

> Neural activity, and by extension neural codes, are *constrained* by connectivity. Brain connectivity is thus crucial to elucidating how neurons and neural networks process information. (Sporns 2007)
>
> . . . structural connection patterns are indeed *major constraints* for the dynamics of cortical circuits and systems, which are captured by functional and effective connectivity. (Sporns 2007)

Not only do neuroscientists commonly refer to neural pathways as constraints, but they often cite them as explaining particular outcomes. As an example of this, consider a case in which a lesion in a particular area of the motor cortex results in paralysis in the arm as opposed to any other area of the body. The explanatory-why question in this case is: why does a lesion in this area cause paralysis in the arm and not anywhere else? For example, why does it not cause paralysis in the leg, face, foot, and so on? The answer to this is clear—a lesion in A produces paralysis in the arm (and nowhere else) because the neural pathways originating in A lead to the arm and

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not to any other location. These neural pathways constrain the flow of signaling—they explain why it is impossible for this signal (or lack of it) to impact areas outside of the downstream site of interest that they lead to. This basic notion of constraint is ubiquitous in neuroscience and central to many different frameworks for understanding the brain (Friston 2011; Bassett et al. 2021).

Consider a few challenges for viewing these neural constraints as non-causal, which is suggested by Lange's analysis. First, scientists often refer to the neural connectivity in these cases as causal and capturing causal information (Sporns 2007; Friston 2011). Second, these neural connections successfully meet standards of interventionist causality, in contrast to Lange's claims. Recall Lange's claim that constraints reveal "no obvious variables to be changed" as they are "fixed" such that changing them "reveals nothing" (Lange 2018, 87–8). These claims fail to hold for neural constraints because we not only consider changes to them, but these changes are present and studied across individuals. For example, the fact that sensory nerve patterns vary across individuals helps explain why viral lesions in the same spinal nerve produce different sensory outcomes across patients (Lee et al. 2008).[4] Differences in neural pathways in the brains of adolescents and adults is studied and cited in explaining behavior differences across these groups (Baum et al. 2017). Finally, another point in favor of viewing these neural pathways as causal is that they are factors that "make-a-difference" to the outcome of interest. This is suggested in the lesion–paralysis case above—if the lesioned area were causally connected to a different downstream location, this would change the location of paralysis.

3.2. Physiology: Vascular pathways

As a second example, consider vascular pathways or blood vessels in the context of physiology. Scientists refer to blood vessels as factors that "constrain" the flow of blood and they cite them in explaining particular outcomes. Consider the case of pulmonary embolism after clot formation in the large veins of the leg. When a clot forms in the large vessels of the leg (common after periods of sitting or with use of some medications), a particular pathophysiological outcome often occurs—the clot can travel to, lodge in, and cause damage in the vasculature of the lung, which is called a pulmonary embolism. In this case, our explanatory question is: when a large clot forms in the leg veins, why does it lead to embolism-related damage in the lung, as opposed to anywhere else in the body? Why doesn't it result in an embolism in the liver, arm, brain, spleen, etc.? The answer to this question involves citing the vascular architecture of the human body—namely, that the veins in the leg lead directly to the lung (where the vessels narrow, trapping the clot) and they do not lead anywhere else. This explains why, given the starting location of such a clot, it is impossible for it to travel to and do damage in any other location. Thus, the fact that the blood vessels constrain the flow of blood in this way explains why such a pathological outcome presents in this area and not another. Similar strategies are used to explain the unique flow of infectious material in the body (Meyers et al. 2005) and the spread of cancerous cells through the lymphatic system (Estourgie et al. 2004). The flow of these materials is constrained and explained by these vessels and anatomical structures.

[4] This is seen in variations in dermatome maps across individuals (Lee et al. 2008).

3.3. Social science: Social structure

As a final example of constraints, consider various types of social structure in the context of sociology (Haslanger 2016; Ross 2023b). In this domain, scientists identify cases in which social structures are said to "constrain" and explain the behavior of individuals (Haslanger 2016). One case involves differences in dietary habits across groups of individuals in society. Studies have shown that individuals from lower socioeconomic groups are more likely to eat "unhealthy" diets compared to individuals from higher socioeconomic groups (Metzl and Roberts 2014). There has been interest in explaining why this is the case—why are individuals from lower socioeconomic groups more likely to eat an "unhealthy" diet?

Consider two common responses to this explanatory-why question. A first suggests that this is explained by an individual's choices—individuals from lower socioeconomic groups are simply making a choice to eat this diet. To the extent that some minority cultures are more commonly represented in this group, it is claimed that cultural preferences are responsible. Alternatively, a second response claims that this difference is explained by social structures, such as the availability of various resources. Individuals from low socioeconomic groups experience many social structural constraints that limit their ability to choose a healthy diet in the first place. They often live in "food deserts" that lack grocery stores with fresh produce and that contain transportation barriers to shop at other stores.[5] In addition to this, many fast-food companies target their advertisements to these low-income areas, which encourages these eating habits (Metzl and Roberts 2014). When these are combined with the lack of other resources—such as time and finances—it makes "choosing" such a diet extremely difficult, if not impossible. When significant social structural limitations exist, they can explain why it is (nearly) impossible for an individual to make any other "choice" and why social structures are more responsible for the outcome.

The suggestion is that differences in social structure, understood in terms of various resources, explain this dietary contrast. When resources are extremely limited for some groups in society, this can constrain and explain particular behaviors of individuals in the group.

4. Explanatory framework

Consider that the three cases above each contain two main factors: a constraint and an entity that is constrained. In the second example, the blood vessel is a constraint and the blood clot is the constrained entity. Importantly, both of these factors have causal influence over the outcome—this is evident because both are hypothetically manipulable in a way that "makes-a-difference" to the outcome (Woodward 2003). Intervening on the presence/absence of the upstream clot explains whether it "will block" or "will not block" some downstream vessel. Intervening on blood vessel connections, on the other hand, explains whether the clot will block "one location" (e.g. vessels in the lungs) or "another location." However, while both factors meet interventionist criteria they are causally relevant to different aspects of the

[5] These locations often have limited bus routes and contain barriers for walking to other stores (such as three-hour walks, routes lacking sidewalks, etc.).

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explanatory target—namely, (i) *whether* blockage occurs and (ii) *where* it occurs. The blood clot causally influences whether a clot is present to cause damage or not, but not where this damage will occur. The blood vessels serve as a constraint that limits possible outcomes of the system, causally influencing which locations the clot can travel to and cause damage.

In order to understand both factors in this case, consider a similar example discussed by Dretske (1988). This example involves an on/off switch that is electrically wired to one of two possible downstream systems, either a bell that rings or a light bulb that shines. Notice that if we intervene on the switch (turning it on/off) we control whether a downstream system is on/off, but we do not control which one. And if we intervene on the electrical wire connection (controlling whether it connects to one system or another), we control which system can be turned on, but not when exactly this happens. Dretske highlights the unique role of each factor by referring to the switch as a *triggering cause* and the wire as a *structuring cause* (Dretske 1988, 42). The electrical wire is a structuring cause because it structures, guides, and constrains the flow of electricity and which downstream system the electricity runs to. Alternatively, the switch is a triggering cause because it triggers when a given system is turned on and off. In this manner, just as we saw in the scientific constraint examples, each of these factors is tuned to explain different features of the target system and different "explanatory-why questions." Similar to the blood vessel example above, the the triggering cause (switch) controls whether electricity flows, while the structuring cause (wire) controls the location it flows to.

How exactly should we understand these cases? What justifies viewing some factors as causal constraints and what role do they play in explanation? The neural pathway, vascular pathway, and social structure factors are genuinely causal because they meet the criteria of interventionist causation (Woodward 2003). These factors are all "difference-makers" for an effect of interest because manipulating them provides control over an effect. However, part of what is revealed by these examples is that causes are not all created equal—factors that meet interventionist causality can differ in significant and important ways. I am going to suggest that these factors should be understood as *causal constraints* in the sense that they have additional features, beyond those specified by interventionism. Causal constraints are causes that: (i) limit the possible values of the explanatory target, (ii) are external to the process they limit, (iii) are viewed as relatively fixed compared to other explanatory factors, and (iv) guide the explanandum outcome as opposed to triggering it (Ross 2023a).

With respect to (i), notice that the pathway and social structure factors have causal influence over the possible outcomes of the system. The particular layout of neural pathways places limitations and constraints on where neural signals can flow. Similarly, vascular pathway architecture constrains the particular locations that blood can flow to. Changing these connections provides control over and explains the possibility space of outcomes—whether the signal or blood can reach greater or fewer possible (downstream) locations. Notice how this captures a form of impossibility explanation similar to that articulated by Lange (2018). If a neural pathway (or vascular pathway) is *not* connected up to location A, it is impossible for the signal (or blood) to flow to this location. This impossibility is not explained by mathematical facts—as we saw with the Königsberg bridge and strawberry cases—

but instead with causal information about pathways that limit the flow of some entity through the system.

The second feature (ii) captures the sense in which constraints are often viewed as external, separate factors from the process they limit. Neural pathways are external to signal propagation, vascular pathways are external to blood flow, and social structure is external to an individual's decision-making. The fact that these constraints are viewed as external often results in their being backgrounded and in receiving less attention than the entity they limit (Ross 2021). Emphasis on the object—at the expense of relevant external factors—can lead the explanatory role of constraints to be downplayed and underestimated. This is seen in social structural cases, in which the explanatory influence of social structure is deemphasized and the role of individuals' decision-making is overstated (Haslanger 2016; Ross 2023b).

A third feature of causal constraints is that they are viewed as more fixed and unchanging than other explanatory factors (Ross 2023a). There are at least two reasons for this. First, the causal constraints in all of these systems change on longer timescales than the entities they constrain. Neural pathways, vascular pathways, and social policies change over time, but they take much longer to do this than the entities (signals, blood flow, and individuals) they limit. Second, these constraints are also more difficult to change than other explanatory factors. Changing social policies and the anatomical structure of the body often requires more complex interventions than local influences on individual decision-making and blood clots. These also explain why causal constraints are more likely to be downplayed and ignored in explanations—we may be biased to focus on factors that operate on shorter timescales and that are easier to intervene on.

Finally, causal constraints are factors that guide the explanandum outcome, as opposed to triggering it Dretske (1988). These are factors that determine which outcomes are possible and off limits. Their main explanatory role is capturing the border between possible and impossible outcomes. However, when these factors operate as extreme constraints—and limit the space to single or few outcomes—they take on more explanatory power in determining what outcomes occur. The outcome always requires a triggering cause, but the causal constraint controls the particular state, location, or relevant feature of the outcome once the system is triggered.

This analysis clarifies four main features that are characteristic of causal constraints in the life and social sciences. This helps capture what makes these causes unique and how they play distinctive roles in scientific explanation. In fact, although Lange does not view constraints as causal, these factors meet various aspects of his framework. First, these causal constraints exhibit a "stronger" form of influence than standard causes. These causal constraints force, guide, and limit the state of an entity, without the entity reciprocating this influence. The blood vessel dictates where the blood will flow, while the blood does not determine features of the vessel. Second, each of these causal constraints provides a type of impossibility explanation. This is because when the pathway or structure dictates which outcomes are possible for the system, it also determines which outcomes are impossible and off limits. These points provide further reasons to consider expanding the notion of explanatory constraints to include causal factors. Finally, when these examples are recognized as causal constraints it becomes clear that there are numerous cases throughout the sciences. Others to consider include causal pathways, circuits, motifs, and topologies, such as ecological pathways, neural circuits, and molecular interaction networks in biology (Ross 2020, 2021).

5. Conclusion

This paper has provided an analysis of causal constraints—what their main features are and what role they play in scientific explanations. I have suggested that causal constraints are a special type of causal factor with particular features. This allows for a straightforward distinction between causal factors that are constraints and for clarity on how they provide unique types of causal explanation. Importantly, this analysis builds on the work of Lange (2018) by revealing how causal constraints meet various features of his framework.

This analysis is important for many reasons. First, this work engages with foundational debates about what factors count as causal or explanatory and what justifies these assessments. Second, attention to constraints matters because they can be easily overlooked despite playing important explanatory roles. In many cases, the fact that constraints are more difficult to change and that they vary on longer timescales can result in downplaying their relevance to, control over, and responsibility in producing outcomes. This account reveals characteristics of constraints that highlight their explanatory role, while clarifying why they can be easier to background and ignore. Third, work in this area supports theories of scientific explanation that "do justice to scientific practice" (Lange 2018, 24). This involves capturing the complexity of systems that scientists study, the concepts they use in their work, and the principled reasons they rely on to provide explanations and understanding of the world.

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