What is a 'mechanism'? A distinction between two sub-types of mechanistic explanations

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Abstract

Mechanistic explanations reveal the rich causal structure of the world we inhabit. For instance, an explanation like "A clock ticks because an internal motor turns a gear which moves the hands" explains a feature of the clock (i.e., the fact that it ticks) by describing the parts and actions that cause it. People often seek out such explanations, as they may be particularly valuable to understanding the world. However, are mechanistic explanations truly a single class of explanation? Here, we distinguish between two subtypes of mechanism: constitutive and etiological. We argue that this distinction, long made by philosophers of science, has cognitive consequences: People treat these two kinds of explanation differently and prefer one kind over the other. We discuss implications for understanding mechanism and for explanation preferences more broadly.

Keywords: explanation, mechanism, information preferences

Introduction

Much research has examined people's understanding of different kinds of explanations, as well as their preferences between them. One such kind of explanation is a *mechanistic* explanation. Mechanistic explanations capture the causal structure underlying an object or event. For example, we might explain that "A clock ticks because an internal motor turns a gear which moves the hands" or "The Grand Canyon came to exist because the river caused erosion of the rock over time." Previous research often demonstrates the particular utility or allure of these explanations (e.g., Callanan & Oakes, 1992; Chuey et al., 2020; Corriveau & Kurkul, 2014; Grief et al., 2006; Lockhart et al., 2019; Trouche et al., 2018). But are mechanistic explanations truly a single category of explanation?

Consider the explanations of the clock and the Grand Canyon. The first explanation (i.e., "A clock ticks because an internal motor turns a gear which moves the hands") describes component parts which interact to sustain an ongoing process (see e.g., Bechtel, 2006; Kaiser & Krickel, 2016). The second explanation (i.e., "The Grand Canyon came to exist because the river caused erosion of the rock over time") however, describes a chain of events that occurred in the past to create a current situation (see e.g., Glennan, 2009; Kaiser & Krickel, 2016). Even at first glance, these explanations—while both providing rich causal information—seem to do so in different ways. Here, we suggest that mechanistic explanations are actually comprised of two different kinds of explanation.

Etiological and Constitutive Mechanisms

Philosophers of science have long since distinguished between two subtypes of mechanism. Etiological mechanisms typically describe a chain of events that cause a certain phenomenon, or, in other words, how things *came to be.* An account of how a tree grew its leaves, for instance, is an etiological mechanistic explanation (see also Skipper and Milstein, 2004; Barros, 2008, Glennan, 2009 for examples of etiological mechanisms). Constitutive mechanisms, in contrast, describe an ongoing causal process by reference to the interaction of smaller parts: They explain how things *work*. Take, for example, an explanation of how a clock works: This explanation would refer to the internal makeup of the clock and describes how different parts move and work together to create the phenomenon in question (see also Bechtel & Abrahamsen, 2005; Bechtel, 2006; Glennan, 2010 for examples of constitutive mechanisms).

Related philosophical discussions have also identified critical differences between these kinds of mechanistic explanations (e.g., Levy & Bechtel, 2016; Kaiser & Krickel, 2016; Rosenberg, 2020). Consider the questions "How does X work?" vs. "How did X come to exist?" Both are 'how' questions seeking mechanistic explanations, but they are clearly seeking different kinds of information. In general, etiological explanations require a linear chain of events that has typically already concluded, whereas constitutive mechanisms typically involve ongoing processes composed of internal parts (Salmon, 1984; Craver, 2001; Glennan, 2009).

Given these differences, might people also treat etiological and constitutive mechanisms as distinct categories of explanation?

Current Studies

Here, we contrast etiological and constitutive mechanisms and ask people to choose one over the other. If people exhibit clear preferences for either etiological or constitutive mechanisms in different contexts, then these subtypes of mechanism must meaningfully factor into people's explanation preferences.

In Experiment 1, we ask people to choose between a question that would prompt an etiological explanation (e.g., "How did X come to be?") and a question that would prompt a constitutive explanation (How does X work?"). In Experiment 2, we ask people to choose directly between an etiological and constitutive explanation of the same phenomenon.

Experiment 1

Do people distinguish between etiological and constitutive mechanisms? If so, we might expect that they have specific preferences to learn about one kind of explanation over the other. Here, we ask participants to choose between a question requiring an etiological mechanistic answer ("How did x come to be?) or a constitutive mechanistic answer ("How does x work?). Comparing questions (rather than explanations) allowed for a broad and naturalistic comparison between etiological and constitutive mechanisms.

Method

One hundred adult participants completed a survey online through Amazon Mechanical Turk. The sample size was chosen on the basis of independent pilot data and was preregistered. All participants lived in the United States. Participants were presented with twelve GIFs depicting some object or entity within a dynamic process, four each in the domain of animals, non-living natural kinds, and artifacts. They were asked to choose between an etiological 'how' question (e.g., "How did x come to be?") and a constitutive 'how' question (e.g., "How does x work?") on the basis of which they would rather have answered. For example, participants were shown an owl twisting its neck 180 degrees, with the caption "This owl has an unusual neck. It can twist its neck almost all the way around in a circle." They were then asked "Which question would you rather have answered?" between "How does this twisting process work?" and "How did its neck come to exist?".

All participants saw all twelve items (in a different random order for each participant), and the order of the questions themselves was also randomized. No other information was collected. For the sake of consistency and comparison with experiments run earlier, data were analyzed in both through simple binomial tests and through t-tests treating participants' scored responses as averages. Redundant analyses are not reported. Full materials for this experiment and all following can be found on the Open Science Framework (OSF) at https://osf.io/enf7y/?view_only=263fb637fee1412ca27d99be5731f639.

Results and Discussion

If people distinguish between etiological and constitutive mechanisms, then we might expect them to have specific preferences for one kind of explanation over the other.

To analyze participants' responses, we scored their responses (where a constitutive answer was scored as 1 and an etiological answer as -1) and treated the sum across a domain as an average. Across all domains, people preferred the constitutive question to the etiological question (all $p<.001$). These preferences were stronger for animals and artifacts than for NLNK (non-living natural kinds), all $t(99)>4.0$, $p<.001$. These results suggest that people distinguish between kinds of mechanistic explanations, as they have systematic preferences to learn about one kind of information over the other.

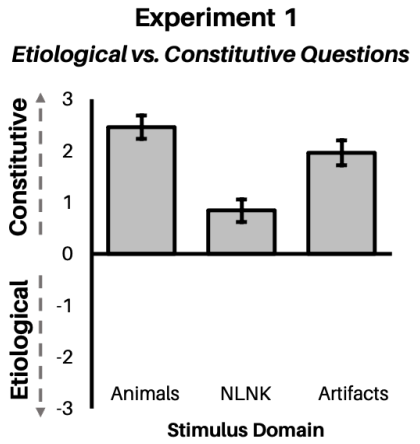

Figure 1: People prefer constitutive mechanistic questions over etiological mechanistic questions. The x-axis represents chance performance. Domain of the stimulus is represented along the axis. Participants' scored responses are represented along the y-axis. Error bars represent +/- 1 SE.

Experiment 2

The previous experiment demonstrated that people prefer to learn about constitutive mechanistic explanations over etiological mechanistic explanations, but do they also exhibit this same preference when choosing between specific explanations? Here, we present participants with an etiological (e.g., "As the bones in the neck grew, the openings for the veins and arteries enlarged; then the veins and arteries grew in and through them") and a constitutive explanation (e.g., "The bones in the owl's neck have large openings that their veins and arteries can slide through and not break while twisting") of each of the same twelve phenomena and ask them "Which explanation is more informative?" Specifying particular explanations now allowed us to approximately match the length and complexity of the explanations.

Method

All elements of the experimental design were identical to those of Experiment 1, except as stated below. One hundred new participants completed the survey online through

Amazon Mechanical Turk. Participants were presented with an etiological and constitutive explanation relating to the item in each GIF asked to choose "Which explanation is more informative?". For instance, for the owl, participants were asked to choose between "The bones in the owl's neck have large openings that their veins and arteries can slide through and not break while twisting" and "As the bones in the neck grew, the openings for the veins and arteries enlarged; then the veins and arteries grew in and through them."

Results and Discussion

Across all domains, people preferred the constitutive explanation to the etiological explanation (all $p<.001$, $d>.80$). Unlike in Experiment 1, participants preferred the constitutive mechanism just as much for non-living natural kinds as for animals ($t(198)=.10$, $p>.05$). However, they had stronger preferences for both animals and non-living natural kinds than for artifacts, all $t(99)>2.8$, $p<.02$, $d>2.8$. In general, as in Experiment 1, people preferred constitutive mechanisms over etiological explanations.

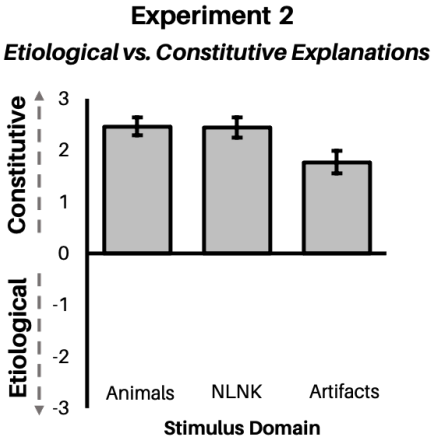

Figure 1: People prefer constitutive mechanistic explanations over etiological mechanistic explanations. The x-axis represents chance performance. Domain of the stimulus is represented along the axis. Participants' scored responses are represented along the y-axis. Error bars represent +/- 1 SE.

General Discussion

Across Experiments 1 and 2, we find that people generally prefer constitutive explanations over etiological explanations. These results thus suggest that there is a meaningful distinction between these two sub-types of mechanistic explanations.

Implications for Understanding Mechanism

The category 'mechanistic explanations' requires at least two subdivisions between etiological and constitutive mechanisms. Future work may want to re-examine research on mechanistic explanations in order to investigate how these particular types of mechanism compare across different measures. For instance, do people's preferences for constitutive explanations mean that they think someone who knows constitutive mechanistic information more of an expert than someone who knows etiological mechanistic information (c.f. Lockhart et al., 2019)? Might there be some contexts where etiological explanations are actually preferred? Are etiological vs. constitutive mechanistic explanations most useful alongside other kinds of explanations (e.g., teleological explanations) in different contexts?

Our work breaks down mechanism into two subcategories of explanation. In principle, however, the taxonomy of mechanistic explanations may be even more detailed (and future work may be interested in a more precise relationship between various subtypes). For instance, parts of animals seem to have two possible types of etiological explanations: one which describes the development of a feature from embryo to adulthood and another which describes its evolution over time. Future work may be interested in kinds of mechanism more broadly.

Implications for Broader Explanation Preferences

Mechanistic explanations are often discussed in explicit contrast with teleological explanations (e.g., Banerjee & Bloom, 2015; Greif et al., 2006; Kelemen, 1999; Liquin & Lombrozo, 2018; Trouche et al., 2018). People's—and especially children's—preference for teleological vs. mechanistic explanations are interpreted as part of broad theories of human cognition: On the one hand, people may seek out and prefer mechanistic explanations (e.g., Callanan & Oakes, 1992; Greif et al., 2006; Trouche et al., 2018). On the other hand, people may actually prefer teleological explanations (or explanations that appeal to something's purpose; e.g., Kelemen, 1999; Kelemen et al., 2013; Heywood & Bering, 2014) even over and above causal explanations.

These research programs have long existed in parallel, despite their seeming incompatibility. The distinction between etiological and constitutive mechanisms may suggest a new way, however, to reconcile these views.

Work that emphasizes the allure of mechanistic explanations (e.g., Buchanan & Sobel, 2011; Lockhart et al., 2019; Keil & Lockhart, in press) often tends to present constitutive explanations. Take for example, the following mechanistic explanation of a refrigerator: "The inside pump is able to push lots of the cooling liquid through pipes so the refrigerator always stays cold" (Lockhart et al., 2019). This explanation refers to internal pieces (the pump, liquid, and pipes) of the refrigerator, thereby explaining an item by reference to a 'lower level' of constitutive parts and how they work with each other. Some of this research even refers explicitly to constitutive mechanisms (e.g., Lockhart et al., 2019; Keil & Lockhart, in press) or frames information specifically as "how things work" (Trouche et al., 2018).

In contrast, work that emphasizes the allure of teleological explanations over mechanistic explanations (e.g., Kelemen, 1999; Kelemen & DiYanni, 2005, Schachner et al., 2017) often tends to present etiological explanations. Take for example, the following mechanistic explanation of an

animal's tail: "The mononykus has a long tail because its feathers were big and stuck out from behind its body" (Kelemen, 1999). This explanation refers to a chain of events that have already been completed (e.g., first the feathers grew large and then they stuck out from the body), and thus seems better characterized as an etiological mechanism.

Before distinguishing between etiological and constitutive mechanisms, these research findings collectively suggested that people sometimes prefer mechanism to teleology and sometimes teleology to mechanism—without offering much of a reason as to why their preferences might shift this way. Here, however, we find that people distinguish between constitutive and etiological mechanisms, and that they tend to prefer constitutive explanations. Moreover, in some cases constitutive mechanisms *also* fare better against teleological explanations (see Joo et al., 2021). In other words, it may be that people may prefer one *kind* of mechanism (i.e., constitutive) over teleology, but not the other (i.e., etiological). To address these possibilities, future research may further examine these subtypes of explanation not only in isolation, but in contrast with teleological explanation.

Moreover, developmental studies play a key part in the broader accounts of people's explanation preferences (e.g., Greif et al., 2006; Kelemen 1999; Schachner et al., 2017). Understanding how kinds of mechanistic explanations factor into explanation preferences and our intuitions about the world may thus also require investigating the extent to which children are also sensitive to these differences.

Conclusion

Both as scientists and throughout our everyday lives, we seek to understand and to explain the world around us. The appeal of different kinds of explanations and the consequences of these preferences have long been topics of interest for cognitive scientists. In order to understand the appeal of mechanistic explanations, a further decomposition of explanatory kinds is required. The difference between etiological and constitutive mechanisms suggests several further questions, not only about mechanism, but about people's explanation preferences more broadly.

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