A Right Way to Explain? Function, Mechanism, and the Order of Explanations

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Abstract

People generally prefer functional explanations over mechanistic ones. Why? One possibility is that people value functional information more. But another possibility is that people don't have an *overall* preference for functional explanations; Instead, people might just expect this information to precede mechanistic information. Here, we ask whether people have preferences for the order of functional and mechanistic information in explanations. In a first set of studies, we show that adults do in fact prefer that functional information precedes mechanistic. In a second set of studies, we show that people have a more general preference for explanations to address the *whole* before *parts*. Finally, we show that the preference for function to precede mechanism may be related to the broader whole-before-parts preference.

Keywords: explanation; function; mechanism; hierarchy; causal explanations; teleology; cognition; psychology

Introduction

Academic journal articles follow a predictable format; we expect an introduction to the context and goals of a study prior to the methods and how the studies work. By first laying out the goals of the paper, authors set up a framework for what follows. This organization is intentional. Without a title or some broader framing, readers may struggle to understand critical manipulations and proposed mechanisms that motivate the paper's conclusions. Just as readers expect the consistent format of journal articles, we might too expect elements in *explanations* to likewise follow certain orders.

Two explanations that are identical in their content may nonetheless vary strongly in comprehensibility depending on the order in which elements are presented. In some ways, it is hardly surprising that the order of information influences the overall interpretations of that information (e.g., Hogarth & Einhorn, 1992). For example, when participants encountered highly ambiguous prose passages without a context-providing illustration or title at the beginning, they performed much worse on subsequent evaluations of comprehension and recall than those provided with such "framing contexts" (Bransford & Johnson, 1972; Bransford & McCarrell, 1974). Order of information also influences *scientific* understanding (e.g. in studies of initial and persisting mental models and misconceptions; see Vosniadou & Skopeliti, 2014; Kendeou & Van Den Broek, 2005; Shtulman, & Valcarcel, 2012). However, the question remains as to how the ordering of different *types* of information influences the perceived quality of those explanations. Do adults have systematic preferences for the relative order of different kinds of information that typically occur in explanations?

Here, we investigate intuitions about the functional and mechanistic components of explanations, contrasting information about *what things are for* with information about *how things work*. Do adults think one of these two forms should precede the other? If they do, how pervasive is that bias, and why might it occur?

Why Function and Mechanism?

Many explanations of real-world phenomena rely on the interplay between mechanisms and functions. While some argue that "the mechanical world is an aimless machine, churning blindly, without its own end or purpose," our actual mechanistic explanations almost always consist of implied function and/or purpose (Craver, 2013, p. 134). While disentangling these two kinds of information as separate, stand-alone explanations can seem somewhat artificial, each kind of information brings about unique kinds of understanding of the same entities (Lombrozo & Wilkenfeld, 2019). Here we examine how interactions between these two kinds of information may critically influence the perceived quality of explanations.

Function – what a thing is for or what job it does – and mechanism, – how a thing works or how the parts inside work together – both explain the same phenomenon but in different ways; Functions appeal to a top-down structure where the phenomenon plays a role in a larger causal picture of the world, whereas mechanisms describe the phenomenon as emergent from the underlying causal relationships that brought it about. Most scientists see the natural world as the product of emergent mechanisms, not the product of purposeful design (Craver, 2013). Yet, complete understanding of a phenomenon often seems to imply understanding of both its underlying mechanisms and its functional roles in the world. Prior studies have considered people's preferences for functional vs mechanistic explanations (e,g. Kelemen, 1999; Kelemen et al., 2013; Trouche et al., 2018; Chuey et al., 2020; Joo, Yousif, & Keil, 2021). In contrast, the current studies do not ask participants to favor one element over the other, but rather to consider how these two elements work together to constitute an explanation.

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Hierarchy in Nature and Explanation

Many phenomena are decomposable. A single entity may contain a rich set of functions and mechanisms embedded in a hierarchical structure (Povich & Craver, 2017). Scientific phenomena can be explained at multiple levels (Craver, 2015). As a given phenomenon can be appropriately explained by appealing either to mechanism or to function (Joo, Yousif, & Keil, 2021; Lombrozo & Wilkenfeld, 2019), the existence of embedded levels of mechanism suggests the presence of levels of functions as well. For example, one might explain the function of an artifact as a whole (e.g. a car), or the function of a single component of that artifact (e.g. an engine). Even children show some implicit understanding of this differentiation of explanatory levels: children will endorse purpose statements for parts of animals, such as tails or teeth (Kelemen, 1999), but not for whole animals (Greif, Kemler Nelson, Keil, & Gutierrez, 2006). The building of even our earliest scientific understandings may rely on understanding that function and mechanism interact in systematic ways to describe phenomena at various levels.

Current Studies

In the present studies we investigate the relation between functional and mechanistic information by first identifying whether adults have a systematic bias for how the two kinds are ordered in explanations. Prior work describes a general preference for teleological (i.e. functional) explanations. We believe that this preference may reflect in part an expectation that explanations should provide functional information prior to mechanistic information. Therefore, we predict that adults prefer that functional information should come *before* mechanistic information in an explanation.

Study 2 investigates a potential cause for the results of Study 1. Function appeals upward (i.e. toward the whole) while mechanistic explanations look downwards (i.e. consider constituent parts), thus putting functional information before mechanistic information is, in Studies 1a and 1b, equivalent to putting information about the whole before information about the parts. Studies 2a and 2b investigates whether the effects of Studies 1a and 1b are due to a sensitivity to this hierarchical pattern independent of function and mechanism by asking participants to consider the proper structure of explanations that cross multiple levels of the hierarchical structure of the world (e.g. whole, parts, and sub-parts). Should information about the whole come before or after information about parts within that whole? In these studies, the explanations do ***not*** include functional or mechanistic information.

While Studies 2a and 2b ask participants to consider hierarchical structure independent of any cues to function or mechanism, Studies 3a and 3b investigate how participants think about the relationship between functional and mechanistic information within the context of hierarchical levels. Is an expectation about the proper order in which to address hierarchical levels (e.g. whole before parts, parts before sub-parts) what mediates the expectations surrounding function (which often appeals upwards, toward the whole) and mechanism (which necessitates appealing downward to component parts) that are documented in Studies 1a and 1b. If adults do have a systematic preference for the order of functional and mechanistic information in an explanation (Studies 1a and 1b), finding limits to this bias may reveal why it exists in the first place (Studies 3a and 3b).

Study 1a

In an initial test of whether adults had intuitions of a systematic order of functional and mechanistic information, we used a forced choice paradigm. We wanted to explore the breadth of this potential effect by investigating artifacts (referred to toward participants as machines) as well as biological parts (referred to in this study as body or plant parts). Further, this first study investigates adults' preferences of the proper order of information both in the abstract (hypothetical condition) as well as when considering explicitly the content of explanations (content condition). While the content condition provided a more ecologically valid paradigm, the hypothetical condition controlled more closely for differences in word count between informational types. Example stimuli items can be found in Table 1. All stimuli and data, including that of excluded participants, can be found on our OSF page (https://osf.io/z4f3e/).

Methods

Participants One hundred-sixty adult participants (mean age = 38.03 years; 66 females, 94 males) completed a survey through Amazon Mechanical Turk. For all the studies in this paper the sample sizes were chosen on the basis of independent pilot data and were pre-registered. All participants in these studies lived in the United States Participants throughout this paper were excluded and replaced if they failed to a) properly recall instructions prior to beginning the task or to b) properly identify the presented stimulus item immediately following the task. In this study, n = 33 participants were excluded and replaced for failing these attention checks.

Procedure In this between-subjects 2 (content: concrete, hypothetical) x 2 (domain: artifact, biological part) design, participants were randomly assigned to one of four conditions: Concrete content about an artifact, concrete content about a biological part, hypothetical framing about an artifact, hypothetical framing about a biological part. Participants were asked to determine which of two kinds of information should a teacher teach her students about first: how the thing works [mechanism] or what the thing is for [function].

Results

The primary results of Study 1a are shown in Figure 1. Participants' responses were dummy coded where a function-first response was coded as a 1, and a mechanism-first response was coded as a 0.

A logistic regression revealed a significant positive intercept (β = 2.51, p < .001), indicating that participants across conditions preferred that functional information be presented first. There was no effect of domain (p = .297), nor of framing (p = 1.00), nor any interaction between these variables (p = .672), therefore throughout this paper results are collapsed across domain and framing condition where relevant. For more information regarding these conditions, see our OSF page. These results indicate that regardless of whether considering artifacts or biological parts, and regardless of whether considering the hypothetical framing or actual content of an explanation, adults prefer that function precede mechanism in explanations.

Discussion

This study supports the hypothesis that adults should prefer function before mechanism in an explanation. These results, however, could be explained by a general preference for functional information. Prior research suggests that children – and even adults and science professors, albeit under time pressure, willingly endorse unwarranted teleological explanations (Kelemen, 1999; Kelemen & Rossett, 2009; Kelemen, Rottman, & Seston, 2013), so participants in this forced choice paradigm perhaps chose the functional answer because of a bias for function, independent of any consideration of order. Study 1b controls for this by asking participants to decide between explanations that each contain *both* teleological and mechanistic information.

Study 1b

While Study 1a demonstrated a preference for functional information to precede mechanistic information, the nature of the forced choice task limits insight into participants' intuitions. Study 1b provides participants with a more ecologically valid paradigm in that they are provided just one explanation and asked how good they believe the order of information to be. Because participants were not given any sort of reference point of the other ways that the explanation could possibly be structured, it is possible that they would not have a systematic anchor and so there would be too much noise between participants to detect any preference, if such a preference even exists outside of forced-choice paradigms.

Methods

Participants N= 320 Amazon Mechanical Turk (mean age = 42.75 years; 174 females, 144 males, 2 preferred not to respond), were included while n = 41 participants had to be excluded and replaced.

Procedure The procedure of Study 1b paralleled that of Study 1a with the following exceptions. In this 2 (domain) x 2 (framing) x 2 (order: Function-then-Mechanism, Mechanism-then-Function), participants were randomly assigned to one of 8 conditions, where they were presented a single explanation with respect to their condition. Participants were asked to rate how good they believed the order of information in an explanation is on a scale of 1 to 100 where 1 means "The order of information is wrong, students won't be able to learn anything at all" and 100 means "The order of information is perfect, students will learn everything that there is to know about this [machine/ body part/ plant part]". The explanation that each participant rated was either one that presented functional information before mechanistic information (F-M), or one that followed the opposite structure (Mechanism-then-Function condition, M-F). Again, each participant saw and rated just one explanation on a scale of 1 to 100.

Results

A logistic regression revealed that, in line with our hypothesis, participants rated F-M explanations significantly higher than M-F explanations (β = -17.93, p < .001) (see figure 2).

Discussion

In Study 1b adults believed that explanations with a function-then-mechanism structure have a better order of explanation than those that present mechanism before function. When considered in combination with the findings from Study 1a, these results suggest that adults have a robust intuition that functional information should precede mechanistic information in an explanation. Taken together, Study 1a and 1b suggest that adults do believe that there is a proper way to structure an explanation: function should come *before* mechanism.

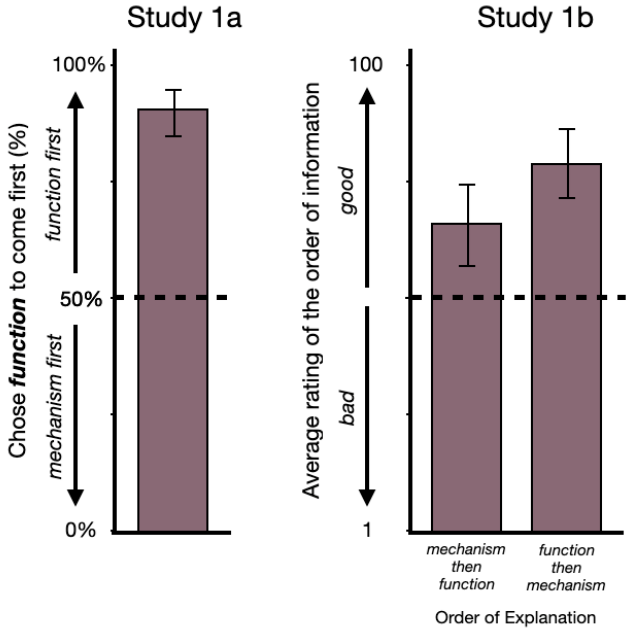

Figure 1: (Study 1a) Participants preferred that functional information *precede* mechanism in an explanation (β = 2.512, p < .001). (Study 1b) Participants rated, on a scale of 1 (bad) to 100 (perfect), the order of information in explanations; Explanations with functional information *before* mechanism were rated higher than those with the opposite structure (i.e. mechanism-then-function) (β = -17.93, p < .001).

Study 2

It is possible that the function-before-mechanism bias demonstrated in Study 1 has little to do with function or mechanism, per se. Rather, this bias may be the result of sensitivity to information implicitly addressed in functional and mechanistic explanations. That is, function, for one, appeals to the role that a thing plays within a larger framework. For example, one might explain the function of a car engine by addressing the role that it plays in a car. To explain mechanism, on the other hand, by definition means looking downward toward the underlying parts that make the thing the way that it is (e.g. explaining how an internal combustion engine works necessitates referencing pistons and spark plugs, amongst other parts and sub-parts). Adults might be equating function with the *whole* and mechanism with the *parts and sub-parts*. The function-before-mechanism preference (Study 1) could then be the result of a more general bias of whole-before-parts-before-sub-parts, independent of any mechanistic or functional information. To disentangle whether adults are motivated by the relationship between function and mechanism or by intuitions of following hierarchical structures in the world, we examined whether adults have intuitions about the order of hierarchical information void of mechanism or function.

Methods

Participants Studies 2a and 2b each consisted of 80 participants run with replacement (Study 2a: mean age = 40.41 years; 35 females, 44 males, 1 preferred not to answer, 25 participants excluded and replaced; Study 2b: mean age = 41.46 years; 36 females, 42 males, 1 non-binary, 1 preferred not to answer; 31 participants excluded and replaced).

Procedure The procedure for Studies 2a and 2b paralleled that of Study 1a with the following exceptions. In these between-subjects designs, participants were asked which piece of information –without any implication of function or mechanism – should come first. In both studies there were two domains (artifact, biology), and only one framing condition (hypothetical). The part whole relations were displayed by showing relevant parts in different colors and referring to these colors in the description (see Table 1).

Participants in Study 2a were asked to decide which kind of information should come first: information about the *whole* machine/body part/plant part, or information about a *part* of that stimulus item. Participants in Study 2b, decided between information of about a *part* and information about a *sub-part* (referred to as a 'part of a part').

Results

Participant responses were dummy coded where selection of the superordinate option was coded as a 1 and the subordinate option was coded as a 0. For example, a participant in Study 2a who indicated that information about the whole should come first would be scored as a 1. A logistic regression revealed that responses were significantly above chance in both Study 2a ($\beta = 1.10$, $p = .003$) and Study 2b ($\beta = 1.24$, $p = .001$); Participants systematically preferred that information about a whole come before information about the part (Study 2a), and information about a part come before information about a sub-part (Study 2b). There was no significant effect of domain in Study 2a ($p = .087$) or Study 2b ($p = .245$) (see Figure 3).

Discussion

Studies 2a and 2b suggest that adults prefer explanations where information about the whole precedes information about the parts, and information about the parts precedes information about sub-parts. Adults prefer that explanations follow a top-down path through the hierarchy of decomposable parts: the *whole* should be addressed before *parts*, which should be addressed before *sub-parts*.

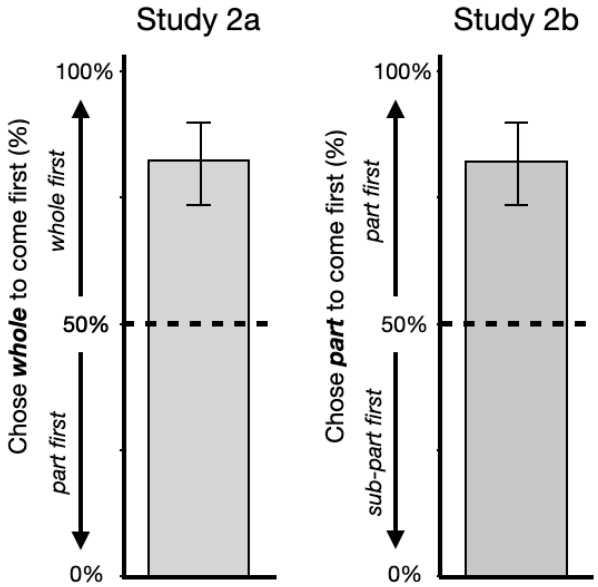

Figure 2: (Study 2a) Participants preferred that information about the whole come before information about the part ($\beta = 1.10$, $p = .003$) and that information about the part come before information about the sub-part ($\beta = 1.24$, $p = .001$) (Study 2b).

Study 3

Study 1 provides evidence that adults prefer function precede mechanism, while Study 2 raises a potentially deflationary account: the function-before-mechanism bias arises from a preference for a structure of whole to precede parts, which then precede sub-parts. Study 3 tests whether the function-before-mechanism bias disappears when the hierarchy is manipulated at the same time. While Study 1 asked participants to consider the function and mechanism of the whole, Studies 3a and 3b pit two biases against each other by

asking participants to consider function and mechanism at various levels of the hierarchy.[1]

Participants encountered a paradigm that mirrors Study 1a with the following exception: rather than being asked to consider the mechanism and function of a whole stimulus item, participants were asked to consider the mechanism of the whole and the function of a *part* (Study 3a) or the mechanism of the whole and the function of a sub-part (Study 3b). As in Study 2b, sub-parts were referred to as parts of parts.

Methods

Participants Studies 3a (mean age = 43.78 years; 38 females, 42 males, 7 participants excluded and replaced) and 3b (mean age = 42.54 years; 41 females, 39 males, 10 participants excluded and replaced) each consisted of 80 participants.

Procedure Participants in Studies 3a and 3b were randomly assigned to consider either an artifact or a biological part. In Study 3a, participants were asked to decide which information should come first: *mechanism* of the *whole* stimulus item, or the *function* of a *part*.

Participants in Study 3b faced a similar pairing; they were asked to determine which should come first: *mechanism* of the *whole* stimulus item, or the *function* of a *sub-part*. Note that the difference between these two studies is the level being considered for the functional option; Study 3a asks about parts while 3b probes about sub-parts.

Results

Responses were again dummy coded; As in Study 1a, responses where function was chosen to come first were coded as a 1 – regardless of the hierarchical level being addressed – and responses where mechanism should come first were coded as a 0. For example, a participant in Study 3a who indicated that the function of the part should come first would be scored as a 1.

Unlike in Study 1a, in Study 3a collapsed responses were not significantly different from chance (p = .655). Overall, participants did not significantly prefer one type of information to precede the other.

In Study 3b, responses were significantly below chance (β = -1.55, p < .001); Participants determined that mechanism of the whole should precede the function of sub-parts in an explanation.

Discussion

In Study 3a, participants did not indicate a clear preference for the order of *mechanistic* information of the *whole* and *functional* information of a *part*. Perhaps discussing the mechanism of a whole entails highlighting the function of

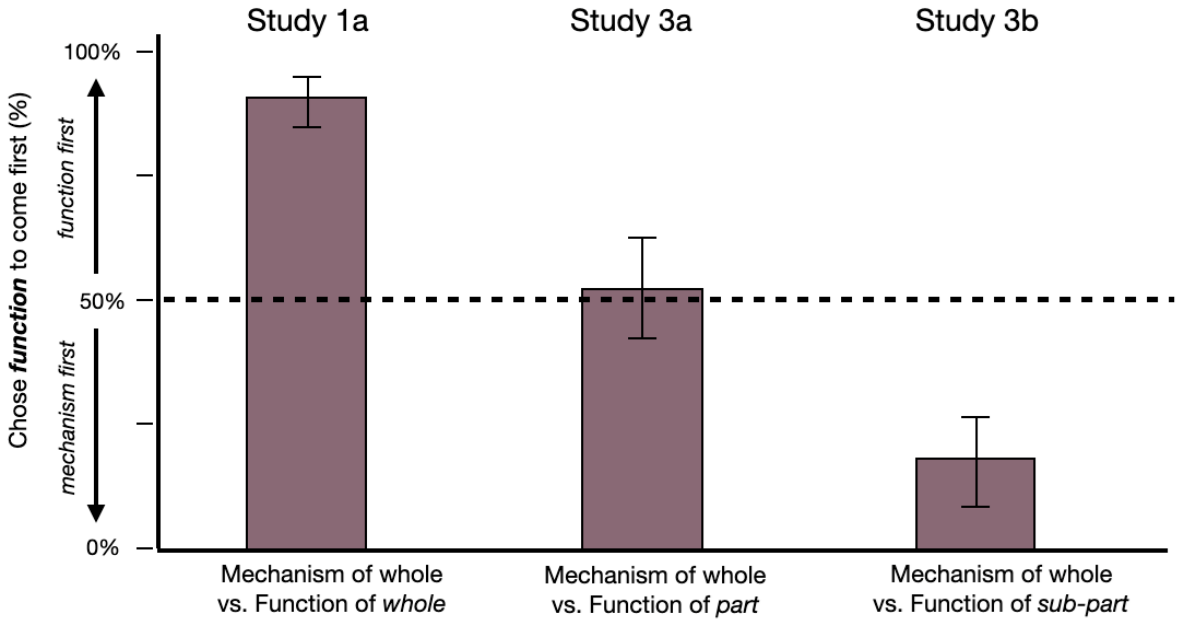

Figure 3: Participants in Study 1a - reprinted here for ease of comparison - preferred that functional information precede mechanism (β = 2.512, p < .001), while participants in Study 3a did not have a clear preference (p = .655) and Study 3b trended in the opposite direction: participants preferred that the mechanism of the whole come before the function of the sub-part (β = -1.55, p < .001). Preferences for the order of mechanistic and functional information were mediated by the hierarchical level being considered.

[1] Based on the findings of Greif et al. (2006) and the stimulus items used in Kelemen (1999), biological parts such as tails – rather than whole animals or plants – were used as "wholes" in the biology condition. Whole artifacts referred to whole stimulus items (e.g. a machine). Parts and sub-parts scaled with respect to this difference in definition of "whole."

parts, making it difficult for participants to clearly differentiate between the two types of information.

In Study 3b, participants indicated that mechanistic information of the whole should precede functional information of sub-parts. That is, participants deviated from their function-before-mechanism bias in favor of satisfying the top-down bias established in Studies 2a and 2b.

General Discussion

Prior studies suggest that children – and even adults under cognitive load – endorse teleological explanations, often over mechanistic explanations (Joo, Yousif, & Keil, 2021; Kelemen, 1999). Studies 1a and 1b provide evidence that this preference for function might be due to a sensitivity to *order*. Selecting functional information then, especially in a forced-choice paradigm, may reflect an expectation of the order of an explanation. Selecting function could indicate the desire for functional information to come first, rather than a preference for function outright.

The results of Studies 1a and 1b demonstrate an expectation that functional information come before mechanistic information in an explanation, but the question remains open as to why that might be the case. Studies 2a and 2b suggest that this preference may in part be explained by a sensitivity to the hierarchical structure of the world. As functional information appeals upwards, toward the whole, and the mechanistic information appeals downwards, toward the underlying components, the preference for function to precede mechanism may be explained by a preference to address things from the top-down (Study 2a, 2b).

Studies 3a and 3b, taken together with Studies 1a and 1b, illustrate how preferences of the order of functional and mechanistic information vary based on the level being considered. When considering a whole entity, there is a strong preference for mechanism to be preceded by function (Study 1a, 1b). When considering function of a part, however, that preference for function is mitigated; In Study 3a adults did not demonstrate an order preference between the mechanism of the whole and the function of the part perhaps because distinguishing between these information types is nonsensical: explaining the mechanism of a whole essentially equates to explaining what functions the parts serve. Further, when deciding between the mechanism of a whole and function of a sub-part, there was no demonstrated preference between the two (Study 3b).

Studies 3a and 3b provide evidence that the relation between function and mechanism in explanations is mediated by the acknowledgement of the naturally occurring hierarchical structure of the world. The preference for functional information to precede mechanism is not guaranteed; When considering the proper structure of explanations, participants consider not only the kind of information being presented, but also the hierarchical level being addressed.

While the effect found in Study 1 was bolstered by the multiple methodologies employed, Studies 2 and 3 lacked the use of multiple parallel measures. Further, Study 1 was broader in its ecological validity than Studies 2 and 3 in that it required participants in the Content condition to consider whole explanations (mean length 67.5 words), rather than just their hypothetical framings (mean length 11 words).

In the present studies we document that adults prefer that functional information precede mechanistic information, that explanations progress from the whole to the parts to the sub-parts, and that these two intuitions at times compete. Study 3 presents evidence that the function-before-mechanism bias may be the result of a preference for explanations to move from the top-down. It remains unclear, however, why this top-down bias might exist and what implications it might have. Future research should explore both the developmental origins of this bias as well as how following – or interrupting – this expectation might impact outcomes such as learning gains and curiosity in both adults and children.

Table 1: Here, we highlight stimulus items from the artifact & hypothetical framings conditions. In the biological condition the word 'machine' was replaced with 'body part' or 'plant part.' Each study used 4 artifacts and 4 biological kinds as stimuli. In Studies 2a-3b, color-coded boxes clarified the aspect of the stimulus item being referenced: the whole (in green), the part (in red), or the part of the part (in blue). All stimulus items (including those from the biological and concrete content conditions) are available on our OSF page.

Study 1a	Here's the machine that the teacher wants to teach about. What should the teacher teach the students FIRST?	
	What the machine is for, like what job it does. *[function]*	How the machine works, like how all the parts inside work together. *[mechanism]*
Study 1b	Here's the machine that the teacher wants to teach about. How good do you think the order of information in this explanation will be? (1 = The order of information is wrong, student won't be able to learn anything at all; 100 = The order of information is perfect, students will learn everything that there is to know about this machine)	
	First, the teacher is going to teach about what the machine is for, like what job it does. Then, the teacher is going to teach about how the machine works, like how all the parts inside work together. *[function-then-mechanism]*	
Study 2a	Here's the machine (in green) and a specific part of the machine (in red). What should the teacher teach the students FIRST?	
	Information about the whole machine (in green). *[whole]*	Information about the part of the machine (in red). *[part]*
Study 2b	Here's the machine (in green), a specific part of the machine (in red), and then a part of that part (in blue). What should the teacher teach the students FIRST?	
	Information about the part of the machine (in red). *[part]*	Information about the part of the part (in blue). *[sub-part]*
Study 3a	Here's the machine that the teacher wants to teach about. What should the teacher teach the students FIRST?	
	Information about the whole machine (in green). *[whole]*	Information about the part of the machine (in red). *[part]*
Study 3b	Here's the machine that the teacher wants to teach about. What should the teacher teach the students FIRST?	
	Information about the part of the machine (in red). *[part]*	Information about the part of the part (in blue). *[sub-part]*

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