Ways of Explaining Properties

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Abstract

Most explanations are either about events (why things happen), or about properties (why objects have the enduring characteristics that they do). Explanations of events have been studied extensively in philosophy and psychology, whereas the explanations of properties have received little or no attention in the literature. The present study is an exploration of the ways in which we explain various types of properties. Ten participants provided explanations of 45 properties by completing sentences of the form: "Xs have p because…" where p is a property of the concept X. When coded into three traditional kinds of explanation (i.e. *causal, purposive, categorical*), nearly half of the explanations did not fit into any of these categories and were classified as "*other*". Different patterns of preference for explanations emerged across the various property types for each domain. A qualitative analysis of the *other* kind revealed that the most frequent form of explanation involved another property of the object, as in '*Xs have property p because they have property q*". Explanations of properties showed a homeostatic character. Simply relating two properties of a concept seems sufficient as an explanation of a property.

Introduction

An event is something that happens. A property in contrast is an enduring characteristic of an object in the world. Humans are very good at partitioning the continuous flow of time into small components with distinct beginnings and ends. This process provides structure, enables us to talk and think about these components of time as individual entities and helps reduce the complexity of our experiences (Zacks & Tversky, 2001). Events usually have clear-cut temporal boundaries, with somewhat less clear spatial boundaries. It always makes sense to ask when an event occurred, but not always where. Properties, in contrast, are exemplified in objects, which are clearly defined spatially, but less so temporally. Objects have more of a where and less of a when. People think of properties as the stable characteristics of objects that can range from the very concrete (*having a blade* as a property of a knife), to the very abstract (*being a democracy* as a property of a state).

These simple differences in character suggest that humans may think about and process events and properties differently. If so, it is surprising that the literature on explanations has focused almost exclusively on explanations of events and very little to no attention has been given to explanations of properties. This paper provides a first exploration into the way we explain properties of natural kind and artifact objects.

From event to property explanations

Events are mainly explained in three distinct ways; causally, teleologically and principle-based (Keil, 2006; Keil & Wilson, 2000). Causal explanations are story-like descriptions of a causal sequence of events. The unification of Germany may be explained by a sequence of events that led to the fall of the Berlin wall and subsequent diplomatic talks between Gorbachev and Kohl resulting in the unification. Teleological explanations are most common for behavioral events. These explanations are framed in folk psychological terms like beliefs, desires and intentions, often referred to as the "intentional stance" (Dennett, 1987). Behaviors of others and our own are explained by the consequences that we intend to achieve with the particular behavior. A friend's choice to go to Peru on holiday may be explained by her newly developed interest in Inca culture, her desires to learn more about it and her beliefs that first hand experience will best achieve that. Principle-based explanations are less prevalent in everyday explanations but are rather more common in scientific explanations. Based on Hempel's deductive-nomological model, events are explained by subsuming them under some principle or general law. The falling of an apple from a tree is explained by two facts. One is the general law, that an object with a larger mass attracts another object with the smaller mass with a force proportional to the product of their masses, and inversely proportional to the square of the distance between them. And the other is that the earth and the apple are such objects.

Thus based on event explanations we can distinguish three main kinds of explanations[1] that may apply to properties: causal, teleological and principle-based. The causal explanation makes reference to the way a property came about, whereas the teleological account would provide an explanation by reference to what the property does either for the object itself or for some agent using the object.[2] Sparrows have wings because their DNA determines the growth of wings in their ontogeny. Or sparrows have wings in order to be able to fly. Principle-base explanations may account for a property by reference to a category. One might say that sparrows have wings because they are in the

[1] For clarity of exposition, the term *kind* will be used for explanations and the term *type* for properties without implying any theoretical commitments for either explanations or properties.
[2] A more detail characterizations for each kind of explanation will be given in the method section under the coding instructions.

category of birds and all birds have wings. The proposition that *all birds have wings* takes the role of the general law in Hempel's model with *sparrows being birds* fulfilling the necessary precondition for the explanation to work.

Principle-based explanations will be termed *categorical* to reflect that in property explanations categories take the role of the general law or principle. Similarly *teleological* explanations will be termed *purposive*. Properties are better characterized by functions than goals and thus the term purposive was more appropriate than teleological for property explanation.

Intuitively the applicability of these different kinds of explanation will depend on both the property that needs to be explained and the domain of the object that the property belongs to. Categorical explanations, for instance, might only work with properties that are at least generally associated with the category, whereas purposive explanations might not work for properties of non-living natural kinds like clouds because there is no mechanism by which the function could influence the occurrence of the property (McLaughlin, 2001). Even if the color of the sky had a particular function, it is difficult to see how that function could be the reason for it having that color. In contrast, the evolutionary advantage that a function of a property would bring for a living natural kind may be considered sufficient to explain the existence of the property. Causal explanations might be more prominent than purposive explanations for features of natural kind objects, whereas the reverse is probably true for artifacts given that they are generally created to fulfill a function.

Study

The current study was designed to explore the different ways in which we explain properties. A qualitative approach was used to allow participants to freely express their views of why certain objects have the properties they do. Five different property types were combined with different natural kind and artifact concepts to create 45 partial sentences for use in a sentence completion task. The explanations elicited from participants were then classified by independent judges in a qualitative analysis.

Method

Participants Ten participants (4 male, 6 female; average age of 28 years) took part in the study. Two participants were fluent bilinguals, one was a competent speaker of English as her second language and the rest were native English speakers. There were no systematic differences in explanations across the different language competencies.

Materials Participants were presented with 45 items on a sentence completion task. Each item was the beginning of a sentence of the form: 'Xs have p because…' where p is a property of the concept X. Participants were asked to complete the sentence by providing an explanation that would satisfy them as a recipient of that explanation. Sixteen concepts (8 natural kinds and 8 artifacts) with an average familiarity rating of 5.6 on a 9-point scale, with 9 being the highest familiarity, were selected from McRae, Cree, Seidenberg, and McNorgan's (2005) property norms. For each concept the norms contain a number of properties classified into 25 different property types (Wu & Barsalou, 2002). Across the 16 concepts, 9 properties were selected for each of 5 different property types resulting in 45 items. The selected properties had a significantly higher production frequency than those properties not selected (Selected: M = 13.9, SD = 7.4; Omitted: M = 10.1, SD = 5.6; $t(212) = 3.8$, $p < .001$). The 5 property types selected were the 4 most frequent and the 7th most frequent in the norms (*external surface feature*: mushrooms are white; *function*: axes are used for chopping; *external component*: mugs have a handle; *superordinate*: ants are insects; and *location*: flamingos live on water). Table 1 shows the distribution of items across property type and domain. The percentage of items of that property type in the norms is given in brackets. The property types with rank 5 & 6 (*entity behavior* and *made of* respectively) were not chosen because *entity behavior* was almost exclusively a type found in natural kinds, and *made of* was likewise confined to artifacts.

Table 1:
Number of items for each property type across domains.

Property Types:	Natural Kinds	Artifacts
External Surface Feature	4 (17%)	5 (15%)
Function	3 (12%)	6 (25%)
External Component	4 (12%)	5 (14%)
Superordinate	5 (11%)	4 (9%)
Location	7 (11%)	2 (6%)

Note: Percentage of items in the norms for each property type are given in brackets

Procedure & Design All participants completed the full set of 45 explanations in their own time. The questionnaire contained a description of the study, a consent form and a page asking for demographic information. Two random orders of items were used.

Coding procedure Three independent judges (one of whom was the first author) classified the explanations into four kinds (*causal*, *purposive*, *categorical* and *other*). Judges were instructed to classify explanations that made explicit reference to something that brought about the property as *causal* explanations. These included stating some process or mechanism, such as an evolutionary process, that lead to the property (e.g. Coconuts grow on trees because that is the way they evolved; Pepper makes you sneeze because it activates sensitive parts in your nose), some constituent of X that results in the property (e.g. Olives are black because of the pigments in their flesh) and sometimes the lack of something that results in the property (e.g. Cellars are damp because they are not cared for).

Explanations were to be classified as *purposive* in case they made reference to something that the property does for either an end user or the object itself (e.g. Bedrooms have walls because they keep the draft out; Penguins have feathers because they keep them warm), something that X does (e.g. Projectors have a light inside them because they project films on screens), something that X needs the property for (e.g. Goldfish have gills because they need them to breath; Rockets are large because they need to store a lot of equipment) or something that X was made to do or that it enables us to do (e.g. Accordions have keys because they were made to play music; Pens have ink because they enable us to write).

Categorical explanations were those explanations that made clear reference to the category membership of X. This could be in form of a superordinate category (e.g. Avocados have pits because they are fruit), a subclass of the superordinate (e.g. Sparrows live on trees because they are birds that can fly) or a general claim about the superordinate category (e.g. Bedrooms have walls because all rooms have walls). Judges were instructed to classify the explanation into these three kinds. A fourth kind—*other*—was used for any item that did not fit into one of the above three.

Results

Coding Results Cohen's Kappa and percentage agreement were calculated for each of the three possible pairings of the independent raters. Raters were consistent on at least three quarters of the items (75%, 80%, 92%) with substantial (Landis & Koch, 1977) Kappa values (.62, .69, .87). The majority of disagreement between raters (95%) involved one of the judges choosing the fourth kind (i.e. *other*). Kappa increased considerably (.94, .95, .99) when omitting the *other* option indicating that the judges were able to classify the *causal*, *purposive* and *categorical* explanations with a very high consistency. The observed disagreement for classification as *other* was owing to differences between the judges in strictness when classifying an explanation as *causal*, *purposive* or *categorical.*

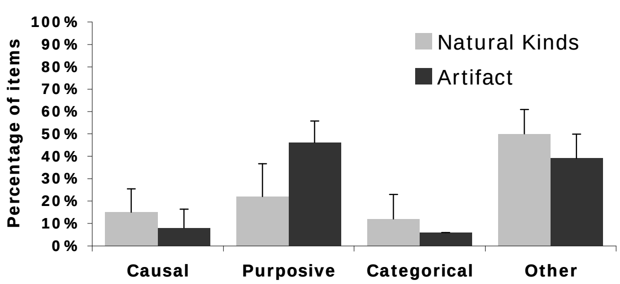

Figure 1: Percentage of items across kinds of explanation within each domain. Error bars indicate 95% confidence intervals.

Frequency Analysis One participant failed to give an explanation to one of the items. The remaining 449 explanations were coded into the four kinds. Figure 1 shows the percentage of explanations for the four kinds of explanation in each domain. Half of the explanations for natural kind items did not fall into one of the traditional kinds of explanation and were coded as *other*. The next most common way of explaining natural kind properties was *purposive* (22%) followed by *causal* (15%) and *categorical* (12%) explanations. For artifact items *purposive* (46%) explanations were the most common, closely followed by *other* (39%). Less than ten percent of artifact items were explained causally (8%) and even fewer items by reference to a superordinate category (6%).

Analyses of variance (ANOVA) by subject (F_1) and item (F_2) were carried out with the proportion as dependent variable and Kind of explanation (three levels: *causal*, *purposive*, *categorical*)[3] and Domain (two levels: natural kinds, artifacts) as factors. The main effect of Domain was non-significant indicating that the probability of using the *other* kind was not significantly different between the two domains ($F_1(1, 9) = 9.75$, $p < .05$, $F_2(1, 43) = 1.33$, $p = .26$, $MinF'(1, 51) = 1.17$, $p = .29$). However the interaction between Kind of explanation and Domain was significant ($F_1(2, 18) = 22.31$, $F_2(2, 86) = 7.56$, $MinF'(2, 100) = 5.65$, $p < .01$). Separate analyses for each domain revealed no effect of Kind of explanation for natural kinds ($F_1(2, 18) = 2.05$, $p = .16$, $F_2(2, 44) = .83$, $p = .44$, $MinF'(2, 62) = .59$, $p = .56$), but a significant effect for artifacts ($F_1(1, 18) = 99.94$, $F_2(1, 42) = 24.28$, $MinF'(1, 57) = 19.53$, $p < .01$)[4]. Post hoc tests on the artifact items using Bonferroni adjustments revealed that significantly more purposive than either causal or categorical explanations were used ($t(9) = 9.4$, $p < .05$, $t(9) = 20$, $p < .05$, respectively).

Figure 2 shows the proportion of the different kinds of explanation for each domain broken down by the type of property being explained. Each type of property showed a different pattern of preference for the various kinds of explanation. Domain only influenced the preference for a particular kind of explanation in surface features and superordinates. For component properties the two domains showed a similar distribution across the different kinds of explanation with *purposive* explanations being the most common. In contrast surface features of natural kinds were explained most often by *causal* explanations, whereas for artifacts the preferred explanation was *purposive*. For both functional and location properties, the two domains were roughly similar in distribution of the different kinds of explanation. Functional properties were mainly explained by the *other* kind, whereas those for locations were somewhat equally distributed across *purposive*, *categorical* and *other*. Explanations for superordinate category membership were almost exclusively in terms of the *other* kind of explanation for natural kinds, but roughly equally distributed between the *other* and the *purposive* for artifacts.

Three-way ANOVAs by subject (F_1) and item (F_2) with the proportion of explanation as dependent variable and Kind of explanation (three levels: *causal*, *purposive*, *categorical*), Type of property (three levels: component, surface feature, superordinate) and Domain (two levels: natural kinds,

[3] The *other* kind of explanation was omitted to avoid violating the independence assumption of ANOVA.

[4] Degrees of freedom for artifacts were adjusted to the lower bound of 1 due to a significant Mauchly's test of sphericity.

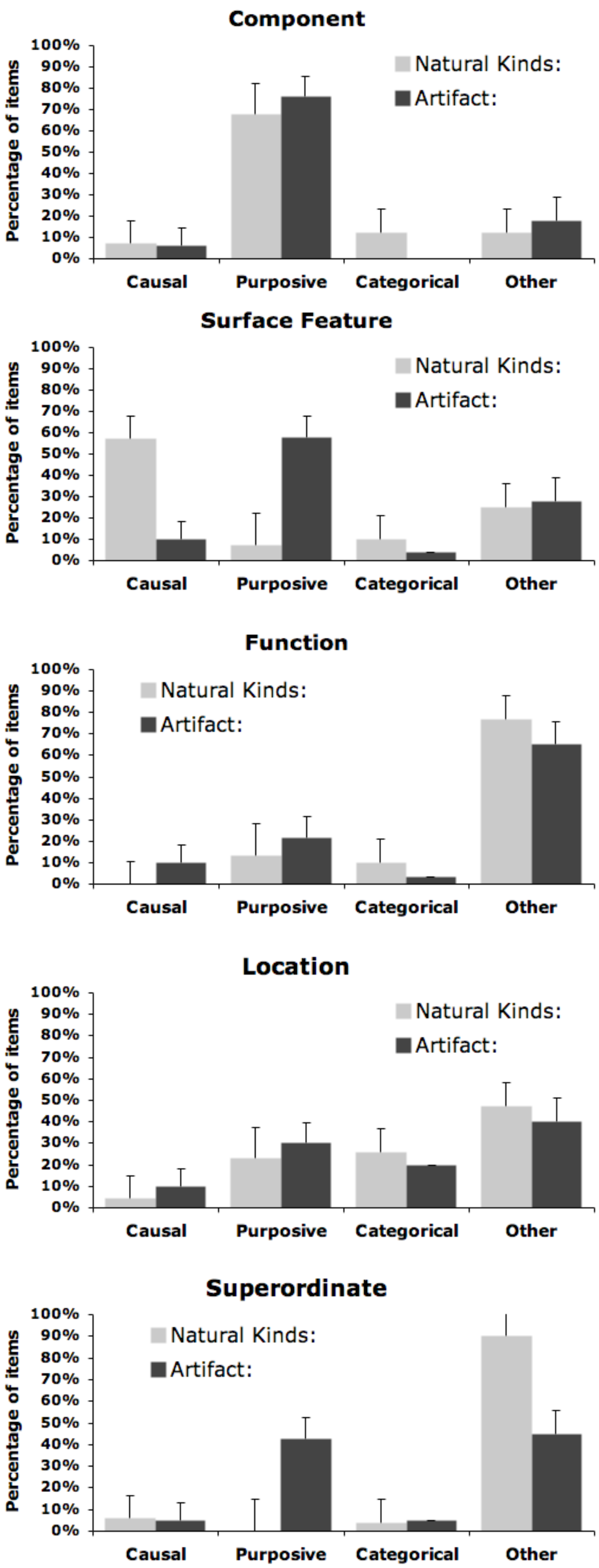

Figure 2: Separate graphs for property types show the percentage of items in each domain across the four types of explanation. Error bars represent 95% confidence intervals.

artifacts) as factors were carried out. Location and function as type of property were not included in these analyses due to unequal sample sizes for the two domains in the item analysis. The three-way interaction between property, explanation and domain was significant ($F_1(4, 36) = 7.87$, $F_2(4, 42) = 4.91$, $MinF'(4, 76) = 3.02$, $p < .05$). Separate analyses for components, surface features and superordinates were carried out. Significant two-way interactions between Domain and Kind of explanation were found for surface features ($F_1(2, 18) = 37.64$, $F_2(2, 14) = 16.05$, $MinF'(2, 25) = 11.25$, $p < .01$) and superordinates ($F_1(2, 18) = 13.91$, $F_2(2, 14) = 7.17$, $MinF'(2, 27) = 4.73$, $p < .05$) but not for components ($F_1(2, 18) = 1.48$, p = .25, $F_2(2, 14) = 1.51$, $p = .25$, $MinF'(2, 32) = .75$, $p = .48$). The pattern of preference for a particular kind of explanation differed across types of property depending on the domain of the object.

In this analysis the main effect of Domain measured differences between the two domains in the use of the *other* kind of explanation. There was no significant effect for surface features or components ($F < 1$, in both cases) but a significant effect was found for superordinates ($F_1(1, 9) = 35.24$, $F_2(1, 7) = 6.81$, $MinF'(1, 10) = 5.71$, $p < .05$). Natural kind superordinates were more often explained by using the *other* kind of explanation than artifacts. Thus domain only had an effect on the way surface features and superordinates were explained.

The data for function and location properties were collapsed across domains and included in a 2 x 3 ANOVA for Type of property (two levels: function, location) and Kind of explanation (three levels: *causal, purposive, categorical*) as factors. The two-way interaction between Property and Explanation was not significant ($F < 1$). A marginally significant main effect for property type ($F_1(1, 9) = 9.7$, $F_2(1, 16) = 7.4$, $MinF'(1, 24) = 4.19$, $p = .052$)[5] indicated that the *other* explanation was chosen significantly more often to explain function than location properties.

Qualitative Analysis The *other* kind contained a diverse set of explanations, which were further analyzed to identify characteristic similarities and establish coherent categories. In the set of 204 explanations a further 5 distinct types were identified. In addition there were 4% of explanations of a non-serious nature and a residual class of idiosyncratic explanations (< 9%). To take the least common of the 5 types first, around 3% of the explanations used the authority of nature or cultural history to explain a particular property. For example, *'it is natural for that object or animal to have that property.'* Some 4% of items made reference to intentionality, explaining the property by pointing out that people in general "like" it. Also around 4% had a counterfactual structure, whereby it was argued in the explanation that if the object did not have that property some other characteristic, mostly some unpleasant consequence, would be the case.

[5] The degrees of freedom were adjusted to the lower bound of 1 due to a significant Mauchly's test of sphericity.

Table 2: Examples of *'Xs have p because they have q'*

Component:

Flamingos have feathers because… they can fly.

Mugs have a handle because… they can be too hot to hold.

Surface feature:

Mushrooms are white because… they grow in the dark.

Bagpipes are plaid because… they are Scottish.

Function:

Axes are used for chopping because… they are sharp.

Mushrooms are eaten in salads because… they can be eaten raw.

Location:

Flamingos live on water because… they eat fish.

Sailboats are found on water because… they can float.

Superordinate:

Bananas are fruit because… they are sweet.

Bagpipes are musical instruments because… they can produce a range of notes.

Fourth, about 10% of explanations had the following form:

Xs have p because p has q,

where p is the property to be explained and q is a property of p. For instance, *'flamingos live on water because the water contains their food.'* The water has the property of containing food, which explains why flamingos have the property of living on water. *'Mugs have patterns because they* (the patterns) *are pretty.'* Being pretty is a property of the patterns that explains why mugs would have them. Apart from q being a property of p, there was a wide variety of possible relations between q and p in these explanations.

The most common set of explanations in the *other* category with nearly 70% took the form:

Xs have p because they have q,

where p and q are both properties of the concept X. *'Emeralds are expensive because they are rare.'* The rareness of emeralds explains why they are expensive. *'Cranes are used for lifting because they have a heavy base and good leverage.'* The properties of having a heavy base and good leverage explain why cranes are used for lifting. In contrast to the other kinds, in these explanations the relation between the two properties was underspecified. The relations were neither clearly causal, nor functional, nor of logical entailment. As with the fourth form of explanation above there was no clearly identifiable set of relations between q and p in these explanations (see table 2).

Discussion

People's preference for a particular kind of explanation was found to depend on the type of property that was to be explained. Domain only had an effect for surface features and superordinates. A large proportion of explanations could not be classified into the traditional kinds of explanation. The majority of those took the form *'Xs have p because they have q,'* where p and q are both properties of the concept X. On second consideration though, this form of explanation also seems to be prevalent in the traditional explanations. In both causal and purposive explanations, one property of a concept was explained by reference to another property. *Flamingos are pink because of their pigments (causal). Catfish live in lakes because they need water (purposive).* The difference between the traditional kinds of explanation and the majority of the *other* kind was therefore not the form per se, but the lack of a clearly identifiable set of relations between q and p for the *other* kind. For purposive explanations for example there was a clearly identifiable functional relation between the two properties. For instance, *'Ants have antennae because they need to feel where they are going'* clearly states the functional role of the property *'needing to feel where they are going'* that the property *'having antennae'* fulfills for ants. In contrast for explanations of the *other* kind there was no homogenous set of relations between the two properties. In the explanation *'Dolphins are mammals because they give birth to live young'* the relation between the two properties is clearly different from the relation in the explanation *'Catfish live in water because they can swim.'* The only common ground that these explanations have is their form.

General Discussion

Explanations of properties are notably different from explanations of events. Events are generally explained in three distinct ways; causally, teleologically and principle-based (Keil, 2006; Keil & Wilson, 2000). In contrast, although explanations of properties are also causal, purposive and category-based, a large proportion does not clearly fall into those categories. Property explanations do not have the narrative form that event explanations generally show. They rather show what one might call a homeostatic character (cf. Boyd, 1999, on the concept of species). Properties of objects stand in various relations to one another enabling them to provide an explanation for each other. Having wings, being small, living on trees and having feathers are all interrelated properties of birds. Wing size and body weight need to stand in a particular ratio to enable flight. Flight in turn makes living on trees a lot more advantageous. Living on trees though is only viable for birds up to a particular size. Each property is intertwined with a number of other properties in various relations. In event explanations the explanandum and the explanans stand in causal, functional or logical relation to one another and generally in a sequential manner. In property explanations this is not always the case. Often the relation between the explanandum and the explanans is underspecified or not clearly stated. The question then is, what makes these explanations plausible despite the lack of a clear causal, functional or logical relation between explanandum and explanans?

Concepts as the core for property explanations

"People's theories of the world embody conceptual knowledge and their conceptual knowledge organization is partly represented in their theories" (Murphy & Medin, 1985, pp. 289). We represent the world in our minds using concepts. Concepts consist of properties and the relations between them. Possessing the concept of emerald involves knowing that they have properties such as *being green, precious, rare, expensive,* and so on. All these bits of knowledge are represented in a large net of interconnected beliefs (Quine, 1960). This net of beliefs is shared and public. Thus, we believe that *emeralds are rare* and *expensive* and that these two properties are related and this knowledge is represented in semantic memory. In providing an explanation for a property, we tap into this conceptual knowledge, find a property that is closely related—be it causally, functionally, or in some other way related—to our target property and state it as the explanation. *Emeralds are expensive because they are rare.* We don't explicitly state how the two properties are related because that is an implicit part of our concept of emeralds. It is implicit because the link between the two properties may be embedded in a complex theory involving other properties and concepts like supply, demand and commodity. Thus making the link explicit may require going beyond the explanation at hand. Based on Gricean (1975) co-operative principles of conversation people may assume that our shared knowledge will fill the gap between the rareness and the value of emeralds so that making the link explicit would make the explanation more informative than it needs to be. One might also argue that our understanding of how the properties are related might be too patchy to provide a complete explanation (Wilson & Keil, 2000). Indeed often we might not even be aware of the lack of our explanatory understanding (Rozenblit & Keil, 2002). We may only know that there is a relationship between rarity and value that is modulated by market force, but lack the deeper knowledge of how it actually works. Despite some research in causal reasoning (Ahn & Kalish, 2000) that suggests that mechanisms are a vital part of inferring causal relations from covariation information, the current study has shown that people are willing to provide an explanation of a property by simply stating another property of the concept without clearly stating a mechanism that links the two properties.

Conclusion

The present study has explored the way we explain properties. Unlike the narrative sequential way of explaining events, property explanations have a homeostatic character. People use one property of a concept to explain another, often without specifying the relation or mechanism between them. This form of explanation is not uncommon. Advertisers, for example, say: *Yogurt drinks are good for you because they contain good bacteria*, whatever those might be. A friend might tell you that a *film is worth watching because it is funny*. And politicians tell us that *diesel cars incur higher tax because they are more polluting*. What relations have to hold between these properties for one to be explanatory for the other requires further work. The hypothesis here is that shared, implicit knowledge represented in our concepts provides the coherence necessary to make these explanations plausible.

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