Available online at www.sciencedirect.com
SCIENCE DIRECT®
COGNITION
ELSEVIER
Cognition 99 (2006) 73–112
www.elsevier.com/locate/COGNIT

# Principled and statistical connections in common sense conception

Sandeep Prasada*, Elaine M. Dillingham

*Department of Psychology, Hunter College, CUNY, 695 Park Avenue, Room 611, North Bldg, New York, NY 10021, USA*

Received 5 March 2004; revised 10 October 2004; accepted 28 January 2005

**Abstract**

Nominal concepts represent things as tokens of types. We report six experiments that investigate the nature of the relations we represent between the type of thing something is (e.g. DOG) and its other properties. The experiments provide evidence that we represent principled connections between the type of thing something is (e.g. DOG) and some of its properties (*k-properties*; e.g. having four legs for dogs), but not other properties (*t-properties*; e.g. being brown for dogs). Principled connections are different from logical, statistical, and causal connections. Principled connections, (i) license the expectation that tokens of the type will generally possess the *k*-property, (ii) license explanation of the presence of *k*-properties in tokens of a type by reference to the type of thing it is, and (iii) license normative expectations concerning the presence of the k-property in tokens of the type. The experiments provide evidence for all three of these aspects of principled connections. The experiments also demonstrate that principled connections must be distinguished from merely strong statistical connections. We suggest that principled connections are one of the fundamental types of relations (in addition to logical, statistical, and causal relations) in terms of which our conceptual knowledge is structured. We argue that principled connections reveal a formal mode of understanding and explanation. This mode of understanding complements other modes of understanding that have been studied within the theory-based approach to conceptual representation. Finally, we suggest that kind representations are distinguished from representations of mere types by the representation of principled connections to *k*-properties.


*Keywords:* Conceptual representation; Modes of explanation; Type-token representations; Generic knowledge; Principled connections

* Corresponding author.
*E-mail address:* sprasada@hunter.cuny.edu (S. Prasada).

0022-2860/$ - see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.cognition.2005.01.003

Concepts are the mechanisms by which we think about things. Thus, the concept DOG provides the means for thinking about dogs and the concept TABLE provides the means for thinking of tables. A fundamental property of nominal concepts is that they represent entities as tokens of types. Thus, the concept DOG provides the means for thinking of indefinitely many entities as being the same with respect to their type (DOG). A question of critical importance for any theory of conceptual representation concerns how we represent the relation between the type of thing something is and other properties it possesses. So, for example, how do we represent the relation between the property of being a dog, and the property of being brown or the property of having four legs? The nature of these relations is important because it determines the types of inferences that can be drawn on the basis of knowledge of the type of thing something is and constrains the manner in which property information may be accessed and used in language and thought. While it is clear what types of relations classical and prototype theories of conceptual representation represent between the type of thing something is and its other properties, the theory- or explanation-based approach to conceptual representation has not explicitly addressed this question. The present research addresses this question within the context of an explanation-based approach to conceptual representation.

## 1. Type-token representations in conceptual representation

Two distinct approaches have emerged in psychological research on conceptual representation (Medin, 1989; Murphy & Medin, 1985). One approach, exemplified by the classical and prototype theories of conceptual representation, views the representation of a type as a *description* of what has to be true of an entity for it to be categorized as a token of a type.[1] The theories differ with respect to the nature of the properties that can be included in the description (representation) of the type and the extent to which entities must have these properties in order to be categorized as a token of the type. In the classical theory, the representation includes only properties that are understood to be individually necessary and jointly sufficient for being a token of the type. As such, the classical theory represents logical relations between the type of thing something is and properties of tokens of the type. The prototype approach, on the other hand, represents statistical and similarity relations between the properties of tokens of types and the representation of the (proto)type (e.g. Rips, Shoben, & Smith, 1973; Rosch & Mervis, 1975). By focusing on representing what has to be true of entities (logically or statistically) in order to be categorized as a token of a type, these approaches are able to account for a range of phenomena related to categorization, but are unable to account for the manner in which concepts mediate understanding and explanation (Murphy & Medin, 1985). Understanding and explanation require knowing not simply what is true (a description of how things are), but also what is responsible for things being as they are.

[1] Exemplar theories are not discussed here as they deny that we form any type representations, however, like the classical and prototype theories, they view conceptual representations as descriptions. In the case of exemplar theories, the descriptions are of exemplars rather than types.

The concepts-as-theories or explanation-based approach recognizes the central role concepts play in understanding and explanation, and thus views concepts as possessing explanatory structure (Carey, 1985; Gelman, 1990; Gelman & Wellman, 1991; Gopnik & Meltzoff, 1997; Keil, 1989; Leslie, 1994; Murphy & Medin, 1985). Most previous research within this approach has drawn upon modern scientific practice in emphasizing the role of causal mechanisms in explanation and has not explicitly addressed the question of how the representation of a type is related to the properties of tokens of the type. The present work formulates and investigates a specific proposal concerning the relations we represent between the type of thing something is and its other properties. To do so, it draws upon one of the non-mechanistic modes of explanation found in Aristotle's theory of explanation. Section 2 presents a brief synopsis of these modes of explanation in order to formulate and situate a key aspect of our proposal.

## 2. Aristotelian modes of explanation and common sense conception

Aristotle notes that we have understanding of some aspect of reality (e.g. why A is B) when we know "on account of what" (e.g. C) it is that way. In such circumstances, we can explain a given aspect of reality (e.g. why A is B) by identifying that on account of which (e.g. C) the aspect of reality is as it is (e.g. A is B). Furthermore, he proposes that there are four types of *aitia*, or explanatory factors (C), that we can identify. These are often referred to as four types of causes, however, a number of scholars have argued that they are best thought of as four types of explanatory factors (Charlton, 1970; Hocutt, 1974; Moravcsik, 1974, 1975, 1991).

The four types of explanatory factors we can identify are as follows. First, we may identify that out of which something is constituted (the "material cause") as the ground for why A is B. For example, we can explain why a given chair is burnable by identifying what it is constituted of (e.g. The chair is burnable because it is made of wood). Second, we may identify what something is (the "formal cause") as the ground for why A is B (e.g. You can sit on that because it is a chair). Third, we may identify the end or sake-for-which something has a property (the "final cause") in order to explain why it has that property. For example, one can explain why a chair has the shape it does by citing the fact that it is for the sake of sitting. Finally, we can explain a thing's existence or its coming to have a given property by identifying that which is responsible for producing the thing or property change (the "efficient cause"). For example, we may identify the carpenter as being responsible for a chair coming into being or some wood coming to have a certain shape. This factor is closest to the modern notion of cause, however, even here there are important differences (Moravcsik, 1974, 1991).

These modes of explanation were meant to identify aspects of reality that stand in relevant relations to one another and thus afford the forms of understanding and explanation described (Moravcsik, 1991). Though Aristotle did not think all of these modes of explanation are required for understanding everything, he saw these modes as providing the means for explaining all aspects of reality (e.g. material and immaterial entities, natural and artifactual kinds, objects and events,…). As such, these modes of explanation abstract from the domain-specific causal mechanisms that may be operative in

any given circumstance. Thus a key property of these explanatory schemes is that they are non-mechanistic. They function by identifying that aspect of reality which renders another aspect of reality intelligible and thus explainable by reference to the former. Reference to causal mechanisms is often crucial to an understanding of *how* something (C) can be responsible for something being a given way (A being B). Consequently, while the Aristotelian modes of explanation allow us to identify what is responsible for things being as they are, they cannot tell us how these factors are responsible for things being as they are. It is important to note, however, that these modes of explanation are compatible with modes of explanation that make reference to underlying causal mechanisms.

We propose that one of the modes of understanding available to common sense conception is the formal mode of understanding whereby we understand tokens of a type to have certain properties because they are the kinds of things they are. For example, we understand Fido to have four legs because he is a dog, but we do not understand him to be brown because he is a dog. In making this proposal, we are psychologizing Aristotle's formal mode of explanation by making a claim about one of the ways in which we make sense of the world. We are not making a claim about the nature of reality.

If our conceptual systems do use this mode of understanding, it follows that we must represent two kinds of connections between the type of thing something is and properties of tokens of that type—one that licenses formal explanations (explanations by reference to the kind of thing something is), and one that does not. Section 3 further characterizes the nature of these two types of connections.

## 3. Principled and statistical connections

The formal mode of understanding distinguishes properties of a token that are determined by the type of thing it is from properties that are not determined by the type of thing it is. We refer to the former properties as *k-properties*, and the connection between types and these properties as *principled connections*. The latter properties are referred to as *t-properties*, and the connection between types and these properties as *factual connections*. Statistical connections are a type of factual connection. It is important to note that k-properties have both principled and factual connections to the type, whereas t-properties merely have factual connections to the type.[2]

As discussed above, principled connections have an explanatory aspect. Tokens of a given type are understood to have the k-properties they do *because* they are tokens of the relevant type. K-properties differ from t-properties that merely have a strong statistical connection to a type in this respect. A strong statistical connection between A and B does not, in itself, support the explanation of A in terms of B or B in terms of A. For example, though barns are typically red, we cannot explain its redness by citing the fact that it is a barn.

[2] The *k* in *k-properties* is meant to serve as a reminder that these properties are determined by the kind of thing something is. The *t* in *t-properties* is meant to serve as a reminder that these are properties that are associated with a type to the extent that tokens of the type possess the properties.

A second characteristic of principled connections is that k-properties are expected to be true of tokens of the type always or for the most part. In this respect, principled connections differ both from logically necessary connections and merely contingent connections. They differ from logically necessary connections by allowing for the possibility that there may be tokens of a type that lack k-properties determined by that type (e.g. three-legged dogs). A logically necessary connection would require that all tokens of the type possess the property in question. On the other hand, if the property is contingent, it only means that not all tokens of the type need to have the property. No further constraints on the expected prevalence of the property follow. Principled connections, on the other hand, support the expectation that k-properties will generally be true of tokens of the type.

Finally, principled connections have a normative aspect. Though it is possible for a token of a type to lack a k-property, we think that tokens of a type *should* have their k-properties. For example, we think dogs should have four legs and that dogs that do not, have something wrong with them. This is a second respect in which k-properties differ from merely typical properties. Mere statistical prevalence does not establish a normative expectation. For example, though barns are typically red, we do not think that barns should be red, or that there is something wrong with non-red barns. It is possible to have personal preferences concerning what things of a given type should be like (e.g. that barns should be red), however, this contrasts sharply with the case of principled connections, whereby we think that tokens should possess their k-properties, not as a matter of personal preference, but because they are the kinds of things they are.

## 4. Proposal

We propose that our conceptual systems contain a formal mode of understanding wherein we represent things as tokens of types and represent principled and statistical connections between the type of thing something is and properties of tokens of the type. Principled connections (i) allow us to understand certain properties (k-properties) to be true of tokens of a type because they are the types of things they are, (ii) license the expectation that k-properties will generally be present in tokens of that type, (iii) license normative expectations concerning the presence of k-properties in tokens of the type.[3] These properties distinguish principled connections from both logical and statistical connections. Principled connections, like statistical and logical connections, are formal in nature in that their properties can be specified independently of specific kinds and

[3] We note that it is possible to find motivation for this cluster of properties of principled connections in Aristotle's writings on the notion of form. As discussed, the form is understood to be the ground for various properties of a thing and thus affords formal explanation of these properties. In a number of places, Aristotle identifies the kind of thing something is with its form, which for natural things, he identifies with the thing's nature. Furthermore, Aristotle says that things that happen by nature happen always or for the most part. Finally, Witt (1998) argues that form is also understood by Aristotle to be intrinsically normative. We note these points of contact as they influenced the proposal developed and investigated in the present paper. The proposal investigated in this paper, however, is a proposal concerning the psychological representation of concepts and should stand or fall as such rather than on the basis of how closely it does or does not correspond to Aristotle's ideas.

properties. They also abstract from domain-specific causal mechanisms, as well as from the specific ways in which specific kinds are related to specific k-properties. As a consequence, we expect to find that principled connections are represented between the type of thing something is and its k-properties across content domains.

## 5. Overview of experiments

The distinction between principled and statistical connections is reflected in both linguistic and non-linguistic phenomena. In Experiment 1A we investigate a linguistic phenomenon that depends on the distinction. Specifically, we investigate whether the types of paraphrases bare plural generic sentences can receive depends on whether they express a principled or statistical connection between a kind and a property. Experiments 2A and 3A investigate non-linguistic phenomena that depend on the distinction between principled and statistical connections. In Experiment 2A, we seek to determine whether participants think that the presence of k-properties, but not t-properties, in a token of a type can be explained by reference to the type of thing it is. As such, the experiment investigates participants' judgments concerning the explanatory potency of types. Because the factor of interest (the kind of thing something is) is abstract in nature, it cannot be pointed at, pictured or otherwise indicated by non-linguistic means. Consequently, we used linguistic means to present this and other potential explanatory factors to the participants. This aspect of the procedure can mislead one into thinking that the experiment is studying linguistic phenomena, when, in fact, language merely provides the means for eliciting judgments concerning the explanatory relevance of certain abstract factors. Similarly, Experiment 3A uses linguistic means to elicit judgments concerning participants' normative expectations concerning k- and t-properties.

We recognize that perhaps not all readers will be fully convinced of the non-linguistic nature of the judgments elicited in Experiments 2A and 3A. As a consequence, we also ran all three experiments with non-native speakers of English (Experiments 1B, 2B, and 3B). It was predicted that native and non-native speakers may perform differently on Experiment 1 because of the linguistic nature of the judgment elicited, but should show the same pattern of performance on Experiments 2 and 3 because of the non-linguistic nature of the judgments elicited in those tasks.

## 6. Experiment 1A

One reflection of the distinction between principled and statistical connections is found in our knowledge of how bare plural generic sentences such as (1) and (2) may be interpreted. Both sentences can be understood as expressing the thought that tokens of the type referred to by the subject (dogs/barns) generally have the property denoted by the predicate (four-legged/red). As a consequence, (1a) and (2a) can be understood to be paraphrases of (1) and (2).

(1) Dogs are four-legged.

(2) Barns are red.
(1a) Dogs, in general, are four-legged.
(2a) Barns, in general, are red.
(1b) Dogs, by virtue of being the kinds of things they are, are four-legged.
(2b) Barns, by virtue of being the kinds of things they are, are red.

In contrast, whereas (1) can be understood to express the thought that dogs are four-legged *because* they are dogs (1b), (2) cannot be understood to express the thought that barns are red because they are barns (2b). Carlson (1995) notes that the linguistics literature has generally tried to analyze generics as either expressing inductive generalizations or rules and regulations, but not both. We follow Cohen (2001) in understanding bare plural generics as having two possible readings: one that expresses an inductive generalization, and another that expresses a rule-like connection between the subject and predicate. Our characterization of the rule-like connection differs from that generally found in the literature on generics in that it emphasizes the explanatory aspect of this link. The rule-like connection is not merely a conditional of some sort that brings with it a normative or statistical element (If something is an S then it must/should always/generally be P), principled connections also have an explanatory aspect (Ss are P *because* they are Ss). This aspect of principled connections is revealed in the acceptability of paraphrases such as (1b).

Thus, in English, bare plural generic sentences can be used to express both the idea of general prevalence of a property in tokens of a type, as well as the idea that tokens of a type possess a given property because they are tokens of that type. Both interpretations are possible if a principled connection is involved. Only the general prevalence reading is possible if a statistical connection is involved. Experiment 1 sought to establish the generality and systematicity of these facts. The items were initially categorized as involving principled or statistical connections on the basis of whether the "by virtue of" paraphrase (1b) sounded natural to the experimenters.

A second goal was to determine whether the predicted difference in the interpretation is due to a qualitative difference between principled and statistical connections, or if it arises from quantitative differences in the prevalence of the critical properties in the principled and statistical conditions. To distinguish between these alternatives, we matched a subset of principled and statistical items on the basis of prevalence estimates provided by our participants. If the differences in interpretation depend on a qualitative difference between principled and statistical connections, the differences should remain for the prevalence-matched items. If the differences in interpretation are due to quantitative differences in prevalence, they should disappear for the prevalence-matched items. A second way we sought to distinguish between these two alternatives was by performing analyses of covariance with the prevalence estimates as the covariate. A final goal of the experiment was to investigate the domain-generality of principled connections by including stimulus materials from natural, artifact, and social kinds.

In sum, if principled and statistical connections differ in the manner proposed, we should find: (i) an interaction between connection type and paraphrase type with the "in general" paraphrase being equally good for the principled and statistical items, and the "by virtue of" paraphrase being significantly better for the principled items than for

the statistical items; (ii) this effect should hold for the subset of items that are matched for prevalence as well as in the analyses of covariance; (iii) the goodness of the "by virtue of" paraphrase of the principled items should not vary as a function of domain.

### 6.1. Method

#### 6.1.1. Participants

Eighteen native speakers of English from an introductory psychology course at Hunter College participated for completion of course credit.

#### 6.1.2. Stimuli

Ninety bare plural generic sentences (see Appendix). Sentences were classified as involving a principled connection if the "by virtue of" paraphrase (1b) sounded natural to the experimenters. Sentences were classified as involving a statistical connection if the "by virtue of" paraphrase sounded odd, and it seemed like the property was generally true of the kind in question. 45 sentences involved principled connections, 45 involved statistical connections. Of these, 15 in each category referred to natural kinds; 15 referred to artifact kinds, and 15 referred to social kinds.

#### 6.1.3. Procedure

Each participant completed a paraphrase judgment task as well as a prevalence estimation task. All participants completed the paraphrase judgment task before the prevalence estimation task.

*6.1.3.1. Paraphrase judgment task.* On each trial, participants were presented with one of the stimulus sentences (1) followed by either the "in general" paraphrase (1a) or the "by virtue of" paraphrase (1b) of the sentence. Participants were asked to "make a judgment as to whether the second sentence can be understood to be a paraphrase of the first sentence. That is, whether the meaning conveyed by the first sentence can be conveyed by the second sentence." Participants made judgments of the goodness of each paraphrase on a 7-point scale. After making their judgment, they pressed the space bar to receive the other paraphrase. Participants received the "in general" paraphrase first for half the sentences and the "by virtue" paraphrase first for the other half. The order of paraphrases for a given sentence was counterbalanced across two versions of the experiment. Order of trials was randomized separately for each participant. PsyScope experimental software (Cohen, MacWhinney, Flatt, & Provost, 1993) was used to present the stimuli and record judgments for all the experiments reported in this paper.

*6.1.3.2. Prevalence estimation task.* Participants were presented with the stimulus sentences (bare plural generics) and asked to estimate the percentage (0–100%) of instances of the kind named by the subject that had the property named by the predicate. The order of trials was randomized separately for each participant.

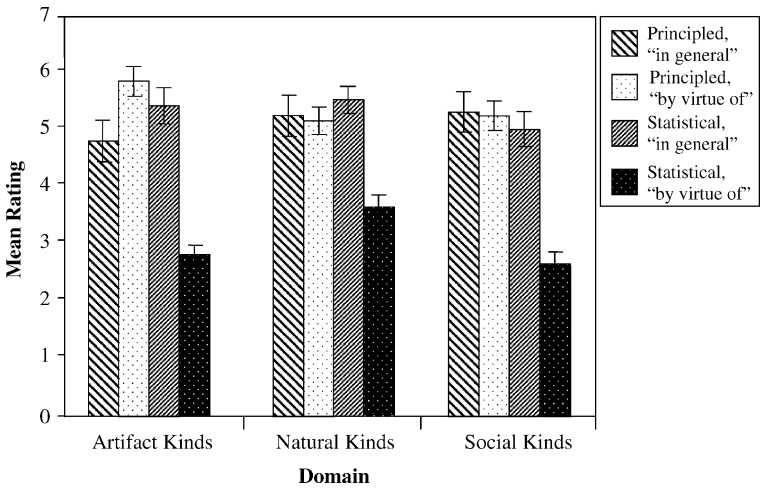


Fig. 1. Mean ratings for Experiment 1A.

### 6.2. Results

The mean ratings given by participants are shown in Fig. 1 and columns 2 and 3 of the Appendix. We performed 2×3×2 ANOVAs with connection type (principled/statistical), domain (natural/artifact/social), and paraphrase type (general/virtue) as the factors and participants' ratings as the dependent measure. Both participant and item analyses were performed.

#### 6.2.1. Distinguishing principled and statistical connections

The key prediction was that there should be a significant interaction between connection type and paraphrase type. This prediction was confirmed ($F_1(1,17)=26.21$, $P<.001$; $F_2(1,84)=292.73$, $P<.001$). Tests of simple effects showed that there was a large and significant difference between the goodness of the "by virtue of" paraphrase for items involving principled ($M=5.44$) and statistical ($M=3.05$) connections ($F_1(1,17)=80.53$, $P<.001$; $F_2(1,88)=242.4$, $P<.001$). In contrast, the goodness of the "in general" paraphrase was not significantly different for principled ($M=5.14$) and statistical connections ($M=5.35$). Thus, as predicted, the "by virtue of" paraphrase was considered a possible paraphrase if principled connections were involved, but not if statistical connections were involved.[4]

[4] We speak of the results in categorical terms, though one could suggest that the data are also consistent with there only being a difference in the relative goodness of the paraphrases. We acknowledge this point, though we do not believe that a theoretically coherent account of the data can be given if one starts with the assumption that the distinction between principled and statistical connections is a graded quantitative distinction rather than a qualitative distinction. The data from the prevalence-matched items and the ANCOVA also argue against this alternative interpretation. Furthermore, the less than numerically categorical results are likely due to a number of theoretically irrelevant factors including the implicit task demand not to choose only 1s and 7s and idiosyncratic properties of items included. Finally, describing all the differences in relative terms also makes the exposition more cumbersome. For all of these reasons, we discuss the results in categorical terms.

In contrast, the "in general" paraphrase was found to be a good paraphrase of items involving both principled and statistical connections.

*6.2.2. Domain-generality of principled and statistical connections*

Given the hypothesis that both statistical and principled connections apply domain generally, we had expected that domain would not interact with connection type and paraphrase type, however, the three-way interaction was significant ($F_1(2,34)=9.33$, $P<.001$; $F_2(2,84)=12.73$, $P<.001$). A closer look at the interaction suggests that this result does not count against the domain-generality of principled and statistical connections. Looking at the principled condition, 2×3 ANOVAs with domain and paraphrase type as factors found no effect of domain, and no effect of paraphrase type in the participant analysis, but a significant effect in the item analysis ($F_2(1,42)=6.35$, $P<.016$), and a significant interaction between paraphrase type and domain ($F_1(2,34)=5.79$, $P<.007$; $F_2(2,42)=9.73$, $P<.001$). As can be seen in Fig. 1, this interaction is due to the "by virtue of" paraphrase being given a slightly higher rating in the artifact condition than in either the natural ($F_1(1,17)=8.45$, $P<.01$; $F_2(1,28)=9.75$, $P<.004$) or social conditions ($F_1(1,17)=4.93$, $P<.04$; $F_2(1,28)=11.81$, $P<.002$) which did not differ from one another. On the other hand, the "in general" paraphrase was given a slightly lower rating for the artifact condition than the natural ($F_1(1,17)=4.52$, $P<.048$; $F_2(1,28)=5.15$, $P<.031$) or social condition ($F_1(1,17)=4.48$, $P<.049$; $F_2(1,28)=6.48$, $P<.017$). The theoretically significant result, however, is that both paraphrases were rated highly across domains for the principled items. The small domain effect is likely to be due to idiosyncratic properties of some items rather than a systematic interaction between the appropriateness of either type of paraphrase and domain. This conclusion is bolstered by the fact that a small domain effect is also found for the "in general" paraphrase which expresses a statistical connection, and statistical connections are universally recognized as applying domain-generally. A similar pattern of results was found for the statistical generics. We do not report those statistics here as they do not bear on the claim that principled connections are applicable across content domains.

*6.2.3. Prevalence and the distinction between principled and statistical connections*

The principled and statistical items overlapped in how prevalent the critical properties were in the relevant kinds, however, on average, the principled items had a higher estimated prevalence of the critical property ($F_1(1,16)=119.16$, $P<.001$; $F_2(1,88)=129.34$, $P<.001$). Consequently, we analyzed data for a subset of principled and statistical items that were matched for their average estimated prevalence. This yielded a set of 10 principled and 10 statistical items, with an average estimated prevalence of 82.01 and 82.6%, respectively. The prevalence estimates were based on the data of 17 participants as data from one participant had to be excluded for not following instructions.

We performed 2×2 ANOVAs with connection type and paraphrase type as the factors and the participants' ratings as the dependent variable. The mean ratings are shown in Fig. 2a. Domain was not included as a factor as there were uneven numbers of items from the different categories in the prevalence-matched data. Importantly, the interaction between connection type and paraphrase type remained significant ($F_1(1,17)=16.06$, $P<.001$; $F_2(1,18)=80.51$, $P<.001$). Furthermore, the form of the interaction was similar

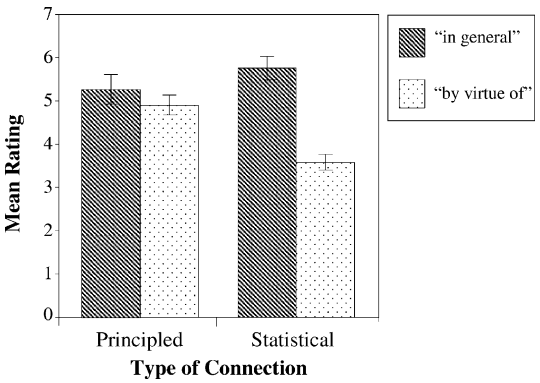


Fig. 2. Mean ratings for prevalence-matched items in Experiment 1A.

to that found with the full data set. There was a large and significant difference between the goodness of the "by virtue of" paraphrase for the principled ($M = 4.91$) and statistical ($M = 3.58$) conditions ($F_1(1,17) = 19.72$, $P < .001$; $F_2(1,18) = 25.53$, $P < .001$). In contrast, the goodness of the "in general" paraphrase was not significantly different for the principled ($M = 5.27$) and statistical ($M = 5.78$) conditions in the participant analysis, though the tiny difference in ratings was significant in the item analysis ($F_2(1,18) = 18.54$, $P < .001$).

In sum, we found a very similar pattern of results for the prevalence-matched items and the full data set. Consequently, the systematic differences we found between the manner in which bare plural generics involving principled and statistical connections can be interpreted cannot be attributed to differences in quantitative differences in prevalence. This conclusion was also supported by the results of ANCOVAs that were performed on the full data set with the prevalence estimates as the covariate. These analyses yielded a pattern of results that was essentially identical to those of the ANOVAs with the full data set on the theoretically relevant comparisons.

### *6.3. Discussion*

Participants systematically distinguished their interpretation of bare plural generics involving principled connections and those involving merely strong statistical connections. The "by virtue of" paraphrase was judged to be a good paraphrase of generics involving principled, but not statistical connections. In contrast, the "in general" paraphrase was judged to be a good paraphrase of both types of connections. These findings are not surprising given that items were designated as either involving principled or statistical connections on the basis of the experimenters' intuitions as to whether they allowed the "by virtue of" paraphrase or not. The results show that these intuitions are robust and generally shared by native English speakers. Experiments 2 and 3 show that this difference in interpretation is not the only reflection of the distinction between principled and statistical connections. The present experiment also demonstrated that these differences in interpretation cannot be attributed to quantitative differences in

the prevalence of the critical properties in the two conditions. Finally, the results suggest that principled connections are found across content domains. The "by virtue of" paraphrase was judged to be a good paraphrase of generics involving principled connections within the artifactual, natural, and social domains.

## 7. Experiment 1B

Part of our linguistic knowledge of English is that bare plural generic sentences can be interpreted as conveying either the notion that a given property is generally true of tokens of a particular type or the notion that a given property is true of tokens of a type because they are the type of thing they are. On the other hand, the fact that we conceive of there being a principled connection between certain kinds and properties, but not others, is not a fact about English (or any language), but part of our conception of things. The pattern of performance found in Experiment 1A required participants to have both types of knowledge. As such, we might expect non-native speakers of English to differ from native speakers in their performance on this task. Given that the general prevalence interpretation is possible for all bare plural generics, but the "by virtue of" interpretation is only possible for a more limited range of cases (i.e. those involving principled connections), it is plausible that non-native speakers of English may know that bare plural generics may have the former paraphrase, but not the latter paraphrase.

### *7.1. Method*

#### *7.1.1. Participants*

Eighteen non-native speakers of English from an introductory psychology course at Hunter College participated for completion of course credit. As we were not studying second language acquisition we did not seek IRB approval to record information about the participants' language histories. The non-native speakers of English at Hunter College constitute a very diverse group and the sample likely included speakers of Spanish, Russian, Chinese and Hindi among other languages. All participants had enough competence in English to be in introductory psychology at Hunter College.

#### *7.1.2. Stimuli*

Same as Experiment 1A.

#### *7.1.3. Procedure*

Same as Experiment 1A.

### *7.2. Results*

The mean ratings are shown in Fig. 3. We performed $2\times3\times2$ ANOVAs with connection type, domain, and paraphrase type as the factors. The result of most interest is the lack of a significant interaction between connection type and paraphrase type. As can be seen from Fig. 3, this is the result of participants rating the "in general" paraphrase

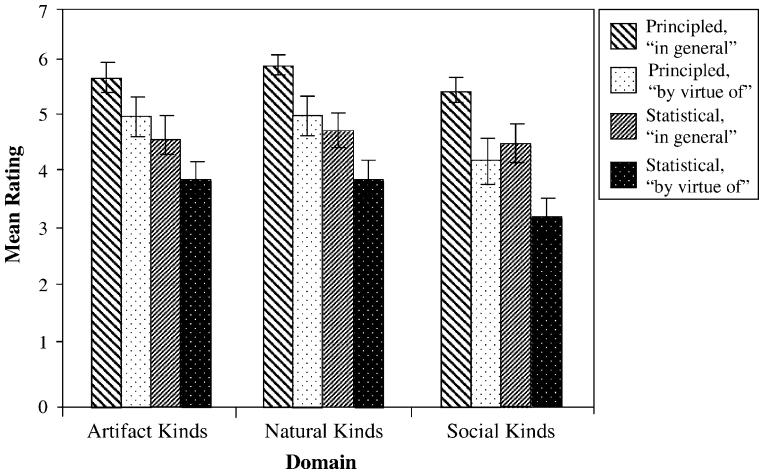


Fig. 3. Mean ratings for Experiment 1B.

highly in both the principled and statistical conditions, while rating the "by virtue of" paraphrase badly in both conditions. This pattern of results contrasts with that found for native English speakers, who found the "by virtue of" paraphrase to be a good paraphrase for the items involving principled, but not statistical connections. This difference between the two populations was confirmed by a significant three-way interaction between experiment, connection type and paraphrase type ($F_1(1,34) = 18.61$, $P < .001$; $F_2(1,88) = 174.16$, $P < .001$).

### 7.3. Discussion

The non-native speakers differed from native speakers in their judgments concerning possible paraphrases of bare plural generic sentences. Unlike native speakers of English, the non-native speakers in this experiment did not distinguish bare plural generics involving principled and statistical connections with respect to the types of paraphrases they may have. The "in general" paraphrase was judged to be a possible paraphrase of both types of bare plural generics and the "by virtue of" paraphrase was judged not to be a possible paraphrase for either type of sentence.

There are two possible interpretations of this result. The most plausible interpretation is that non-native speakers did not know a linguistic fact about English. Specifically, they did not know that bare plural generics can be used to convey the notion that the property denoted by the predicate is true of tokens of the type denoted by the subject because they are tokens of that type. Though all languages can express generic thoughts, they differ in the ways in which they do so. Furthermore, within a language, there can be different ways of expressing generic thoughts with different restrictions on the types of generic thoughts that can be expressed by a given linguistic form. The non-native speakers in the present experiment seem to have learned that bare plural forms can be used to express generic thoughts of one type, but not that they can also be used to express another type of generic thought when principled connections are involved.

A more radical interpretation of the data is that the participants in Experiments 1A and 1B do not differ in their linguistic knowledge, but differ in the way they conceive of the world. Specifically, the non-native speakers understand all the items used in the experiment as involving statistical connections and thus only allow the "in general" paraphrase for all of the items. This is extremely implausible. Furthermore, the data from Experiments 2B and 3B show this not to be the case.

In sum, the results of Experiments 1A and 1B show that the distinction between principled and statistical connections is reflected linguistically in whether or not bare plural generics in English can receive a "by virtue of" paraphrase and that whereas native speakers of English know this to be the case, non-native speakers do not. The rest of the experiments investigate non-linguistic reflections of the distinction.

## 8. Experiment 2A

Experiment 2A was designed to provide an explicit test of the hypothesis that principled connections support formal explanations. We asked participants to judge various possible explanations for why a token of a type had a given k- or t-property. For example, participants were asked to judge various explanations for the four-leggedness of a given dog (3).

(3) Why does that (pointing to a dog) have four legs?
(3a) Because it is a dog.
(3b) Because most dogs have four legs.
(3c) Because it has the essence of a dog which causes it to have four legs.

We expected formal explanations (3a) to be judged to be good responses when the property to be explained was a k-property, but not when it was a t-property. Furthermore, we expected this form of explanation to apply domain-generally.

Two other types of explanations were included as controls. In *statistical explanations* (3b), the potential explanatory factor was a strong statistical connection between a type and a property. We did not expect statistical explanations to be judged to be very good for either k- or t-properties. We also did not expect the goodness of this form of explanation to vary as a function of domain. In *causal-essence* explanations (3c), the potential explanatory factor was the causal-essence of the kind. We expected this type of explanation to be rated more highly for the items in the natural kind condition than the artifact or social kind conditions. It is important to stress that the statistical and causal-essence explanations were included as controls. They were not meant to be tests of either statistical explanation or a belief in the existence of causal essences. For a recent review of evidence that we often behave as though things have causal essences see Gelman (2003).

Participants were asked to judge the naturalness of explanations containing these three explanatory factors (3a–c). Because the explanatory factors were presented linguistically, the ratings will invariably also be sensitive to linguistic properties of the explanations. This limits our ability to directly compare the goodness of different explanatory factors (since they appear in explanations that differ in linguistic form). However, any systematic

difference in the naturalness of a given type of explanation for k-properties and t-properties cannot be due to linguistic factors as the linguistic form of the explanation was held constant. Such differences must be interpreted as arising from our conceptual understanding.

The primary motivation of Experiment 2A was to investigate whether reference to the kind of thing something is can explain the presence of k-properties, but not t-properties. Secondly, we sought to investigate whether this form of explanation applies domain-generally. Thirdly, we sought to determine whether differences in the explanatory adequacy of formal explanations for principled and statistical connections are due to quantitative differences in the prevalence of the critical properties in the two conditions. Finally, a systematic difference in the goodness of formal explanations for principled and statistical items would provide a way of distinguishing the items that is distinct from the one used to originally designate the items as involving principled and statistical connections.

### *8.1. Method*

#### *8.1.1. Participants*

Eighteen native speakers of English from an introductory psychology course at Hunter College participated for completion of course credit.

#### *8.1.2. Stimuli*

The sentences used in the previous experiments were used to generate questions of the form in (3). For each question, a response containing a formal explanation (3a), a statistical explanation (3b), and a causal-essence explanation (3c) was generated. Some of the sentences in Experiment 1 had predicates that could be interpreted as either referring to a capacity or the exercise of the capacity (e.g. Birds fly). For these items, the question sought an explanation for the capacity (e.g. Why can that (pointing to a bird) fly?).

#### *8.1.3. Procedure*

Each participant completed an explanation evaluation task as well as a prevalence estimation task. All participants completed the explanation evaluation task before the prevalence estimation task.

*8.1.3.1. Explanation evaluation task.* On each trial, participants were presented with one of the stimulus questions (3) followed by one of the three response types (3a–c). Participants were asked to make a judgment as to the extent to which the answer seems to be a good or natural response to the question on a 7-point scale. Furthermore, participants were told "We are simply interested in your gut feeling about how natural or good a given response is to the question. We are not interested in whether it is a scientifically or socially good or acceptable answer, only if it feels natural". After participants made their judgment, they pressed the space bar to receive the second possible explanation, and similarly for the third possible explanation. Participants received 1/6 of the items in each of the six possible orders of the three explanation types. The order of explanations for a given question was

counterbalanced across six versions of the experiment. Order of trials was randomized separately for each participant.

### 8.2. Results

We performed 2×3×3 ANOVAs with connection type (principled/statistical), domain (natural/artifact/social), and explanation type (formal/statistical/causal-essence) as the factors and participants' ratings as the dependent measure. The mean ratings are shown in Fig. 4 and columns 4–6 of the Appendix.

#### 8.2.1. Formal explanations involving principled and statistical connections

The key prediction was that formal explanations would be judged to be good when the property to be explained was a k-property, but not when it was a t-property. Furthermore, it was important to show that participants would not treat all explanations in the same manner. Consequently, we predicted a significant interaction between connection type and explanation type. This prediction was confirmed ($F_1(2,34)=9.74$, $P<.001$; $F_2(2,168)=38.53$, $P<.001$). Tests of simple effects show that there was a large and significant difference in the goodness of formal explanations involving principled ($M=5.1$) and statistical ($M=3.4$) connections ($F_1(1,17)=108.83$, $P<.001$; $F_2(1,88)=193.24$, $P<.001$). On the other hand, there was a smaller but significant difference in the goodness of statistical explanations involving principled ($M=5.05$) and statistical ($M=4.28$) connections ($F_1(1,17)=14.01$, $P<.002$; $F_2(1,88)=37.76$, $P<.001$). Similarly, there was a small but significant difference in the goodness of causal-essence explanations involving principled ($M=2.99$) and statistical ($M=2.1$) connections ($F_1(1,17)=15.97$, $P<.001$; $F_2(1,88)=104.41$, $P<.001$) though both conditions received very low ratings. The important finding here is that, as predicted, participants judged formal explanations to be good explanations when they involved principled connections, but not when they involved statistical connections. The difference in the goodness of

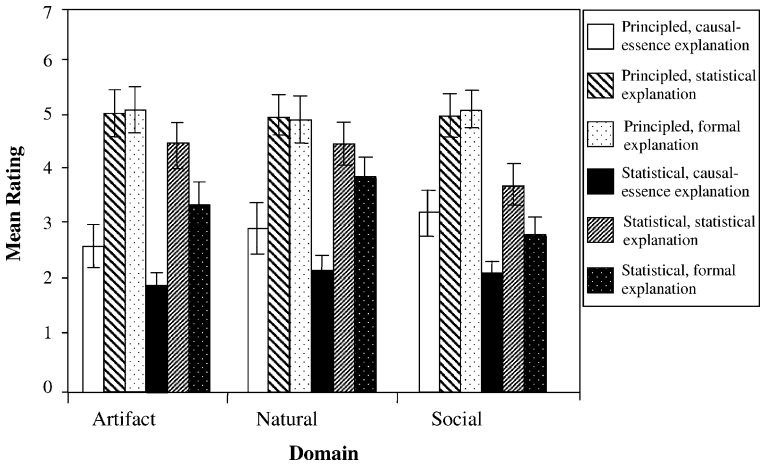


Fig. 4. Mean ratings for Experiment 2A.

formal explanations for k-properties and t-properties was large and significant. On the other hand, the difference in the goodness of explanations for k-properties and t-properties in the two control conditions was much smaller.

*8.2.2. Domain-generality of formal explanation*

There was a significant interaction between connection type, domain, and explanation type ($F_1(4,68)=2.54$, $P<.048$; $F_2(4,168)=3.68$, $P<.007$) indicating that not all forms of explanation for k- and t-properties applied in the same manner across domains. The key prediction was that formal explanations should be applicable domain-generally when principled connections are involved. Looking at the data from the formal explanations we find a significant interaction between connection type and domain ($F_1(2,34)=11.48$, $P<.001$; $F_2(2,84)=12.95$, $P<.001$). For the statistical items, there was a significant effect of domain in the participant analysis ($F_1(2,34)=11.9$, $P<.001$), but not the item analysis. For the principled items, there was no effect of domain in either the participant or item analysis. Thus, as predicted, formal explanation applied domain-generally when the property to be explained had a principled connection to the kind mentioned in the explanation.

*8.2.3. Prevalence and formal explanation*

Using data from the prevalence estimation task, we generated a subset of principled and statistical items that were matched for their average estimated prevalence. This yielded a set of nine principled and nine statistical items, with an average estimated prevalence of 80.99 and 80.52%, respectively. The prevalence estimates were based on the data of 17 participants as data from one participant had to be excluded for not following instructions.

We performed 2×3 ANOVAs with connection type and explanation type as the factors. The mean ratings by condition are shown in Fig. 5a. As with the full data set, there was a significant interaction ($F_1(2,34)=3.79$, $P<.033$; $F_2(2,32)=5.63$, $P<.008$). Tests of simple effects show that the interaction was due to the fact that there was a large and significant difference between the goodness of formal explanations involving principled connections ($M=5.01$) and statistical connections ($M=3.64$) ($F_1(1,17)=64.83$, $P<.001$; $F_2(1,16)=20.51$, $P<.001$), but smaller differences in the two control conditions.

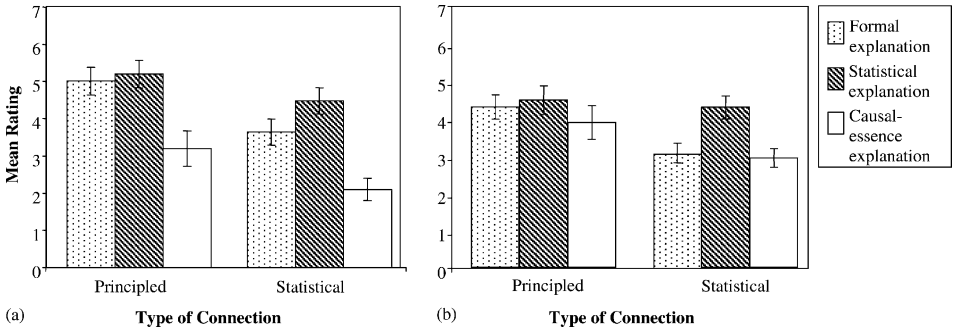


Fig. 5. (a) Mean ratings for prevalence-matched items for native English speakers (Experiment 2A); and (b) mean ratings for prevalence-matched items for non-native English speakers (Experiment 2B).

Statistical explanations were found to be better in the principled condition ($M = 5.2$) than in the statistical condition ($M = 4.48$) in the participant analysis ($F_1(1,17) = 13.22$, $P < .002$), but not the item analysis. Finally, causal-essence explanations were found to be better in the principled condition ($M = 3.2$) than the statistical condition ($M = 2.1$) ($F_1(1,17) = 19.22$, $P < .001$; $F_2(1,16) = 41.35$, $P < .001$), though they were rated badly in both conditions. In sum, we found a very similar pattern of results for the prevalence-matched items and the full data set. Most importantly, the preference for formal explanations for k-properties relative to t-properties remained virtually unchanged. Consequently, the preference for formal explanation of k-properties in comparison to t-properties cannot be attributed to quantitative differences in prevalence of the critical properties in the principled and statistical items. The results of the ANCOVAs with the full data set also supported this conclusion by yielding an essentially identical pattern of results as those of the ANOVAs with the full data set.

### *8.3. Discussion*

The results show that principled connections support formal explanation. Participants found it possible to provide a formal explanation of a property when the property was a k-property, but not when it was a t-property. It is worth noting that participants also found the statistical and causal explanations to be better for k-properties than t-properties. This suggests that perhaps k-properties were generally understood to be more worthy of explanation than t-properties. Importantly, however, the difference between the goodness of formal explanations for k- and t-properties was twice as large as the difference in goodness for the explanations in the two control conditions. Thus, reference to the kind of thing something is really does help explain the presence of k-properties, but not t-properties. The data from the prevalence-matched items and the analyses of covariance show that the difference in the explanatory adequacy of formal explanations for k- and t-properties cannot be attributed to differences in the prevalence of k- and t-properties. Finally, the data show that formal explanation applies to k-properties across content domains.

An alternative explanation for the difference in the goodness of formal explanations for k- and t-properties was suggested by one of the reviewers. The alternative appeals to a possible discourse-related confound in our stimuli. It was suggested that the kind identity of the questioned object might have been more likely to convey contrastive information in the discourse contexts elicited by the questions in the principled condition than the statistical condition. Thus questions like *Why does that* (pointing to a dog) *have four legs*? may have been more likely to suggest a context in which there are multiple kinds of animals than questions like *Why is that* (pointing to a barn) *red*? were to suggest a context in which there are multiple kinds of buildings. If this were the case, answers that identify the kind of thing something is may sound more natural in the principled condition than in the statistical condition. There is a priori no reason to expect that this should be the case for our stimuli, however, we tested for this possibility explicitly. We presented the questions used in Experiment 2A to another 18 participants and asked them to rate "How likely is it that this question was asked in a context in which there were types of [animals] other than [dogs] present?" No difference was found between the principled ($M = 4.7$) and statistical

($M = 4.9$) conditions. The difference found in the appropriateness of formal explanations for k- and t-properties cannot be attributed to differences in the discourse contexts elicited by the items in the principled and statistical conditions.[5]

We were surprised by how highly participants rated statistical explanations for k-properties, and even t-properties. It seems that reference to the general prevalence of a property within a kind can serve to explain the presence of that property in a token of the type. It is probably this intuition that is behind covering law approaches to explanation. As statistical explanations were included as controls, we do not pursue the nature of this result further, however, it calls out for further psychological experimentation. Finally, we were surprised by the uniformly low scores the causal-essence explanations received, as well as the lack of a preference for this form of explanation in the domain of natural kinds as compared to the other domains. This is likely due, in part, to the relative awkwardness of the sentence that was used in this condition. There is a great deal of evidence that people behave as though things have causal essences (see Gelman, 2003 for a comprehensive review of evidence in favor of this view). It is also possible that this is a case in which there is a conflict between our conceptual systems' implicit knowledge and our explicitly held beliefs. As mentioned earlier, this condition was included as a control condition rather than as a test of this theory, and thus we do not pursue this unexpected result further.

## 9. Experiment 2B

In Experiment 2A, the explanatory factors were presented via linguistic means because they could not be presented non-linguistically. The first two factors could not be presented non-linguistically because they are abstract. The causal-essence could not be presented non-linguistically because it is generally unknown even if it can, in principle, be known. To perform the task, participants had to understand the language used in the explanations, however, they did not need to know any further linguistic facts (e.g. how the explanations could be paraphrased). The differences in the goodness of a given type of explanation for k-properties and t-properties must have reflected conceptual knowledge. As a consequence, we expected non-native speakers of English to perform like native English speakers in this task.

### *9.1. Method*

#### *9.1.1. Participants*

Eighteen non-native speakers of English from an introductory psychology course at Hunter College participated for completion of course credit.

---

[5] Actually, a discourse explanation would have to be more intricate than the one suggested. It would require not only that instances of multiple kinds be imagined to be present in the context in which the question is asked, but also that these kinds contrast on the property mentioned in the question (e.g. four-leggedness). There is no reason to believe that such fine-grained contexts were elicited or that our principled and statistical items accidentally happened to differ in their ability to elicit such fine-grained discourse contexts.

*9.1.2. Stimuli*

Same as Experiment 2A.

*9.1.3. Procedure*

Same as Experiment 2A.

*9.2. Results and discussion*

The mean ratings are shown in Fig. 6. We performed 2×3×3ANOVAs with connection type, domain, and explanation type as the factors. The result of most interest is the significant interaction between connection type and explanation type ($F_1(2,34)=5.82$, $P<.007$; $F_2(2,168)=29.39$, $P<.001$). Tests of simple effects showed that there was a significant difference in the goodness of formal explanations involving principled ($M=4.32$) and statistical ($M=3.3$) connections ($F_1(1,17)=17.28$, $P<.001$; $F_2(1,88)=79.71$, $P<.001$). There was also a significant difference in the goodness of causal-essence explanations involving principled ($M=3.96$) and statistical ($M=3.0$) connections ($F_1(1,17)=11.51$, $P<.003$; $F_2(1,88)=83.32$, $P<.001$). On the other hand, the difference in the goodness of statistical explanations involving principled ($M=4.42$) and statistical ($M=4.24$) connections was not significant in the participant analysis and was marginally significant in the item analysis ($F_2(1,88)=3.19$, $P<.078$).

The important finding here is that, just like the native speakers of English, the non-native speakers judged formal explanations to be good explanations when they involved principled connections, but not when they involved statistical connections. As can be seen in Fig. 6, the overall pattern of results is very similar to that of the native speakers, except that the non-native speakers seem to be avoiding the extremes of the scale to a larger extent than the native speakers and generally rate the causal-essence explanations to be better than did the native speakers. An ANOVA comparing the ratings given to formal explanations in the two experiments for principled and statistical items found a significant

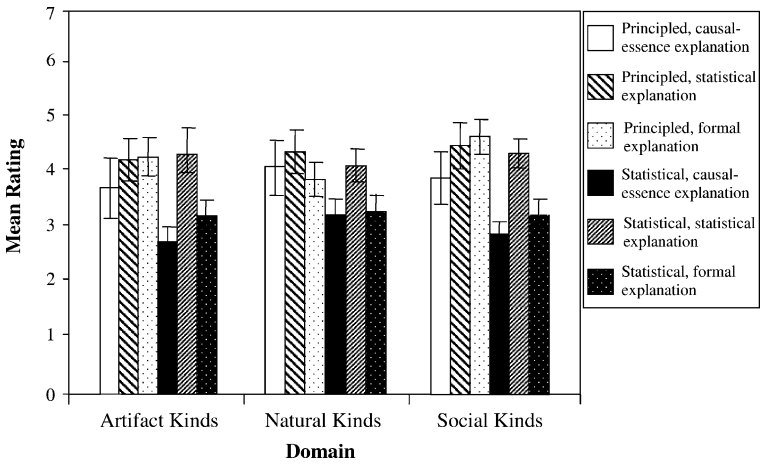


Fig. 6. Mean ratings for Experiment 2B.

interaction ($F_1(1,34) = 5.03$, $P < .032$; $F_2(1,88) = 19.33$, $P < .001$), however, as we will see this difference was not found for the prevalence-matched items.

The prevalence-matched items show virtually an identical pattern to that found in the full data set. There was a significant interaction between connection type and explanation type ($F_1(2,24) = 8.99$, $P < .001$; $F_2(2,44) = 7.4$, $P < .002$) (see Fig. 5b). Tests of simple effects found a significant difference in the goodness of formal explanations involving principled ($M = 4.28$) and statistical ($M = 3.05$) connections ($F_1(1,17) = 26.22$, $P < .001$; $F_2(1,22) = 28.27$, $P < .001$). The difference in the goodness of causal-essence explanations involving principled ($M = 3.87$) and statistical ($M = 2.92$) connections was also significant ($F_1(1,17) = 8.37$, $P < .01$; $F_2(1,22) = 31.01$, $P < .001$). On the other hand, the difference in the goodness of statistical explanations involving principled ($M = 4.47$) and statistical ($M = 4.27$) connections was not significant in either analysis.

Importantly, the ANOVA comparing the ratings given to formal explanations in the two experiments to principled and statistical items found no significant interaction. Thus, native and non-native speakers did not differ in their judgments concerning the naturalness of formal explanation. They both found them to be natural for k-properties, but not t-properties. The results of the ANCOVAs on the full data set yielded an essentially identical pattern of results as those of the ANOVAs with the full data set.

## 10. Experiment 3A

As discussed above, principled connections are hypothesized to have a normative aspect. Experiment 3A investigated whether we form normative expectations concerning k-properties but not t-properties. We presented participants with normative statements such as (4) and asked them to judge whether the sentences were true or not.

(4) Clocks, by virtue of being clocks, should have alarms.
(4a) Clocks should have alarms.

We used this form rather than the simpler form in (4a) because we did not want to elicit judgments as to what participants might think would be desirable in some ideal world, but what properties they thought things should have by virtue of being the kinds of things they are. It was predicted that normative statements involving principled connections would be judged to be true, whereas those involving statistical connections would not be. A connection between normativity and indefinite singular generics (e.g. *A dog has four legs*) has long been noted (Burton-Roberts, 1977). Cohen (2001) argues that bare plural generics can also have normative force if they are interpreted as expressing rule-like connections. Our stimuli build on this observation in two ways. First, the normative aspect is made explicit by including *should* in the bare plural generic. Second, the source of the normativity is made explicit by including the locution *by virtue of*.

### 10.1. Method

#### 10.1.1. Participants

Eighteen native speakers of English from an introductory psychology course at Hunter College participated for completion of course credit.

#### 10.1.2. Stimuli

The sentences used in Experiment 1 were used to generate statements of the form (4). Sentences with predicates that could be interpreted as either referring to a capacity or the exercise of the capacity (e.g. Birds fly), were modified so that they unambiguously referred to the capacity (e.g. Birds should be able to fly).

#### 10.1.3. Procedure

Each participant completed a truth-value judgment task as well as a prevalence estimation task. All participants completed the truth-value judgment task before the prevalence estimation task.

*10.1.3.1. Truth-value judgment task.* Participants were presented with the normative statements one at a time and asked to "…make a judgment as to whether it seems natural to say that the sentence is true". They were told that, "We are not interested in whether it is socially acceptable or not to say that the sentence is true. We are also not interested in whether, upon reflection or analysis it really is true. We are simply interested in the extent to which the sentence strikes you as a true statement on first encounter." The rating scale had 1 labeled as "definitely not true" and 7 labeled as "definitely true". Each participant judged every stimulus sentences. Sentences were presented in random order.

### 10.2. Results

#### 10.2.1. Normative expectations concerning k- and t-properties

The mean ratings are shown in Fig. 7 and column 7 in the Appendix. ANOVAs with connection type and domain as factors and participants' ratings as the dependent variable were conducted. As predicted, there was a large and significant effect of connection type ($F_1(1,17)=210$, $P<.001$; $F_2(1,84)=500$, $P<.001$), with normative statements concerning the presence of k-properties being judged to be true ($M=5.87$) and those concerning t-properties not to be true ($M=2.86$).

#### 10.2.2. Domain-generality of normative expectations concerning k- and t-properties

The ANOVA also yielded a significant effect of domain ($F_1(2,34)=8.28$, $P<.001$; $F_2(2,84)=9.88$, $P<.001$), and a significant interaction ($F_1(2,34)=23.35$, $P<.001$; $F_2(2,84)=20.01$, $P<.001$). The interaction was due to the fact that participants distinguished the items involving principled and statistical items to a greater extent in the artifact ($M=6.4$ vs 2.92) and social ($M=5.82$ vs 2.09) conditions than the natural condition ($M=5.37$ vs 3.56). Importantly, the difference was significant in all three domains: artifact kinds ($F_1(1,17)=125.55$, $P<.001$; $F_2(1,28)=201.09$, $P<.001$), natural kinds ($F_1(1,17)=61.38$, $P<.001$; $F_2(1,28)=58.83$, $P<.001$), social kinds

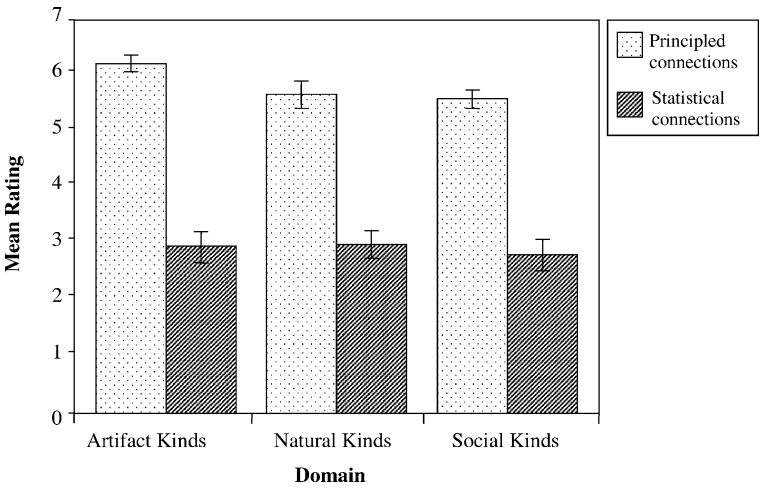


Fig. 7. Mean ratings for Experiment 3A.

($F_1(1,17)=214.56$, $P<.001$; $F_2(1,28)=334.13$, $P<.001$). Thus though participants generally had normative expectations concerning the presence of k-properties, but not t-properties, the extent to which they did so varied across domains. Unlike the small domain differences found in the previous experiments, which were most likely due to idiosyncratic differences in the items, the present experiment displayed a more prominent domain difference. In particular, the difference between the ratings for principled and statistical items for natural kind items was roughly half the size of the difference for the artifact and social domains. Closer inspection of the items used in the natural kind condition suggests that there were systematic reasons behind this domain difference that are independent of the distinction between principled and statistical connections. We defer discussion of these reasons to the discussion section.

*10.2.3. Prevalence and normative expectations concerning k- and t-properties*

Matching items on average estimated prevalence yielded 10 principled and 10 statistical items with means of 84.64 and 83.77%, respectively. An ANOVA with connection type as the factor and participants' ratings as the dependent variable found that, just as was the case with the full dataset, there was a significant effect of connection type ($F_1(1,17)=38.4$, $P<.001$; $F_2(1,18)=34.19$, $P<.001$) with principled items receiving significantly higher ratings ($M=5.29$) than the statistical items ($M=3.46$) (see Fig. 8a). Once again, the results of the ANCOVAs on the full data set also supported this conclusion by yielding an essentially identical pattern of results as those of the ANOVAs with the full data set.

*10.3. Discussion*

The data confirm the main prediction—that we form normative expectations concerning the presence of k-properties, but not t-properties. There was, however, an

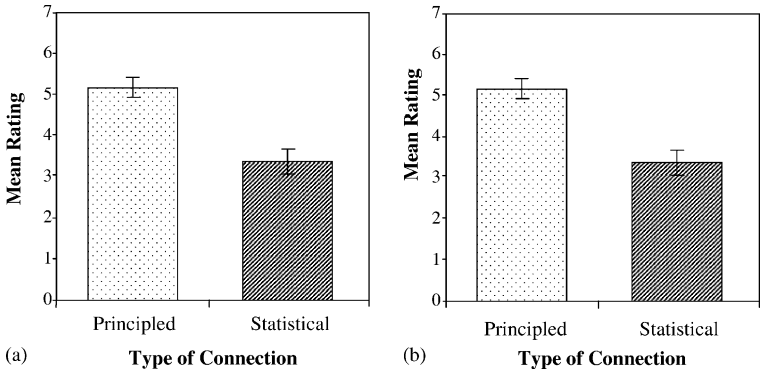


Fig. 8. (a) Mean ratings for prevalence-matched items for native English speakers (Experiment 3A); and (b) mean ratings for prevalence-matched items for non-native English speakers (Experiment 3B).

unexpected domain effect. As we will see, it is best not to interpret this effect as compromising the domain-generality of principled connections and their licensing of normative expectations. There are independent reasons why normative expectations concerning natural kinds should differ from those in other domains.

It is likely that some of the natural kind principled items yielded lower ratings than items in other domains for three reasons. First, a number of the items in the natural kind principled condition had k-properties that are not present at all times during development, but instead characterize tokens of the type in their mature or fully developed state (e.g. cherries/red, bananas/yellow, strawberries/red). As such, at different points in development, the kind of thing something is determines different properties on a given dimension. An unripe strawberry *should* be green, not red, and there is nothing wrong with it not being red. These cases contrast with cases like the greenness of grass or spinach, which should be green throughout development. Given this difference, it is not surprising that both the grass and spinach items were rated highly. Though the notion of development applies to some items within the natural kind principled condition, it does not apply to artifact or social kinds and thus provides a reason why the natural kind principled condition may have received slightly lower ratings than the other principled conditions. A second reason why this may have happened is that the natural kind principled condition contained two k-properties that we conceive of as being intrinsically negative (though they may not be negative properties for tokens of the given type to have). One item concerned the fragility of eggshells and the other concerned the slow speed at which turtles walk. It is not surprising that it should be a little odd to say that something should have an intrinsically negative property.[6] Finally, there was one example of a third type of item that, for

[6] It is unclear the extent to which our conception of these properties is negative independently of the specific terms used to refer to them. Thus, does the fact that it is natural to describe slowness as the absence of speed, rather than fastness as the absence of slowness indicative of our conception of rate of change of position (velocity), or does it reflect markedness phenomena that are linguistic in nature? In the case of fragility, it seems that both *fragile* and *delicate* can be used to describe things that are easily damaged or broken, but they differ in whether this property is understood to be a negative property or not.

systematic reasons, may have contributed to the slightly lower ratings for the natural kind principled condition. This item concerned the relation between being a bird and having the ability to fly. This is a case in which there are known subkinds for which flying is not a k-property (e.g. penguins, ostriches). Individual penguins and ostriches are not understood to have anything wrong with them because they are unable to fly, as would be the case for instances of other kinds of birds. Given that participants were likely aware of these systematic exceptions, it is not surprising that they hesitated a little in endorsing the notion that birds should be able to fly.

Turning to the question of why items with statistical connections received higher ratings in the natural kind condition than the other conditions, we find that one of the highest rated items was one in which presence of the t-property would be beneficial to tokens of the relevant type (wearing collars for dogs). As such, there would be reason to say that tokens of the relevant types should have the property in question. The notion of being beneficial to a token of a type *qua* that type applies to tokens of some natural kinds, but not artifactual or social kinds, and thus provides a reason for domain differences. The few other items that received slightly higher ratings were ones in which it is plausible that at least some people represented principled rather than statistical connections and thus are best seen as a source of noise.

It is important to note, however, that despite these reasons for either wanting to endorse the notion that tokens of a type should have t-properties or being hesitant about endorsing the notion that tokens of the type should have a k-property, normative statements involving k-properties were given significantly higher ratings than those involving t-properties in each of the three domains. Thus, it seems that the existence of a principled connection, but not merely a strong statistical connection, licenses normative expectations across content domains.

## 11. Experiment 3B

Given that normative expectations concerning which properties tokens of a given type should have do not depend on linguistic knowledge, and our claim that the task used in Experiment 3A elicits judgments concerning normative expectations, rather than linguistic judgements, we predicted that non-native speakers of English should show the same pattern of results. Experiment 3B tests this prediction.

### *11.1. Method*

#### *11.1.1. Participants*

Eighteen non-native speakers of English from an introductory psychology course at Hunter College participated for completion of course credit.

#### *11.1.2. Stimuli*

Same as Experiment 3A.

*11.1.3. Procedure*

Same as Experiment 3A.

*11.2. Results*

The mean ratings are shown in Fig. 9. ANOVAs with connection type and domain as factors and participants' ratings as the dependent variable were conducted. As predicted, there was a large and significant effect of connection type ($F_1(1,17)=218.78$, $P<.001$; $F_2(1,84)=510.56$, $P<.001$) with normative statements concerning the presence of k-properties being judged to be true ($M=5.83$) and those concerning t-properties not to be true ($M=2.94$). The ANOVA also yielded a significant effect of domain ($F_1(2,34)=3.99$, $P<.028$; $F_2(2,84)=3.24$, $P<.044$) and a marginally significant interaction ($F_1(2,34)=2.48$, $P<.1$; $F_2(2,84)=2.07$, $P<.13$). As with the native speakers, the difference between the ratings of the principled and statistical items was smallest for the natural kind items, however, as the marginally significant interaction indicates, this difference was not as pronounced for the non-native speakers. Closer inspection of the data suggests that one reason for this small difference may be that the non-native speakers did not appreciate some of the subtle markedness and interpretive aspects of terms like *fragile* and *slow* discussed above. An ANOVA with experiment and connection type found a significant effect of connection type ($F_1(1,34)=428.1$, $P<.001$; $F_2(1,88)=459.49$, $P<.001$), but there was no hint of an effect of experiment or an interaction between experiment and connection type. Thus, native and non-native speakers distinguished their normative expectations concerning k-properties and t-properties in the same way.

Turning to the prevalence-matched data (7 principled and 7 statistical with means of 73.32 and 74.98%), we also find a significant effect of connection type ($F_1(1,17)=51.29$, $P<.001$; $F_2(1,12)=24.49$, $P<.001$) (see Fig. 8b). Furthermore, as was the case with

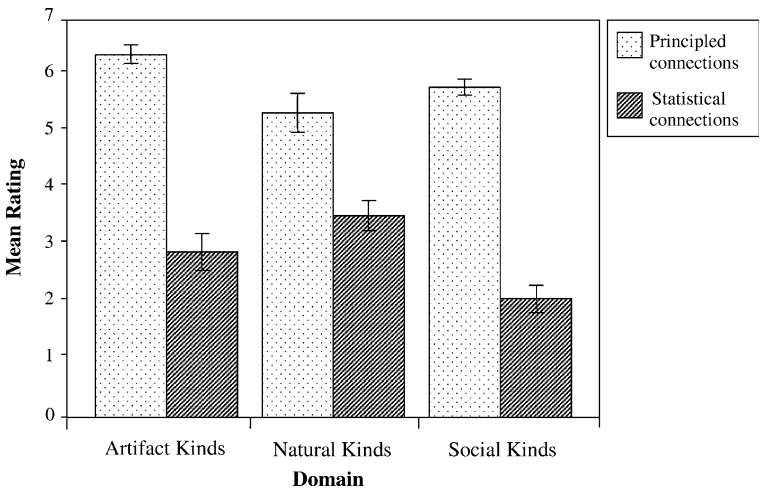


Fig. 9. Mean ratings for Experiment 3B.

the full body of data, an ANOVA with experiment and connection type found a significant effect of connection type ($F_1(1,34)=72.21$, $P<.001$; $F_2(1,14)=34.78$, $P<.001$), but there was no hint of an effect of experiment or an interaction between experiment and connection type.

Finally, the results of the ANCOVAs with the full data set yielded an essentially identical pattern of results as those of the ANOVAs with the full data set providing further evidence that the observed differences cannot be attributed to differences in prevalence. In sum, the data from the non-native speakers essentially replicated the native speakers' data in showing that principled connections license normative expectations, but strong statistical connections do not. Furthermore, principled connections license normative expectations across content domains.

## 12. General discussion

The experiments provide evidence that our conceptual systems represent a principled connection between the type of thing something is and some of its properties (k-properties), but not other properties (t-properties). Principled connections were shown to have linguistic as well as non-linguistic reflections. Experiments 1A and 1B showed that native English speakers, but not non-native English speakers, think that bare plural generics can be paraphrased as expressing the thought that tokens of the type referred to by the subject possess the property denoted by the predicate because they are tokens of that type if the property is a k-property, but not if it is a t-property. Experiments 2A and 2B revealed that it is possible to explain the existence of a k-property, but not a t-property, in a token of a type by referring to the type of thing something is. Finally, Experiments 3A and 3B showed that we form normative expectations concerning the presence of k-properties, but not t-properties.

Together, these experiments demonstrate that we represent principled connections between specific kinds of things and some of their properties and that these connections are fundamentally different from statistical connections. Furthermore, as discussed earlier, principled connections also differ from logically necessary connections. In the rest of the general discussion, we discuss (i) the distinction between k- and t-properties and its relation to other distinctions between properties in the literature on conceptual representation; (ii) the relation of the formal mode of understanding to other modes of understanding; (iii) the scope of the formal mode of understanding; (iv) constraints on k-properties; and (v) conclusions and open questions concerning the acquisition and use of principled connections.

### *12.1. Distinguishing the distinction between k- and t-properties from other distinctions*

We investigated the possibility that the type of thing something is provides an explanation for why its tokens have certain properties (k-properties), but not other properties (t-properties). If the type explained all of a token's properties there would be no basis for distinguishing between different tokens of a type. As such, the distinction between k- and t-properties is theoretically motivated and intrinsic to the formal mode of

understanding. Furthermore, though the formal mode of understanding makes a distinction between k- and t-properties, it does *not* assume that conceptual (type) representations can be reduced to combinations of feature/property representations. In fact, the type must be explicitly represented as having principled connections to k-properties, but statistical connections to t-properties. This contrasts sharply with the feature-based approach to conceptual representation, which assumes that representations of concepts (types) are *reducible* to the representation of combinations of features. The feature-based tradition contains a number of distinctions between different types of properties that may superficially seem to be similar to the distinction between k- and t-properties and so we seek to briefly clarify these differences.

At first glance, one might be tempted to assimilate the distinction between k- and t-properties to the analytic/synthetic distinction (e.g. Katz, 1972). This would be a mistake, however, because k-properties are not logically necessary properties of a type (e.g. having four legs is not a logically necessary property of dogs), consequently they could not be analytic properties. For the same reason, the distinction should not be confused with the distinction between definitional and characteristic properties (e.g. Smith & Medin, 1981). A slightly different distinction is made by some researchers between properties that are part of a concept's core and those that are part of its prototype or identification procedure (Landau, 1982; Miller, 1977; Smith & Medin, 1981; Smith, Medin, & Rips, 1984). The latter properties are meant to be useful for "quick and dirty" categorization and thus are perceptually salient and easy to compute, though usually not very diagnostic. Core properties, on the other hand, tend to be described as being relatively hidden, less accessible, and used for reasoning and as "ultimate arbiters of categorization". A brief glance at our stimuli will confirm that most of our k-properties, as well as our t-properties, are perceptually salient and easily accessible. Furthermore, many of the k-properties are not terribly diagnostic (e.g. four-leggedness for dogs, yellowness for bananas), and are unlikely to be used as "ultimate arbiters of categorization". In fact, some of the k-properties used in these experiments (e.g. ability to fly for birds) are sometimes given as examples of prototypical properties (e.g. Smith, 1989). Despite their similarity to prototypical properties, as the experiments reported in this paper demonstrate, k-properties differ from merely typical properties in a number of ways. It is also worth noting that though k-properties are usually typical properties in that they are generally true of tokens of the relevant type, they need not be. For example, the natural life-span of a chicken is a k-property of chickens even though the vast majority of chickens are raised on poultry farms and killed before they reach this age.

K-properties should also be distinguished from causally central properties (Medin & Shoben, 1988; Sloman, Love, & Ahn, 1998). Though many k-properties are likely to be causally central, this need not be the case. So, for example, the yellowness of a canary is a k-property even though it is not a causally central property of canaries. Similarly, it does not seem like the relevant differences between k-properties and t-properties can be attributed to differences in "mutability" (Medin & Shoben, 1988; Sloman et al., 1998). Properties are considered mutable to the extent that they can be easily changed without affecting other properties of a thing or the identity of the thing. It seems, however, that some of the k-properties studied are quite mutable. It is easy to change the number of

legs of a dog, color of a banana, crunchiness of a carrot, and leave their identity and most of their properties intact. As such, being relatively immutable cannot be a necessary condition for being a k-property. Furthermore, Medin and Shoben (1988) and Sloman et al. (1998) give the roundness of an orange and a cantaloupe as an example of a mutable property of oranges and cantaloupes, though these are clearly k-properties by the tests used in the experiments reported.

Finally, it should be noted that the distinction between k- and t-properties is reflected in a range of linguistic and non-linguistic phenomena in addition to the ones investigated in the present paper. These include: (i) k-properties, but not t-properties can appear in indefinite singular sentences (5) when they are interpreted generically; (ii) it is often possible for k-properties, but not t-properties, to appear in definite singular sentences (6) that are interpreted generically; (iii) we consider having a k-property, but not a t-property, to be one aspect of being a given kind of thing (7); (iv) answers to the question *what's an x*? that mention a k-property sound appropriate, whereas those that mention a t-property do not (8).

(5) A dog is four-legged./#A barn is red.
(6) The dog is four-legged./#The barn is red.
(7) Having four legs is one aspect of being a dog./#Being red is one aspect of being a barn.
(8) What's a dog/barn? A dog is a four-legged animal./#A barn is a red building.

None of these differences are likely to be explainable in terms of other distinctions that have been discussed in the literature on conceptual representation.

In sum, we hope it is clear that the distinction between k- and t-properties differs in important ways from a number of distinctions that have been discussed in the literature. This should not be surprising given the radically different frameworks within which the distinctions are made. Feature-based theories replace the representation of a type by a combination of features, whereas the formal mode of understanding represents explicit connections between the representation of the type and properties of tokens of the type. In fact, the present proposal is even compatible with the hypothesis that conceptual (type) representations of basic concepts such as DOG are semantically atomic (Armstrong, Gleitman, & Gleitman, 1983; Fodor, 1998; Fodor, Garrett, Walker, & Parkes, 1980).

### *12.2. The formal mode of understanding and its relation to other modes of understanding*

The formal explanatory structure embodied in a concept's principled connections is distinct from, and complementary to, the forms of explanation investigated by most work within the theory-based approach to concepts. This is due to the two lines of work investigating distinct modes of understanding provided by common sense conception.

In the formal mode, the kind of thing something is is the *source* of understanding and explanation, not its object. Furthermore, this mode of understanding is non-mechanistic. Things are understood to have the k-properties they do because they are the kinds of things they are, not because of some underlying or mediating mechanism(s). Though this

mode of explanation may not be acceptable from a scientific point of view, intuition and the present experiments demonstrate that it does play a role in our common sense conceptions of things.

In other modes of understanding, the answer to why, for example, dogs have four legs, cannot be the fact that they are dogs. Instead, we must search for a different sort of answer. One sort of answer makes reference to the thing's fundamental constituents and the causal mechanisms that give rise to its properties. This is the type of answer we seek when we adopt the physical stance, which is what we do when we do science (Dennett, 1987). Given our general ignorance of underlying constituents and specific types of causal mechanisms (Murphy, 2000, 2002; Rozenblit & Keil, 2002; Wilson & Keil, 2000), this mode of understanding is usually manifested as psychological essentialism. That is, the belief that there are hidden, unknown, and possibly unobservable essences that are the cause of a given type of thing's observable properties (Gelman, 2003; Medin & Ortony, 1989). Another mode of understanding seeks to understand why dogs have four legs by identifying the sake-for-which dogs have four legs (e.g. for the sake of walking). This is the type of answer we seek when we adopt the design or teleological stance (Dennett, 1987). Finally, we can also adopt an intentional stance and explain behavior by reference to intentional mental states (e.g. Car alarms go off when you bump into a car because they think you are trying to steal the car) (Dennett, 1987).

While the development and use of these modes of understanding has been the subject of much research (e.g. Carey, 1985; Gelman, 1990; German & Johnson, 2002; Gelman & Wellman, 1991; Gergely, Nadasdy, Csibra, & Biro, 1995; Gopnik & Meltzoff, 1997; Inagaki & Hatano, 2002; Johnson & Solomon, 1997; Kelemen, 1999; Keil, 1989, 1994; Leslie, 1994; Matan & Carey, 2001; Opfer & Gelman, 2001; Springer & Keil, 1991, among many others), the formal mode of understanding has not been previously identified or studied. It will be important for future research to investigate how the formal mode of understanding interacts with these other modes of understanding in the course of development and the performance of various cognitive tasks. Another important question concerns the relation of these modes of understanding to the Aristotelian *aitia*, or modes of explanation, which seem to have an important role in how we conceive and talk about things (Chomsky, 1975; Moravcsik, 1975, 1981; Prasada, 1999, 2000, 2003, 2005; Prasada, Ferenz, & Haskell, 2002; Pustejovsky, 1995). We suspect the various stances will best be understood as arising from particular configurations and constraints on these basic modes of understanding.

### *12.3. Scope of the formal mode of understanding and explanation*

In this section we consider two questions concerning the scope of the formal mode of understanding. First, does this form of understanding apply to type-token representations from all content domains? Second, do all type-token representations allow us to represent principled connections between types and k-properties? We answer yes and no, respectively. The experiments in this paper demonstrate that we represent principled connections across a wide range of content domains. Furthermore, the following examples suggest that there are no constraints on the content domains within which we may represent principled connections.

Unicorns, by virtue of being unicorns, have horns (imaginary material beings).
Ghosts, by virtue of being ghosts, can pass through material barriers (imaginary immaterial beings).
Triangles, by virtue of being triangles, have three sides (real immaterial beings).
Funerals, by virtue of being funerals, are sad (events).
Governments, by virtue of being governments, make laws (institutions).
Libraries, by virtue of being libraries, have books in them (places).

This is expected given that principled connections abstract from domain-specific causal mechanisms. In this respect, principled connections are crucially different from Strevens (2000) *K-laws* which represent causal laws that connect kinds and observable properties (e.g. "it's a causal law that tigers have stripes" (p. 154)). It is for this reason that Strevens (2000, 2001) limits the applicability of K-laws to natural kinds. Principled connections, on the other hand, are represented across content domains.

It does not follow, however, that we represent principled connections between all types and properties of tokens of those types. To see that this is the case, consider a complex type such as WHITE BEAR. Though we can represent strong statistical connections between such types and certain t-properties (9a,b), it does not seem like they have any k-properties. Thus, there do not seem to be any properties that we understand to be true of tokens of the types *because* they are tokens of the type (9c), or properties we think they *should* have in virtue of being white bears (9d). This is the case even though the type WHITE BEAR seems to identify a unique natural kind (polar bears). Thus, while we represent a principled connection between POLAR BEAR and living in a cold climate (10a–d), we do not represent a principled connection between WHITE BEAR and living in a cold climate (9c,d). This remains true even if we have a "theory" for why white bears may live in cold climates (e.g. cold climates have snow which is white, and thus being white provides a good form of camouflage). Furthermore, there is a strong statistical connection between WHITE BEAR and every property that is a k-property of POLAR BEAR. As such, the correlational structure of the category of white bears is nearly identical to that of the category of polar bears. Consequently, insofar as inductive inferences are constrained by correlational structure, the concept WHITE BEAR and POLAR BEAR should have the same inductive depth. Despite these similarities, the two concepts differ with respect to their ability to represent principled connections. Thus, with respect to the question as to whether all type-token representations represent principled connections between types and k-properties, the answer seems to be "no".

(9a) White bears live in cold climates.
(9b) White bears, in general, live in cold climates.
(9c) #White bears, by virtue of being white bears, live in cold climates.
(9d) #White bears, by virtue of being white bears, should live in cold climates.
(10a) Polar bears live in cold climates.
(10b) Polar bears, in general, live in cold climates.
(10c) Polar bears, by virtue of being polar bears, live in cold climates.
(10d) Polar bears, by virtue of being polar bears, should live in cold climates.

We suggest that type-token representations that allow us to represent k-properties (e.g. POLAR BEAR) provide the means to think about what we take to be *kinds* of things. That is, at least part of thinking of something as an instance of a kind, is to think of it as having some of its properties because it is the kind of thing it is. Consequently, we expect instances of kinds to generally share a number of properties other than their kind identity, namely, their k-properties. On the other hand, type-token representations that do not allow us to represent k-properties (e.g. WHITE BEAR), provide the means for thinking about *mere types* or *classes* by allowing us to think of indefinitely many entities as fitting the description specified by the type. This kind of representation does not afford the expectation that tokens of the type will generally share properties other than their type identity. Linguistically, kind concepts are expressed through the use of non-phrasal nominals (i.e. monomorphemic nouns (e.g. *dog*), noun–noun compounds (e.g. *picnic table*), and adjective–noun compounds (e.g. *polar bear*, *blackbird*)). Phrasal nominals (e.g. *white bear*, *white things*, *animals that we try not to think about*…) express mere types.[7]

### *12.4. Constraints on k-properties*

The present research raises important questions concerning how we come to know that a given property is a k-property of a given kind. The experiments demonstrate that being a highly prevalent property cannot be sufficient for regarding a property as a k-property. There must exist other means for determining which properties of a given kind of thing should be understood to be k-properties. Though we did not perform a formal analysis, informal inspection of the items used in the experiments suggests differences in the types of k-properties found in different domains. Furthermore, the number of k-properties also seemed to vary across domains. It was relatively easier finding items involving principled connections than statistical connections for natural kinds, whereas the opposite held true for social kinds. It was also easier to find principled connections for natural kinds than artifact kinds. These observations are consistent with previous work on the inductive depth of categories in different domains (e.g. Gelman, 1988; Markman, 1989). They also suggest domain-specific constraints on which properties are likely to be k-properties. Overhypotheses such as *Each kind of animal has the means for self locomotion* (Goodman, 1955, 1983; Shipley, 1993) could provide a mechanism through which the search for k-properties is constrained and principled connections established between specific kinds and k-properties within a domain. Of course, unless these overhypotheses are innate, it is unclear how such overhypotheses are established.

It remains for future research to determine the nature of the domain-specific constraints that guide the establishment of principled connections. Here, we discuss a domain general constraint on k-properties. This constraint may be illustrated by

[7] Note the directionality of the mappings. Thus, there seem to be derived non-phrasal nominals such as *dancer*, which can either express either a kind or a class. The structure of the mappings between different kinds of type-token representations and language clearly requires further investigation.

considering whether 3D extension is a k-property of DOG. The relative goodness of sentences such as (11) may suggest that it is a k-property of DOG, however, closer inspection reveals this not to be the case. Thus, it is odd to explain the 3D extension of a dog by citing the fact that it is a dog (12,12a). On the other hand, an explanation that cites the fact that it is a material being (12b) sounds perfectly natural. Further evidence comes from the oddness of (13a) relative to (13b).

(11) Dogs, by virtue of being the kinds of things they are, are extended in three dimensions.
(12) Why is that (pointing to a dog) extended in three dimensions?
(12a) #Because it is a dog.
(12b) Because it is a material being.
(13a) #Dogs, by virtue of being dogs, are extended in three dimensions.
(13b) Dogs, by virtue of being material beings, are extended in three dimensions.

Considerations of this sort suggest that 3D extension is a k-property of MATERIAL BEING, not DOG. Similarly, four-leggedness is a k-property of DOG, not DACHSHUND. More generally, k-properties are represented as having an immediate or direct connection to the kind of which they are k-properties. That is, if a property $p$ is represented as a k-property of a given kind $K$, then there can be no superordinate kind $K'$ of the kind $K$, for which $p$ is also a k-property.[8] Sentences such as (11) can sound okay because they contain the non-specific noun *thing*, which can substitute for the appropriate term in the kind hierarchy.

Other constraints on k-properties will come from more general constraints on the projection of properties. Thus, certain properties such as "weighs more than 100 pounds" are unlikely to be projected as either k- or t-properties. What makes these properties unlikely to be projected is a difficult question, however, we assume that many of the factors discussed by Goodman (1955, 1983) could serve to limit the kinds of properties that are projected as either k- or t-properties

It is important to note, however, that the validity of our proposal does not require that we be able to specify in advance what are possible k- or t-properties. The experiments establish that we make a distinction between k- and t-properties and demonstrate a number of linguistic and non-linguistic phenomena that depend on the distinction. These findings suggest that our conceptual systems come prepared to represent things as tokens of types and represent principled and statistical connections between the type of thing something is and properties of tokens of the type. This does not require that we know all the k- or t-properties of any given type.

[8] It is important to keep in mind that this constraint applies within the formal mode of explanation, whereby we are seeking to explain k-properties of things in terms of the kinds of things they are. In other modes of understanding, the connection will not be immediate. For example, within a teleological mode of explanation, the connection between DOG and four-leggedness would be mediated by the sake-for-which dogs have four legs (e.g. walking/running).

### *12.5. Conclusions and open questions*

Common sense concepts provide us with the means to understand and talk about things in the world from rich and intricate perspectives (Chomsky, 1996). The experiments reported in this paper reveal one small aspect of how they do so. Specifically, they suggest that when we think of something as an instance of a given kind, we think that some of its properties (k-properties) are determined by the kind of thing it is. The experiments reveal that we expect these properties to be generally true of instances of that kind; that we think instances of the kind should have these properties; and that we can explain the presence of these properties in an instance of the kind by making reference to the kind of thing it is. As such, the experiments provide evidence that we represent principled connections between the kind of thing something is and some of its properties.

Previous research in psychology and philosophy has accorded a great deal of importance to whether a given property is a necessary or contingent property of a given type of thing. The results of the present experiments suggest that the distinction between principled and merely factual, even if statistically strong, connections is important to a number of linguistic and non-linguistic phenomena. Current work in our lab suggests that principled connections are also relevant to a number of other linguistic and non-linguistic phenomena including those described above (5–8). We would like to suggest that principled connections are one of the fundamental types of relations (in addition to logical, statistical, and causal relations) in terms of which our conceptual knowledge is structured. It remains for future research to determine other linguistic and non-linguistic phenomena that depend on the representation of principled connections.

The findings also raise a host of questions concerning the conditions under which children and adults form principled connections, as well as the mechanisms by which they establish this type of connection, the ways in which the mode of understanding embodied in principled connections is related to other modes of understanding, and the ways in which principled connections may enter into online processing. We have begun to address some of these questions, and hope that others will join in the effort to understand this aspect of common sense conception.

## Acknowledgements

This work was supported by PSC-CUNY 34, GRTI, and startup grants to the first author. We received infrastructure support from RCMI grant RR03037 from the National Center for Research Resources (NIH) to the Gene Center at Hunter College. We thank three anonymous reviewers for their comments and criticisms. One of the reviewers provided especially detailed and constructive criticism, for which we are particularly grateful.

## Appendix

Stimuli and results for experiments with native English speakers. Column 1 contains the stimulus items used in Experiment 1A. These items were used as a base to generate the items used in the rest of the experiments. Columns 2 and 3 contain the mean ratings given to the "in general" and "by virtue of" paraphrases of bare plural generics in Experiment 1A. Columns 4–6 present the mean ratings for the three types of explanations rated by participants in Experiment 2A. Column 7 presents the mean ratings for statements expressing normative expectations in Experiment 3A. Column 8 presents the mean prevalence of k- and t-properties estimated by participants in Experiments 1A, 2A, and 3A.

| | Experiment 1A | | Experiment 2A | | | Experiment 3A | Prevalence estimates |
|---|---|---|---|---|---|---|---|
| | "in general" | "by virtue of" | Causal-essence | Statistical | Formal | "should" | |
| *Principled connections* | | | | | | | |
| *Artifact kinds* | | | | | | | |
| Airplanes have wings | 3.83 | 6.78 | 2.50 | 4.56 | 4.50 | 6.82 | 96.13 |
| Ambulances have sirens | 5.50 | 5.72 | 2.39 | 5.33 | 5.22 | 6.44 | 97.96 |
| Cars have four wheels | 4.17 | 5.83 | 2.50 | 5.56 | 5.39 | 5.61 | 98.45 |
| Diapers are absorbent | 5.06 | 5.44 | 3.11 | 4.94 | 5.72 | 6.67 | 95.86 |
| Fire trucks have hoses | 4.61 | 5.61 | 2.72 | 5.17 | 5.61 | 6.61 | 97.84 |
| Needles are sharp | 5.22 | 6.17 | 2.83 | 5.00 | 5.33 | 6.61 | 96.47 |
| Raincoats are waterproof | 6.00 | 5.56 | 2.72 | 5.72 | 5.39 | 6.78 | 96.38 |
| Roller skates have wheels | 3.61 | 5.56 | 2.78 | 4.94 | 5.00 | 6.83 | 94.61 |
| Sandpaper is rough | 5.33 | 5.89 | 2.89 | 5.28 | 4.50 | 5.89 | 95.75 |
| Scissors cut | 4.56 | 5.22 | 2.78 | 5.33 | 4.61 | 6.56 | 93.25 |
| Spandex is stretchy | 4.94 | 5.78 | 3.00 | 4.83 | 4.78 | 6.67 | 94.10 |
| Submarines are airtight | 4.72 | 6.50 | 2.33 | 4.94 | 4.72 | 6.06 | 95.34 |
| Tables are flat | 5.44 | 6.11 | 2.67 | 5.50 | 5.39 | 5.72 | 94.85 |
| Trains travel on tracks | 4.39 | 6.00 | 2.11 | 4.89 | 5.11 | 6.17 | 98.53 |
| Trampolines are bouncy | 4.89 | 5.94 | 2.78 | 5.28 | 5.00 | 6.67 | 96.22 |
| *Natural kinds* | | | | | | | |
| Bananas are yellow | 5.11 | 4.39 | 2.94 | 4.94 | 5.28 | 5.28 | 87.94 |
| Birds can fly | 5.22 | 5.33 | 3.33 | 5.00 | 5.61 | 5.00 | 89.80 |
| Carrots are crunchy | 5.33 | 5.00 | 3.06 | 4.67 | 5.39 | 4.89 | 87.90 |
| Cheetahs run fast | 5.83 | 6.44 | 2.94 | 4.83 | 5.56 | 5.61 | 95.17 |
| Cherries are red | 5.67 | 3.67 | 3.22 | 4.89 | 5.50 | 4.83 | 91.19 |

(*continued on next page*)

| | Experiment 1A | | Experiment 2A | | | Experiment 3A | Prevalence estimates |
|---|---|---|---|---|---|---|---|
| | "in general" | "by virtue of" | Causal-essence | Statistical | Formal | "should" | |
| Dogs are four-legged | 4.78 | 5.67 | 2.83 | 4.89 | 5.06 | 6.17 | 97.59 |
| Eggshells are fragile | 5.22 | 6.33 | 2.17 | 4.67 | 5.00 | 4.83 | 94.79 |
| Grass is green | 5.06 | 5.06 | 3.00 | 4.33 | 5.11 | 5.72 | 94.47 |
| Lemons are sour | 5.89 | 6.00 | 3.28 | 5.11 | 4.89 | 6.00 | 95.48 |
| Milk is white | 5.06 | 4.83 | 3.00 | 5.17 | 4.17 | 5.39 | 92.12 |
| Rocks are hard | 4.39 | 5.72 | 3.67 | 5.56 | 5.00 | 5.61 | 95.69 |
| Snow is white | 5.28 | 5.28 | 2.94 | 5.22 | 4.78 | 5.50 | 95.81 |
| Spinach is green | 5.56 | 4.61 | 2.50 | 4.61 | 4.44 | 6.00 | 95.13 |
| Strawberries are red | 5.44 | 4.50 | 3.06 | 5.44 | 4.50 | 5.28 | 91.18 |
| Turtles walk slowly | 5.11 | 4.83 | 2.89 | 4.67 | 4.94 | 4.44 | 93.55 |
| *Social kinds* | | | | | | | |
| Architects design buildings | 5.33 | 5.28 | 3.33 | 5.33 | 5.44 | 6.28 | 93.90 |
| Artists are creative | 5.50 | 5.56 | 3.61 | 4.72 | 5.28 | 6.00 | 89.08 |
| Cheerleaders are spirited | 5.39 | 4.89 | 3.89 | 4.89 | 5.33 | 5.56 | 85.58 |
| Christians read the bible | 5.06 | 5.28 | 3.56 | 5.06 | 5.28 | 5.22 | 76.11 |
| Dancers move gracefully | 5.00 | 4.44 | 3.56 | 5.22 | 5.28 | 5.94 | 84.26 |
| Doctors diagnose ailments | 4.89 | 5.44 | 2.72 | 5.61 | 5.61 | 5.50 | 92.15 |
| Gymnasts are flexible | 5.83 | 5.50 | 4.22 | 4.50 | 3.72 | 6.72 | 94.93 |
| Hindus don't eat beef | 5.33 | 4.61 | 3.28 | 5.28 | 4.94 | 5.67 | 84.54 |
| Jews don't eat pork | 5.44 | 4.28 | 2.78 | 4.94 | 4.78 | 4.61 | 81.02 |
| Journalists report news | 5.33 | 5.33 | 2.83 | 5.50 | 5.61 | 4.83 | 88.51 |
| Lifeguards can swim | 4.28 | 6.33 | 2.89 | 5.56 | 5.06 | 6.83 | 95.87 |
| Mormons don't drink alcohol | 5.39 | 5.22 | 3.33 | 5.56 | 4.72 | 5.39 | 70.28 |
| Police officers wear badges | 5.61 | 5.44 | 2.28 | 5.56 | 5.22 | 5.89 | 93.47 |
| Teachers impart knowledge | 5.39 | 5.56 | 3.22 | 4.89 | 4.83 | 6.39 | 87.99 |
| Tightrope walkers have good balance | 6.22 | 5.94 | 3.50 | 4.94 | 4.89 | 6.50 | 94.26 |
| *Statistical connections* | | | | | | | |
| *Artifact kinds* | | | | | | | |
| Barns are red | 5.22 | 2.83 | 2.56 | 3.56 | 4.39 | 2.33 | 72.58 |
| Bricks are red | 5.50 | 3.28 | 2.78 | 4.17 | 5.00 | 3.11 | 71.30 |
| Bulldozers are yellow | 5.78 | 2.17 | 1.67 | 3.22 | 3.56 | 2.89 | 69.98 |
| Cars have radios | 5.67 | 3.17 | 1.56 | 2.22 | 3.50 | 3.89 | 85.74 |
| Clocks have alarms | 5.56 | 3.50 | 2.11 | 3.61 | 4.17 | 3.89 | 74.29 |
| Diapers are white | 5.11 | 2.50 | 2.00 | 4.06 | 5.39 | 2.89 | 78.64 |

(*continued on next page*)

| | Experiment 1A | | Experiment 2A | | | Experiment 3A | Prevalence estimates |
|---|---|---|---|---|---|---|---|
| | "in general" | "by virtue of" | Causal-essence | Statistical | Formal | "should" | |
| Fire trucks are red | 6.06 | 3.83 | 2.17 | 4.50 | 5.50 | 4.44 | 88.91 |
| Glue is white | 5.44 | 3.22 | 1.83 | 3.61 | 4.56 | 2.17 | 77.06 |
| Hair nets are black | 5.83 | 2.83 | 1.78 | 2.89 | 4.39 | 1.61 | 64.03 |
| Rocking chairs are wooden | 5.61 | 2.78 | 2.06 | 3.22 | 4.28 | 3.50 | 75.88 |
| Shower caps are transparent | 4.72 | 2.28 | 1.50 | 3.00 | 4.22 | 3.06 | 63.57 |
| Tables are made of wood | 5.39 | 3.11 | 2.00 | 3.17 | 5.06 | 2.61 | 65.49 |
| Taxis are yellow | 5.06 | 3.17 | 1.50 | 3.67 | 5.11 | 3.72 | 80.01 |
| Trampolines are black | 4.94 | 1.94 | 1.89 | 3.22 | 3.94 | 2.11 | 64.29 |
| Wallets are made of leather | 5.67 | 2.11 | 1.72 | 3.06 | 4.89 | 1.61 | 63.53 |
| *Natural kinds* | | | | | | | |
| Bears perform at circuses | 3.56 | 1.78 | 2.83 | 3.94 | 4.17 | 1.39 | 36.03 |
| Birds are kept in cages | 5.28 | 3.17 | 2.44 | 4.39 | 5.00 | 3.22 | 50.68 |
| Cats like milk | 6.00 | 4.06 | 1.56 | 2.11 | 2.17 | 4.13 | 83.54 |
| Dogs bark at strangers | 5.33 | 4.56 | 2.06 | 4.11 | 5.06 | 3.72 | 72.11 |
| Dogs wear collars | 5.61 | 2.39 | 2.11 | 4.00 | 5.11 | 4.94 | 70.44 |
| Eggshells are white | 5.67 | 3.11 | 2.89 | 4.56 | 5.28 | 4.11 | 84.24 |
| Oranges are grown in Florida | 5.28 | 3.83 | 2.33 | 4.39 | 5.22 | 3.06 | 66.20 |
| Pigeons sit on statues | 5.67 | 3.06 | 2.28 | 3.78 | 4.22 | 3.17 | 66.88 |
| Pigs are kept in pens | 6.11 | 4.11 | 2.22 | 3.89 | 4.67 | 3.72 | 74.23 |
| Raccoons eat garbage | 5.28 | 3.22 | 2.06 | 3.61 | 4.78 | 2.94 | 67.71 |
| Rocks are jagged | 5.78 | 4.50 | 1.94 | 4.50 | 5.06 | 3.44 | 74.83 |
| Squirrels are found in parks | 6.11 | 4.39 | 2.00 | 4.00 | 4.11 | 3.72 | 68.25 |
| Summers are humid | 6.11 | 4.28 | 2.17 | 3.33 | 4.17 | 3.94 | 77.89 |
| Winters are snowy | 6.00 | 4.50 | 2.28 | 4.72 | 4.56 | 4.50 | 72.39 |
| Worms are used as bait | 5.61 | 3.72 | 1.94 | 3.44 | 4.94 | 3.33 | 62.59 |
| *Social kinds* | | | | | | | |
| Artists are eccentric | 4.83 | 4.11 | 2.11 | 2.94 | 3.72 | 3.33 | 67.63 |
| Bikers have tattoos | 5.56 | 3.00 | 1.61 | 2.00 | 4.17 | 1.89 | 65.05 |
| Brazilians like soccer | 5.72 | 2.89 | 2.06 | 2.89 | 3.78 | 2.00 | 71.79 |
| Celebrities are arrogant | 5.17 | 3.50 | 1.67 | 1.94 | 3.00 | 1.67 | 54.57 |
| Englishmen drink tea | 5.61 | 3.39 | 2.22 | 2.39 | 3.39 | 2.28 | 67.15 |
| Frenchmen drink wine | 5.00 | 2.44 | 2.06 | 2.67 | 3.44 | 2.11 | 67.86 |

(*continued on next page*)

| | Experiment 1A | | Experiment 2A | | | Experiment 3A | Prevalence estimates |
|---|---|---|---|---|---|---|---|
| | "in general" | "by virtue of" | Causal-essence | Statistical | Formal | "should" | |
| Germans drink beer | 4.17 | 2.22 | 2.06 | 2.72 | 3.89 | 2.06 | 67.78 |
| Golfers wear plaid pants | 5.56 | 1.94 | 2.44 | 2.78 | 3.72 | 2.11 | 48.93 |
| Hindus live in India | 4.94 | 2.72 | 2.50 | 2.67 | 4.67 | 2.06 | 67.90 |
| Italians are catholic | 4.61 | 2.44 | 1.72 | 2.28 | 3.33 | 2.06 | 70.00 |
| Mexicans eat spicy food | 5.67 | 2.44 | 2.61 | 3.17 | 3.33 | 2.71 | 69.76 |
| Muslims are middle eastern | 4.94 | 2.67 | 1.94 | 3.28 | 4.50 | 1.94 | 66.57 |
| Police officers eat donuts | 5.39 | 1.83 | 2.50 | 3.78 | 3.50 | 1.78 | 63.19 |
| Professors are absent-minded | 4.17 | 2.11 | 2.11 | 3.28 | 3.61 | 1.67 | 40.47 |
| Texans are tall | 4.22 | 2.11 | 2.72 | 4.22 | 4.39 | 1.61 | 50.35 |

## References


Armstrong, S. L., Gleitman, L. R., & Gleitman, H. (1983). What some concepts might not be. *Cognition*, *13*, 263–308.

Burton-Roberts, N. (1977). Generic sentences and analyticity. *Studies in Language*, *1*, 155–196.

Carey, S. (1985). *Conceptual change in childhood*. Cambridge, MA: MIT Press.

Carlson, G. N. (1995). Truth conditions of generic sentences: Two contrasting views. In G. N. Carlson, & F. J. Pelletier (Eds.), *The generic book* (pp. 224–237). Chicago, IL: University of Chicago Press.

Charlton, W. (1970). *Aristotle's physics: Books 1 and II*. Oxford: Oxford University Press.

Chomsky, N. (1975). *Reflections on language*. New York: Random House.

Chomsky, N. (1996). *Powers and prospects: Reflections on human nature and the social order*. Boston: South End Press.

Cohen, A. (2001). On the generic use of indefinite singulars. *Journal of Semantics*, *18*, 183–209.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: A new graphic interactive environment for designing psychology experiments. *Behavioral Research Methods, Instruments, and Computers*, *25*, 257–271.

Dennett, D. C. (1987). *The intentional stance*. Cambridge, MA: MIT Press.

Fodor, J. A. (1998). *Concepts: Where cognitive science went wrong*. New York: Oxford University Press.

Fodor, J. A., Garrett, M. F., Walker, E. C. T., & Parkes, C. H. (1980). Against definitions. *Cognition*, *8*, 263–267.

Gelman, R. (1990). First principles organize attention to and learning about relevant data: number and the animate–inanimate distinction as examples. *Cognitive Science*, *14*, 79–106.

Gelman, S. (2003). *The essential child: Origins of essentialism in everyday thought*. London: Oxford University Press.

Gelman, S. A. (1988). The development of induction within natural kind and artifact categories. *Cognitive Psychology*, *20*, 65–95.

Gelman, S. A., & Wellman, H. M. (1991). Insides and essences: Early understanding of the non-obvious. *Cognition*, *38*, 213–244.

Gergely, G., Nadasdy, Z., Csibra, G., & Biro, S. (1995). Taking the intentional stance at 12 months of age. *Cognition*, *56*, 165–193.

German, T. P., & Johnson, S. (2002). Function and the origins of the design stance. *Journal of Cognition & Development*, *3*, 279–300.

Goodman, N. (1955). *Fact, fiction, and forecast* (1st ed.). Cambridge, MA: Harvard University Press.

Goodman, N. (1983). *Fact, fiction, and forecast* (4th ed.). Cambridge, MA: Harvard University Press.

Gopnik, A., & Meltzoff, A. N. (1997). *Words, thoughts, and theories*. Cambridge, MA: MIT Press.

Hocutt, M. (1974). Aristotle's four becauses. *Philosophy*, *49*, 385–399.

Inagaki, J., & Hatano, G. (2002). *Young children's naïve thinking about the biological world*. New York: Psychology Press.

Johnson, S. C., & Solomon, G. E. A. (1997). Why dogs have puppies and cats have kittens: The role of birth in young children's understanding of biological origins. *Child Development*, *68*, 404–419.

Katz, J. (1972). *Semantic theory*. New York: Harper row.

Keil, F. C. (1989). *Concepts, kinds, and conceptual development*. Cambridge, MA: MIT Press.

Keil, F.C. (1994). The birth and nurturance of concepts by domains: The origins of concepts of living things. In Mapping the Mind: Domain Specificity in Cognition and Culture, L.A. Hirschfield & S.A. Gelmann (Eds), Cambridge University Press.

Kelemen, D. (1999). The scope of teleological thinking in preschool children. *Cognition*, *70*, 241–272.

Landau, B. (1982). Will the real grandmother please stand up. *Journal of Psycholinguistic Research*, *11*, 47–62.

Leslie, A. M. (1994). ToMM, ToBY, and agency: Core architecture and domain specificity. In L. A. Hirschfeld, & S. A. Gelman (Eds.), *Mapping the mind: Domain specificity in cognition and culture*. New York: Cambridge University Press.

Markman, E. M. (1989). *Categorization and naming in children*. Cambridge, MA: MIT Press.

Matan, A., & Carey, S. (2001). Developmental changes within the core of artifact concepts. *Cognition*, *78*, 1–26.

Medin, D.L. (1989). Concepts and Conceptual structure. American Psychologist; 44, 1469–1481.

Medin, D., & Ortony, A. (1989). Psychological essentialism. In S. Vosniadou, & A. Ortony (Eds.), *Similarity and analogical reasoning*. Cambridge, MA: Cambridge University Press.

Medin, D. L., & Shoben, E. J. (1988). Context and structure in conceptual combination. *Cognitive Psychology*, *20*, 158–190.

Miller, G. A. (1977). Practical and lexical knowledge. In P. N. Johnson-Laird, & P. C. Wason (Eds.), *Thinking: Readings in cognitive science*. Cambridge, MA: Cambridge University Press.

Moravcsik, J. M. E. (1974). Aristotle on adequate explanations. *Synthese*, *28*, 3–17.

Moravcsik, J. M. E. (1975). *Aitia* as generative factor in Aristotle's philosophy. *Dialogue*, *14*, 622–638.

Moravcsik, J. M. E. (1981). How do words get their meanings. *Journal of Philosophy*, *78*, 5–24.

Moravcsik, J. M. E. (1991). What makes reality intelligible?. In L. Judsion (Ed.), *Aristotle's physics: A collection of essays*. Oxford: Oxford University Press.

Murphy, G. L. (2000). Explanatory concepts. In F. C. Keil, & R. A. Wilson (Eds.), *Explanation and cognition*. Cambridge, MA: MIT Press.

Murphy, G. L. (2002). *The big book of concepts*. Cambridge, MA: MIT Press.

Murphy, G. L., & Medin, D. L. (1985). The role of theories in conceptual coherence. *Psychological Review*, *92*, 289–316.

Opfer, J. E., & Gelman, S. A. (2001). Children's and adult's models for predicting teleological action: The development of a biology-based model. *Child Development*, *72*, 1367–1381.

Prasada, S. (1999). Names for things and stuff. In R. Jackendoff, P. Bloom, & K. Wynn (Eds.), *Language, logic, and concepts*. Cambridge, MA: MIT Press.

Prasada, S. (2000). Acquiring generic knowledge. *Trends in Cognitive Sciences*, *4*, 66–72.

Prasada, S. (2003). Conceptual representation of animacy and its perceptual and linguistic reflections. *Developmental Science*, *6*, 18–19.

Prasada, S. (2005). Being near the ceramic, but not the mug: On the role of construal in spatial language. In L. A. Carlson, & E. van der Zee (Eds.), *Functional features in language and space: Insights from perception, categorization and development*. Oxford: Oxford University Press.

Prasada, S., Ferenz, K., & Haskell, T. (2002). Conceiving of entities as objects and as stuff. *Cognition*, *83*, 141–165.

Pustejovsky, J. (1995). *The Generative Lexicon*. Cambridge, MA: MIT Press.

Rips, L. J., Shoben, E. J., & Smith, E. E. (1973). Semantic distance and the verification of semantic relations. *Journal of Verbal Learning and Verbal Behavior*, *12*, 1–20.

Rosch, E., & Mervis, C. B. (1975). Family resemblances: studies in the internal structure of categories. *Cognitive Psychology*, *7*, 573–605.

Rozenblit, L. R., & Keil, F. C. (2002). The missunderstood limits of folk science: An illusion of explanatory depth. *Cognitive Science*, *26*, 521–562.

Shipley, E. F. (1993). Categories, hierarchies, and induction. *Psychology of Learning and Motivation*, *30*, 265–301.

Sloman, S. A., Love, B. C., & Ahn, W. K. (1998). Feature centrality and conceptual coherence. *Cognitive Science*, *22*, 189–228.

Smith, E. E. (1989). Concepts and induction. In M. I. Posner (Ed.), *Foundations of cognitive science*. Cambridge, MA: MIT Press.

Smith, E., & Medin, D. (1981). *Concepts and categories*. Cambridge, MA: Harvard University Press.

Smith, E., Medin, D., & Rips, L. (1984). A psychological approach to concepts: Comments on Rey's 'concepts and stereotypes'. *Cognition*, *17*, 265–274.

Springer, K., & Keil, F. C. (1991). Early differentiation of causal mechanisms appropriate to biological and nonbiological kinds. *Child Development*, *62*, 767–781.

Strevens, M. (2000). The essentialist aspect of naïve theories. *Cognition*, *74*, 149–175.

Strevens, M. (2001). Only causation matters: Reply to Ahn et al.. *Cognition*, *82*, 71–76.

Wilson, R. A., & Keil, F. C. (2000). The shadows and shallows of explanation. In F. C. Keil, & R. A. Wilson (Eds.), *Explanation and cognition*. Cambridge, MA: MIT Press.

Witt, C. (1998). Form, normativity, and gender in Aristotle: A feminist perspective. In C. A. Freeland (Ed.), *Feminist interpretations of Aristotle*. University Park, PA: Pennsylvania University Press.