Abstract

Nominal concepts represent things as tokens of types. Recent research suggests 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 differ from logical, statistical, and causal connections. Principled connections license (i) the expectation that tokens of the type will generally possess their k-properties, (ii) formal explanations (i.e., explanation of the presence of k-properties in tokens of a type by reference to the type of thing it is), and (iii) normative expectations concerning the presence of k-properties in tokens of the type. The present paper investigates the hypothesis that representing principled connections requires representing properties as aspects of being the relevant kind of thing (Aspect Hypothesis). Experiment 1 provides a direct test of the Aspect Hypothesis. Experiments 2 and 3 provide indirect tests of the Aspect Hypothesis. All three experiments provide support for the Aspect Hypothesis. Experiment 4 investigates a prediction of the Aspect Hypothesis concerning the manner in which formal explanations are licensed by principled connections. Finally, Experiment 5 investigates a prediction of the Aspect Hypothesis concerning the nature of the normative expectations licensed by principled connections. Together these results provide strong evidence for the idea that representing principled connections involves representing a property as being an aspect of being a given kind of thing. The results also help clarify the manner in which formal explanation differs from other modes of explanation. Finally, the results of the experiments are used to motivate a proposal concerning the formal structure of the conceptual representations implicated by principled connections. This structure provides a domain-general way of structuring our concepts and embodies the perspective we take when we think and talk of things as being instances of a kind.

Keywords: Conceptual representation; Modes of explanation; Type-token representations; Generic Knowledge; Principled connections; Formal aspect of concepts
1. Introduction

A key property of nominal concepts such as dog and table is that they provide us the means for thinking of indefinitely many things as being the same with respect to the type of thing they are (dog; table). That is, they allow us to represent things as tokens of a type. Not all mental representations function in this manner. For example, indexical representations such as the demonstrative that, as well as object files within the visual attentional system, provide the means for directing attention to a single entity (or what is represented as a single entity) (Feigenson & Carey, 2005; Kahneman, Treisman, & Gibbs, 1992; Pylyshyn, 1989; Scholl, 2001). They do not provide the means for thinking of indefinitely many entities as being the same in any respect. In fact, such representations do not, in and of themselves, provide the means for thinking that even two entities are the same in any respect (e.g., two uses of that do not require that the things that are referred to be the same in any respect). The respect in which any two entities indicated by two indexical representations are the same must be specified on the basis of the content of the indexical representations, by a mechanism other than the indexical representations themselves. Type–token representations, on the other hand, provide the means for thinking of indefinitely many things as being the same with respect to the type of thing they are (i.e., as distinct tokens of the same type).

As such, representation of basic nominal concepts such as dog and table require a mechanism such as the one in (1). Such a mechanism may be used to generate indefinitely many new representations (2), each of which provides the means for thinking about a different instance of the same kind $K$.

1. $K_i$
2. $K_1 K_2 K_3 \ldots$

The representations in (2) are the mechanisms by which we think about and store information about specific instances of kinds. These representations can be linked to indexical and perceptual representations accounting for the fact that we can often direct our attention to and perceive those entities that we think of as instances of kinds. The mechanism in (1), on the other hand, allows us to think about a kind as such and thus cannot be directly linked to perceptual representations. We can think and talk about kinds, but we cannot perceive them as we can instances of kinds (Gelman, 2003; Waxman, 2004).

We do not, however, think of things as merely instances of a given kind (e.g., dog). We also think of them as having various properties (e.g., being brown, having four legs, being hungry, ...). Consequently, a key question for theories of conceptual representation concerns how we represent the relation between the type of thing something is and other properties it possesses. The present research addresses this question. The answer to this question is also of relevance to many areas of cognitive science including theories of the semantics of generics as an important class of generics characterize kinds of things (Carlson, in press; Krifka et al., 1995; Leslie, 2007) as well as theories of the acquisition, interpretation, and processing of generic language (Chambers, Graham, & Turner, 2008;
Cimpian & Markman, 2008; Gelman, Goetz, Sarnecka, & Flukes, 2008; Hollander, Gel-
man, & Raman, in press; Khemlani, Leslie, Glucksberg, & Fernandez, 2007; Leslie, 2008; Prasada, Salajegeh, Bowles, & Poeppel, 2008). Furthermore, insight into how we
represent the relation between the type of thing something is and its other properties is
likely to inform theories of nonmonotonic reasoning, as most generalizations we know
have exceptions and it is likely that the manner in which we reason about exceptional
properties will depend on the manner in which they are connected to types (Pelletier &
Elio, 2005). Relatedly, the results of the present research should have implications for
theories of knowledge representation in artificial intelligence where developing formal-
isms that naturally capture default reasoning is often an explicit goal (Reiter, 1992).

While it is clear that classical and prototype theories of conceptual representation repre-
sent logical and statistical connections between the type of thing something is and its other
properties, the theory- or explanation-based approach to conceptual representation has gen-
erally not addressed this question explicitly (but see Prasada & Dillingham, 2006). The pres-
ent research addresses this question within the context of an explanation-based approach to
conceptual representation.

1.1. Modes of explanation in common sense conception

The theory- or explanation-based approach recognizes the central role concepts play
in understanding and explanation, and thus has sought to discover the modes of explana-
tion that are implicit in common sense conception. Previous research within this
approach has found that our conceptual systems exploit causal-essential, teleological,
and intentional modes of explanation (e.g., Carey, 1985; Gelman, 1990; Gelman &
Bloom, 2007; Gelman & Wellman, 1991; German & Johnson, 2002; German, Niehaus,
Roarty, Giesbrecht, & Miller, 2004; Gergely, Nadasdy, Csibra, & Biro, 1995; Gopnik &
Meltzoff, 1997; Inagaki & Hatano, 2002; Johnson & Solomon, 1997; Keil, 1989,
1994; Kelemen, 1999; Lombozo & Carey, 2006; Opfer & Gelman, 2001; Springer &
Keil, 1991; among many others). These modes of explanation differ with respect to
both their explanatory principles as well as their domains of application (Keil, 1994).
The essentialist mode allows certain properties of a given kind of thing to be under-
stood as being caused by an (usually unknown) essence and is most clearly applicable
to natural kinds. The teleological mode allows one to explain the existence and proper-
ties of various kinds of things by reference to functions, goals, and ends, and thus it is
limited to those kinds of things for which such notions seem appropriate (e.g., artifacts,
parts of living things). Finally, the intentional mode allows one to explain behavior by
reference to intentional mental states, and thus it is limited to applying to those kinds
of things to which intentional mental states are attributed as well as artifacts on some
accounts (e.g., Bloom, 1996).

Prasada and Dillingham (2006) proposed that in addition to these modes of explanation,
our conceptual systems contain a formal mode of explanation wherein certain properties of
instances of a kind are understood to be explained by their being the kinds of things they
are. For example, Fido is understood to have four legs because he is a dog, but he is not
understood to be brown because he is a dog. As such, the formal mode of understanding distinguishes properties of an instance of a kind that are explained by the kind of thing it is from properties that are not explained by the kind of thing it is. It follows that our conceptual systems must represent two kinds of connections between the kind of thing something is and properties of instances of that kind—one that licenses formal explanations (explanations by reference to the kind of thing something is) and one that does not. Furthermore, because formal explanations involve explaining properties of an instance of a kind by reference to the kind of thing it is, this mode of explanation is not limited in its applicability to one or another kind of thing but applies to things of all kinds, including immaterial things (e.g., this has three sides because it is a triangle). The formal mode of explanation complements rather than replaces the modes of explanation studied in previous research. Investigation of the formal mode of explanation and the representations that support it is important because it promises to reveal a domain-general way of structuring our concepts that differs from the types of domain-general structure that have been investigated in previous research on conceptual structure. Furthermore, such an investigation should shed light on the structure of the conceptual mechanisms that allow us to think and talk about things as instances of a kind.

We postpone a more detailed discussion of the relation of the formal mode of explanation to the other modes of explanation until the general discussion. The next section presents Prasada and Dillingham’s (2006) proposal concerning the two types of connections represented between the kind of thing something is and its other properties. The experiments in the present paper investigate the manner in which the connections that license formal explanations are represented.

1.2. Principled and factual/statistical connections

The formal mode of understanding distinguishes properties of an instance of a kind that are determined by the kind of thing it is from properties that are not determined by the kind of thing it is. Prasada and Dillingham (2006) referred to the former properties as k-properties, and the connection between kinds and these properties as principled connections. The latter properties were referred to as t-properties, and the connection between kinds 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 kinds, whereas t-properties merely have factual connections to kinds. Finally, it should be kept in mind that designation of a property as a k- or t-property is always relative to a kind. Thus, red is a k-property of strawberries, but a t-property of flowers.

Prasada and Dillingham (2006) characterized principled connections as having an explanatory aspect, a normative aspect, and a statistical aspect. Specifically, principled connections license formal explanations whereby we can explain the presence of a k-property in an instance of a kind by reference to the kind of thing it is (e.g., that has four legs because it is a dog). Principled connections also license normative expectations concerning the presence of k-properties (e.g., people think dogs should have four legs). Finally, principled
connections license the expectation that instances of a kind will generally possess their k-properties. These three aspects of principled connections distinguish them from both logical and statistical connections.

Unlike logically necessary connections, principled connections allow for the possibility that there may be instances of a kind that lack k-properties determined by that kind (e.g., three-legged dogs). Unlike logically contingent connections, which place no constraints on expected prevalence, principled connections support the expectation that k-properties will generally be true of tokens of the type.

Turning to statistical connections, we see that merely strong statistical connections between kinds and properties do not license formal explanations. For example, though barns are typically red, the redness of a barn cannot be explained by citing the fact that it is a barn. Similarly, mere statistical prevalence does not establish a normative expectation. For example, though barns are typically red, people do not think that barns should be red (except, perhaps, as a personal preference), or that there is something wrong with nonred barns.

1.3. Evidence for the existence of principled connections

Prasada and Dillingham (2006) provided empirical evidence for the existence of principled connections in a series of experiments. In a first experiment, they showed that it is possible to identify a set of kinds and properties for which participants paraphrase bare plural sentences such as (3) as meaning either (3a) or (3b) showing that participants understand these properties to be true of instances of a kind because they are the kinds of things they are (3a), and that these properties are understood to generally be true of instances of the kinds in question (3b). As such, the connection between these kinds and properties was shown to display two key characteristics of principled connections—an explanatory link between kinds and k-properties, and a statistical expectation concerning the prevalence of k-properties.

3. Dogs are four-legged.
3a. Dogs, by virtue of being the kinds of things they are, are four-legged.
3b. Dogs, in general, are four-legged.
4. Barns are red.
4a. Barns, by virtue of being the kinds of things they are, are red.
4b. Barns, in general, are red.

For a different set of kinds and properties, such as the ones in (4), participants only found the paraphrase stating the general prevalence of the property (4b) to be appropriate, indicating merely a statistical connection between the kinds and properties in question. Furthermore, the same pattern of results was found across a wide range of content domains (natural kinds, artifact kinds, social kinds), suggesting that the representation of principled and statistical connections is not limited to items of one or another kind but may be represented for any kind of thing. Finally, Prasada and Dillingham (2006) found that these differences
between the two sets of stimuli could not be attributed to differences in the prevalence of the properties in question. Virtually identical results were found for a subset of the stimuli that were matched on the average prevalence of the characterizing properties.

In a second experiment, Prasada and Dillingham (2006) showed that when asked to explain the presence of a k- (5) or t-property (6) in an instance of a kind, participants found formal explanations of k-properties (5a) to be much better than those of t-properties (6a). Once again, this pattern of results was found across content domains. Furthermore, the differences in the acceptability of formal explanations of k- and t-properties could not be attributed to prevalence differences as the same pattern was found for a prevalence-matched subset of the data.

5. Why does that (pointing to a dog) have four legs?
5a. Because it is a dog.
6. Why is that (pointing to a barn) red?
6a. Because it is a barn.
7. Dogs, by virtue of being dogs, should have four legs.
8. Barns, by virtue of being barns, should be red.

Finally, in a third experiment, Prasada and Dillingham (2006) showed that participants have normative expectations concerning the presence of k- but not t-properties by showing that participants generally judge statements such as (7) to be true, but this is not the case for sentences like (8). As with the other experiments, this pattern of results was found across content domains. Once again, the differences between connection types were not attributable to differences in prevalence of the k- and t-properties, as the same pattern of results was found for a prevalence-matched subset of the stimuli.

Together these data provide evidence for the existence of principled connections within our conceptual systems. That is the connection represented between the kind of thing something is and some of its properties is such that these connections license (a) formal explanations of the properties, (b) normative expectations concerning these properties, and (c) the expectation that instances of a kind will generally possess these properties. In addition to the phenomena discussed above, the statistical aspect of principled connections was also revealed in participants’ estimates of the prevalence of k-properties in Prasada and Dillingham (2006) as well as work currently in progress, which shows that principled connections support statements concerning the prevalence of k-properties in principle. For example, In principle, all dogs have four legs is judged to be true (S. Prasada & D. Ruttkayova, unpublished data). It is important to note, however, that not all generic statements work this way (e.g., Carlson, 1995; Leslie, 2008), and thus it is important not to extend the statistical aspect of principled connections to generics generally.

1.4. Representation of principled connections

Prasada and Dillingham (2006) provided evidence that our conceptual systems represent principled connections between kinds and some properties, but they did not address the question of how principled connections are represented. Ideally, the manner in which
principled connections are represented should provide an explanation for why they have the properties they do, as well as provide insight into the nature of formal explanation and the type of normativity licensed by principled connections. The data in Prasada and Dillingham (2006) show that principled connections license formal explanations; however, they do not tell us why principled connections license formal explanations, or why or how formal explanations are explanatory. Similarly, the data show that principled connections license normative expectations concerning the presence of k-properties; however, the source of this normativity is not identified. The source of the expectation that instances of a kind will generally possess their k-properties was also not identified. The next section presents a proposal concerning how principled connections are represented and how this representation of principled connections helps explain their key properties. The experiments investigate this proposal.

1.5. The Aspect Hypothesis

We hypothesize principled connections require representing a formal relation between a kind and a property. Specifically:

To represent a principled connection between a kind and a property requires representing the property as one aspect of being that kind of thing.

We refer to this hypothesis as the Aspect Hypothesis. According to the hypothesis, principled connections are a certain sort of a part–whole relation between the property and kind in question. For example, four-leggedness is understood to be one aspect/part of being a dog. On the other hand, redness is not understood to be one aspect/part of being a barn. Experiment 1 provides a direct empirical test of the Aspect Hypothesis (the hypothesis that k-properties, but not t-properties, are represented as aspects of the kinds in question). It is important to note that the Aspect Hypothesis does not, and is not meant to, provide a criterion for identifying k-properties. Instead, it proposes how principled connections between kinds and properties (identified in some other manner) are represented. Furthermore, the Aspect Hypothesis helps explain the key characteristics of principled connections. To see this, let us consider a specific example. If having four legs is represented as one aspect of being a dog, it is clear why it should be possible to explain the four-leggedness of any given dog by citing the fact that it is a dog. The existence of a whole presupposes the existence of its parts, and thus the existence of a part (k-property) is rendered intelligible by identifying the whole (kind of thing) of which it is a part. Thus, knowing that something is a dog explains why it has four legs because having four legs is represented as one aspect of being a dog. On the other hand, citing the fact that it is an animal or that it is brown is not explanatory because having four legs is not understood to be an aspect of being an animal or being brown. In sum, representing properties as an aspect of being a given kind of thing allows for the possibility of exploiting a part–whole principle to provide formal explanations.

The Aspect Hypothesis also helps provide a natural explanation for our normative expectations concerning the presence of k-properties. If having four legs is understood to be one aspect of being a dog, then a dog should have four legs, otherwise it would be incomplete
and/or have something wrong with it. That is, representation of k-properties as an aspect of being a given kind of thing allows for the possibility of exploiting a principle of perfection to ground normative expectations concerning the presence of k-properties. Finally, the Aspect Hypothesis helps explain why instances of a kind are expected to generally have their k-properties. Insofar as having four legs is an aspect of being a dog, all dogs are expected to have four legs. Having four legs, however, is only one aspect of being a dog. Dogs, by virtue of being dogs, are also material entities, and thus causally interact with their environments. Under certain special circumstances, the causal interactions a dog happens to be subject to may prevent a k-property from developing or being present in a given instance. As there is no reason to suppose that these special circumstances will generally prevail, dogs are expected to generally have four legs. The foregoing suggests that the Aspect Hypothesis potentially provides an explanation of the key properties of principled connections.

The experiments in this paper investigate the Aspect Hypothesis. It is important to note that the Aspect Hypothesis is not a theory of what determines whether a given property of a thing is a k-property of that kind of thing. The development of such a theory must be an important goal for future research (see Section 7). The present research seeks to determine how properties that are known to be k-properties of a given kind of thing are represented.

1.6. Overview of experiments

Experiments 1–3 investigate the validity of the Aspect Hypothesis. Experiment 1 provides a direct test of the hypothesis by investigating whether those properties that previous research has identified as k-properties are judged by participants to be aspects of being the relevant kinds of things. Experiments 2 and 3 provide indirect tests of the Aspect Hypothesis. Having established that k-properties are represented as aspects of kinds of things, Experiment 4 investigates a prediction of the Aspect Hypothesis concerning the manner in which formal explanations are licensed by principled connections. Finally, Experiment 5 investigates a prediction of the Aspect Hypothesis concerning the nature of normative expectations licensed by principled connections.

2. Experiment 1

The primary goal of Experiment 1 was to determine whether representation of a principled connection between a given kind and a property involves representing the property as an aspect of being that kind of thing. In contrast, t-properties, which merely have a strong statistical connection to a kind, should not be so represented. We investigated this possibility by asking participants to make truth-value judgments concerning statements that identified k- or t-properties (9a,b) as being aspects of a given kind of thing.

9a. Being four-legged is one aspect of being a dog.
9b. Being red is one aspect of being a barn.
We used the stimuli from Prasada and Dillingham (2006) to generate stimuli for the experiments in the present paper, as this allowed us to directly relate the findings of the present experiments to previous findings concerning principled and statistical connections. It is important to note that Prasada and Dillingham (2006) did not identify k- and t-properties on the basis of whether they are understood to be aspects of a given kind or not. Instead, the properties were initially identified on the basis of whether or not bare plural sentences such as (3) and (4) could receive “by virtue” paraphrases (3a) and (4a). Subsequently, principled and statistical connections were shown to differ with respect to their ability to license formal explanations and normative expectations (see above, Prasada and Dillingham 2006 for details).

A second goal was to determine whether the predicted difference in judgments is due to a difference in the manner in which principled and statistical connections are represented, or if it reflects only 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 the participants that completed the judgment task as well as a different set of participants. If the differences in the judgments are due to a difference in the manner in which principled and statistical connections are represented, the differences should remain for the prevalence-matched items. We also conducted regression analyses with the full set of stimuli to determine if connection type predicts variance over and above that which may be predicted by prevalence. Finally, we sought to determine whether the Aspect Hypothesis characterizes the manner in which principled, but not statistical connections, are represented across a wide range of content domains.

2.1. Method

2.1.1. Participants

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

2.1.2. Stimuli

Ninety sentences were generated from the stimuli used by Prasada and Dillingham (2006). The generated sentences identified either a k- or t-property as being one aspect of being the relevant kind of thing (e.g., Being four-legged is one aspect of being a dog). Half the sentences involved principled connections (k-properties), and the other half involved statistical connections (t-properties). For each connection type, 15 sentences involved properties of natural kinds, 15 involved properties of artifact kinds, and 15 involved properties of social kinds. The base set of sentences from which the stimuli for all of the experiments in this paper were derived is given in column 1 of the Appendix. We chose to use aspect rather than part because aspect seemed like a more natural way to refer to many of the properties, even though in the stimulus sentences both terms are naturally interpreted in the same manner as roughly meaning not all. In response to a reviewer’s query as to why we did not use part, we have subsequently
run a version of the present experiment in which we used *part* in place of *aspect* and have found a virtually identical pattern of results.

2.1.3. Procedure

Eighteen participants completed a judgment task as well as a prevalence estimation task. These participants completed the judgment task before the prevalence estimation task. Another 18 participants completed only the prevalence estimation task.

2.1.3.1. Judgment task: On each trial, participants were presented with one of the stimulus sentences and asked to “indicate the extent to which the sentence strikes you as being true.” Participants made judgments on a seven-point scale. The 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 in all the experiments reported in this paper.

2.1.3.2. Prevalence estimation task: Participants were presented with the bare plural versions of the sentences (e.g., *Dogs are four-legged*) 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.

2.2. Results

The mean ratings given by participants in the judgment task are shown in Fig. 1 and column 2 of the Appendix. We performed a $2 \times 3$ ANOVA with connection type (principled/statistical) and domain (artifact/natural/social) as the factors and participants’ ratings as the dependent variable. Both participant and item analyses were performed. We use the conventional $F_1$ and $F_2$ to report participant and item analyses respectively.

![Fig. 1. Mean ratings for Experiment 1.](image_url)
2.2.1. Distinguishing the representation of principled and statistical connections

As predicted by the Aspect Hypothesis, there was a large and significant effect of connection type with sentences involving principled connections receiving significantly higher ratings ($M = 6.08$) than those involving statistical connections ($M = 3.84$) ($F_{1[1,17]} = 74.55$, $p < .001$; $F_{2[1,83]} = 236.92$, $p < .001$). There was also a small but significant effect of domain ($F[2,34] = 11.64$, $p < .001$; $F[2,83] = 6.72$, $p < .002$). Finally, there was a significant interaction between connection type and domain ($F[2,34] = 10.4$, $p < .001$; $F[2,83] = 3.56$, $p < .033$). Importantly, however, the difference between the rating for the items involving principled connections and the items involving statistical connections was large and significant in each of the domains (artifact kinds: $F_{1[1,17]} = 68.75$, $p < .001$, $F_{2[1,27]} = 110.54$, $p < .001$; natural kinds: $F_{1[1,17]} = 37.61$, $p < .001$, $F_{2[1,28]} = 54.03$, $p < .001$; Social kinds: $F_{1[1,17]} = 82.27$, $p < .001$, $F_{2[1,28]} = 84.94$, $p < .001$).

2.2.2. Prevalence and the representation of 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 than the statistical items (85.65% vs. 60.75%). Consequently, we analyzed data for a subset of principled and statistical items that were matched for their average estimated prevalence. This subset was generated by including the largest number of highest prevalence statistical connection and lowest prevalence principled connection items for which the average prevalence was the same. This yielded a set of 14 principled and 14 statistical items, with an average estimated prevalence of 72.23% and 72.79%, respectively. In this, and all the experiments in this paper, we report the analyses for the data set generated on the basis of the prevalence estimates obtained from the participants that did not complete the judgment task. The estimated prevalences for all the items are reported in column 9 of the Appendix.

We performed a one-way ANOVA with connection type as the factor and the participants’ ratings for the prevalence matched items as the dependent variable. The mean ratings are shown in Fig. 2. Domain was not included as a factor in the prevalence-matched analyses reported in this paper, as there were uneven numbers of items from the different domains in the prevalence matched data. Importantly, the effect of connection type remained significant ($F_{1[1,17]} = 46.76$, $p < .001$; $F_{2[1,26]} = 29.38$, $p < .001$). Consequently, the differences we found between the manner in which k- and t-properties are represented cannot be attributed to differences in prevalence. As the prevalence-matched analyses did not include domain as a variable, these analyses do not allow us to draw conclusions about potential domain differences.

We also conducted a regression analysis, with connection type (principled vs. statistical) and prevalence estimates both entered as predictors and with the dependent variable (“aspect” ratings) as the criterion to see if connection type accounts for a significant amount of variance above and beyond the prevalence estimates. An advantage of the regression analysis is that it allows us to look at the data from all of the items. The analysis showed that connection type accounted for a significant amount of variance over and above prevalence (pr = .628, $t[86] = 7.48$, $p < .05$). Prevalence was also found to account for a
significant amount of variance (pr = .375, t[86] = 3.75, p < .05). Thus, the dependent measure was also influenced by a factor other than connection type, namely prevalence. More importantly, the results of the regression analysis are consistent with those of the subset analysis in that they show that the differences in participants’ ratings involving principled connections and statistical connections cannot be simply due to differences in the prevalence of k- and t-properties.

2.3. Discussion

The results provide support for the Aspect Hypothesis. Sentences that identified k-properties as an aspect of being a given kind of thing struck participants as being true. This was not the case for sentences that identified t-properties as an aspect of a given kind of thing. Ideally, one might have expected the ratings for the sentences containing t-properties to be lower; however, there are probably two factors that are responsible for why this was not so. First, participants in these experiments really seem to avoid choosing the extreme values on the scales. Secondly, it is possible that at least some participants may have used an alternative strategy for responding. The alternative strategy would be based on the observation that for any specific instance of a kind, the k- or t-property it possesses represents only one aspect of that instance (e.g., one aspect of Fido is that he has four legs; one aspect of this barn is that it is red). Given this observation, participants could have made their judgments by estimating the prevalence of the instances of the kind that had the k- or t-property. If participants were using such an alternative strategy, the judgments for sentences involving t-properties would be higher than if they were responding in the expected manner. Of course, if participants were exclusively using such an alternative strategy, then their judgments would be fully predicted by the prevalence of the properties, but as the results of the prevalence-matched and regression analyses show, the differences between connection
types cannot be attributed to differences in prevalence of the k- and t-properties for the items used in the experiments.

Finally, though there was a small interaction with domain, k-properties were found to be represented as aspects of being a given kind of thing in each domain. This is what would be expected given the formal nature of principled connections. The small domain differences are likely to be due to idiosyncratic properties of the stimuli. The small differences certainly do not suggest that the Aspect Hypothesis is valid in only some domains or that the distinction between principled and statistical connections is limited to one or another domain.

3. Experiment 2

Experiment 1 provided direct evidence in support of the Aspect Hypothesis by demonstrating that we endorse the truth of statements such as (9a), but not (9b). The present experiment tests another prediction of the hypothesis. Specifically, if k-properties are represented as aspects of being a given kind of thing, it should be possible to characterize an arbitrary instance of the kind as possessing the property. On the other hand, if t-properties are not represented as aspects of being a given kind of thing, then an arbitrary instance of the kind should not be expected to possess the property. As such, it should be possible to interpret indefinite singular sentences as characterizing an arbitrary instance of the kind when a k-property (principled connection) is involved (10a), but not when a t-property (statistical connection) is involved (10b). On the other hand, both types of sentences should be interpretable as characterizing a specific, but unidentified instance of a kind.

10a. A dog has four legs.
10b. A barn is red.

The linguistics literature on generics has long noted that generic interpretations of indefinite singular sentences such as (10a,b) is possible when there is some type of special (‘‘analytic/essential/definitional’’) connection between a kind and a property (e.g., Burton-Roberts, 1977; Carlson & Pelletier, 1995; Cohen, 2001; Dahl, 1975; Lawler, 1973). In this experiment, we seek experimental support for this observation and thus indirect support for the Aspect Hypothesis. More generally, the experiments in this paper and Prasada and Dillingham (2006) seek to characterize the nature of this special connection and how it is represented in the mind.

3.1. Method

3.1.1. Participants

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

3.1.2. Stimuli

Eighty-four indefinite singular sentences were generated from the set of stimuli used by Prasada and Dillingham (2006). Four of the original items were not used because they were
mass nouns (glue, spandex, snow, milk) that do not have a natural unit of occurrence (e.g., a ? of glue) and thus could not be used in the indefinite singular form. Mass nouns for which there was a natural unit of occurrence were used with that unit (e.g., a blade of grass). The items involving summer and winter were also excluded as they sounded odd in the indefinite singular construction on any interpretation.

3.1.3. Procedure

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

3.1.3.1. Judgment task: On each trial, participants were presented with one of the stimulus sentences in the indefinite singular form on a computer screen, followed by a question concerning the interpretation of the sentence. The “arbitrary instance interpretation” question asked them “Can this sentence be used to describe what any X is like?” We are aware of the fact that any x is not exactly equivalent in meaning to an arbitrary x; however, we used the former locution because we felt it was more likely to be easily understood by our participants. The “specific instance interpretation” question asked them “Can this sentence be used to describe what one specific X is like?” To make the nature of the interpretations clear to the participants, the instructions included an example of a situation where it seemed clear that a specific instance was being referred to (A dog was barking), as well as an example where it seemed pretty clear an arbitrary instance was being referred to (A lion is a carnivorous animal). Participants made judgments on a seven-point scale. After participants had made their judgment, they pressed the space bar to receive the question concerning the other possible use of the sentence. Participants received the “specific instance interpretation” question first for half of the sentences, and the “arbitrary instance interpretation” question first for the other half of the sentences. The order of questions for a given sentence was counterbalanced across two versions of the experiment. Order of trials was randomized separately for each participant.

3.1.3.2. Prevalence estimation task: Same as Experiment 1.

3.2. Results

The mean ratings given by participants are shown in Fig. 3 and columns 3 and 4 of the Appendix. We performed $2 \times 2 \times 3$ ANOVAs with connection type (principled/statistical), interpretation type (arbitrary instance/specific instance), and domain (artifact/natural/social) as the factors and participants’ ratings as the dependent variable.

3.2.1. Connection type and the interpretation of indefinite singulars

As predicted, there was a significant interaction between connection and interpretation types ($F_1[1,17] = 37.03, p < .001; F_2[1,78] = 240.15, p < .001$). This interaction was due to the fact that the arbitrary instance interpretation was significantly better for the items
involving principled connections than those involving statistical connections ($F_{1}[1,17] = 36.58, \ p < .001; \ F_{2}[1,82] = 225.05, \ p < .001$), but the specific instance interpretation was equally good for both types of items ($F_{1}[1,17] = .35, \ p < .562; \ F_{2}[1,82] = .772, \ p < .382$). There was also a small, but significant effect of domain ($F_{1}[2,34] = 3.93, \ p < .029; \ F_{2}[2,78] = 4.06, \ p < .021$), as well as a significant three-way interaction ($F_{1}[2,34] = 5.49, \ p < .009; \ F_{2}[2,78] = 4.58, \ p < .013$). Importantly, however, the arbitrary instance interpretation was rated as better for items involving principled connections than items involving statistical connections in each domain (artifact kinds: $F_{1}[1,17] = 36.08, \ p < .001; \ F_{2}[1,26] = 284.17, \ p < .001$; natural kinds: $F_{1}[1,17] = 21.93 \ p < .001; \ F_{2}[1,24] = 43.52, \ p < .001$; social kinds: $F_{1}[1,17] = 44.27, \ p < .001; \ F_{2}[1,28] = 72.62, \ p < .001$). Furthermore, the specific instance interpretation was rated as being equally good for the principled and statistical items in each domain (artifact kinds: $F_{1}[1,17] = .451, \ p < .511; \ F_{2}[1,26] = 1.18, \ p < .287$; natural kinds: $F_{1}[1,17] = 2.42, \ p < .139; \ F_{2}[1,24] = 4.33, \ p < .048$; social kinds: $F_{1}[1,17] = 1.24, \ p < .282; \ F_{2}[1,28] = .573, \ p < .455$). As such, the small interaction with domain is probably best interpreted as due to idiosyncrasies in particular items, though the slightly higher ratings for the arbitrary instance interpretation in the artifact condition than the natural kind is reminiscent of Gelman et al.’s (2008) finding that indefinite singular generics are used more often for artifacts than animals and thus is potentially worthy of further study. With respect to the Aspect Hypothesis what is most important is the finding that the arbitrary instance interpretation was rated to be better for items involving principled connections than items involving statistical connections in each domain.

3.2.2. Prevalence and the interpretation of indefinite singualrs

A $2 \times 2$ ANOVA with connection and interpretation types as the factors was performed on the prevalence-matched subset of the data. The mean ratings are shown in Fig. 4. As was the case with the full data set, there was a significant interaction ($F_{1}[1,17] = 29.46, \ p < .001; \ F_{2}[1,26] = 18.21, \ p < .001$). The arbitrary instance interpretation received
significantly higher ratings when it involved principled connections than when it involved statistical connections ($F_1[1,17] = 27.06, p < .001; F_2[1,78] = 28.29, p < .001$). In contrast, the specific instance interpretation was rated as being equally good for both types of connections ($F_1[1,17] = .032, p < .86; F_2[1,26] = .073, p < .889$). Thus, the prevalence-matched data showed the same pattern of results as the full data set. This rules out the possibility that differences in the interpretation of items involving principled and statistical connections may be due to differences in the prevalence of the k- and t-properties in the stimulus set.

This conclusion was supported by a regression analysis with connection-type (principled vs. statistical) and prevalence ratings entered as predictors, and the arbitrary interpretation ratings as the criterion that showed that connection type accounted for a significant amount of variance over and above prevalence ($pr = .562, t[81] = 6.11, p < .05$). Prevalence was also found to account for a significant amount of variance ($pr = .691, t[81] = 8.60, p < .05$).

3.3. Discussion

The results of the experiment show that it is possible to use k-properties, but not t-properties, to characterize arbitrary instances of a kind. This is what would be expected if k-properties are represented as aspects of being a given kind of thing, but t-properties are not so represented. The fact that the same sentences did not differ in their ability to characterize specific instances makes it clear that the difference in the ability of k- and t-properties to characterize arbitrary instances of a kind cannot be attributed to some spurious difference in the sentences, involving principled and statistical connections. As such, the present experiment provides further support for the Aspect Hypothesis. Experiment 3 provides another indirect test of the hypothesis.
4. Experiment 3

If we understand k-properties to be aspects of being a given kind of thing, then an attempt to define the kind should make reference to k-properties. In contrast, properties that merely have strong statistical connections to a kind should not be included in definitions, as they are not understood to be aspects of being the relevant kind of thing. Thus, for example, (11a) sounds like a reasonable partial definition of a dog, but (11b) does not seem to be a reasonable partial definition of a barn.

11a. A dog is a four-legged animal.
11b. A barn is a red building.

Cohen (2001) has noted the connection between the ability of a property to appear in indefinite singular sentences that are interpreted generically and their ability to appear in definitions. In addition to providing another test of the Aspect Hypothesis and further characterizing the nature of principled connections, the present experiment in conjunction with the previous experiment will potentially provide experimental evidence for the connection between generic interpretations of indefinite singulars and definitions.

Given the broadly shared opinion that concepts cannot be represented as definitions (Armstrong, Gleitman, & Gleitman, 1983; Fodor, Garrett, Walker, & Parkes, 1980; Murphy, 2002; Rosch & Mervis, 1975), the fact we are talking about definitions, partial or otherwise, may be surprising. It is important, however, to distinguish between the technical sense of definition and the types of things one finds in a dictionary or may use in conversation in response to a question such as what is an x? (Chomsky, 1996; McGilvray, 2005; Quine, 1987). Technical definitions require that we represent the necessary and sufficient features of the thing being defined. It is clear we do not represent definitions of this sort. It is an empirical question, however, what constraints characterize the informal partial definitions we find in everyday speech in response to questions such as what’s an x? The present experiment investigates the possibility that such informal definitions may include k-properties, which are understood to be aspects of being a given kind of thing. On the other hand, t-properties should not be included because they are not understood to be aspects of being a given kind of thing. Lexicographers have spent much effort determining the characteristics of a good dictionary definition. Our purpose here is not to provide such a characterization. Instead, our purpose is to determine whether k-properties, unlike t-properties, are good candidates for inclusion in informal definitions, and thus, presumably, also dictionary definitions.

4.1. Method

4.1.1. Participants

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

All 90 of the stimuli used in Prasada and Dillingham (2006) were used to generate partial definitions of the form given in (11a).

4.1.3. Procedure

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

4.1.3.1. Judgment task: On each trial, participants were presented with a question on a computer screen, such as, ‘‘What is a dog?’’ After reading the question, participants pressed the space bar to receive a possible answer to the question (‘‘A dog is a four-legged animal.’’). Participants were asked to ‘‘rate how good an answer the response is to the question.’’ They were warned that it was likely that none of the answers was likely to sound wonderful, and that they would all likely seem to be only partial answers but that some of the answers may, nevertheless, sound better than others. Participants made judgments on a seven-point scale. Order of trials was randomized separately for each participant.

4.1.3.2. Prevalence estimation task: Same as Experiment 1.

4.2. Results

The mean ratings given by participants are shown in Fig. 5 and column 5 of the Appendix. We performed $2 \times 3$ ANOVAS with connection type (principled/statistical) and domain (artifact/natural/social) as the factors and participants’ ratings as the dependent variable.

4.2.1. Connection type and informal definitions

As predicted, participants gave significantly higher ratings to the answers that included a k-property than those that included a t-property ($F_{1[1,17]} = 141.8, p < .001;$

![Fig. 5. Mean ratings for Experiment 3.](image-url)
There was also a small but significant effect of domain ($F_{1}[2,34] = 20.67, p < .001; F_{2}[2,84] = 7.06, p < .001$). The interaction was significant in the participant analysis ($F_{1}[2,34] = 9.87, p < .001$), but only marginally significant in the item analysis ($F_{2}[2,84] = 2.64, p < .077$). Importantly, answers that contained k-properties were judged to be better than those that contained t-properties for each of the domains (artifact kinds: $F_{1}[1,17] = 70.27, p < .001; F_{2}[1,28] = 68.55, p < .001$; natural kinds: $F_{1}[1,17] = 80.77, p < .001; F_{2}[1,28] = 27.45, p < .001$; social kinds: $F_{1}[1,17] = 139.96, p < .001; F_{2}[1,28] = 37.1, p < .001$).

4.2.2. Prevalence and informal definitions
We performed a one-way ANOVA with connection type as the factor and the participants’ ratings for the prevalence-matched items as the dependent variable. The mean ratings are shown in Fig. 6. Importantly, the effect of connection type remained significant ($F_{1}[1,17] = 64.20, p < .001; F_{2}[1,26] = 12.65, p < .001$). Consequently, the differences we found in the goodness of informal definitions that included k- as opposed to t-properties cannot be solely attributed to differences in prevalence.

The regression analysis also showed that connection type accounted for a significant amount of variance over and above prevalence ($r = .472, t[86] = 4.96, p < .05$). Prevalence was also found to account for a significant amount of variance ($r = .311, t[86] = 3.03, p < .05$).

4.3. Discussion
The results of the experiment show that partial definitions that include k-properties are judged to be more appropriate than those that include t-properties. This is what would be
expected if k-properties are represented as aspects of being a given kind of thing, but t-properties are not so represented. Furthermore, this difference was found in each content domain and cannot be simply attributed to differences in the prevalence of k- and t-properties in our stimuli. As such, the results provide further evidence for the Aspect Hypothesis. The results of this experiment along with those of the previous experiment also provide experimental support for Cohen’s (2001) observation that indefinite singular sentences that can be interpreted generically allow the formulation of definitions of their subject terms in terms of their predicate terms. We note that the Aspect Hypothesis provides an explanation for why such a connection is found.

The results of the present experiment may tempt one to assimilate the distinction between k- and t-properties to the distinction between definitional and characteristic properties (e.g., Smith & Medin, 1981). This temptation should be resisted. K-properties, unlike definitional properties, are not necessary. This is why many k-properties have been identified as examples of characteristic properties in previous research. For similar reasons, the distinction between k- and t-properties should not be assimilated to the distinction between analytic and nonanalytic properties (e.g., Katz, 1972), or properties of the core of a concept versus those of identification procedures (Landau, 1982; Miller, 1977; Smith & Medin, 1981; Smith, Medin, & Rips, 1984). Finally, the distinction also cannot be captured in terms of causal centrality or mutability (Medin & Shoben, 1988; Sloman, Love, & Ahn, 1998). K-properties need not be causally central (e.g., yellowness of a canary), and in many cases they can be easily changed without changing most other properties of the thing (e.g., turning a banana brown by putting it in the refrigerator).

The distinction between k- and t-properties is not reducible to these distinctions because they are fundamentally different sorts of distinctions. The distinction between k- and t-properties is a distinction between two types of connections (i.e., principled and factual/statistical connections) that are represented between the representation of the kind of thing something is and the representation of its properties. Causal centrality and mutability, on the other hand, are concerned with the number and types of dependencies that are represented between different properties of a given kind of thing (Sloman et al., 1998). They are not concerned with what sort of connection(s) is/are represented between kind representations and property representations. This is why, as discussed above, k-properties may be mutable or causally central or not. Though the distinction between k- and t-properties cannot be reduced to these other distinctions, they are likely to be correlated. Nevertheless, it is important to make these distinctions as we expect an adequate theory of conceptual representation will have to specify both the nature of the connections represented between the kind of thing something is and its other properties as well as various types of interproperty relations that will be relevant to notions such as causal centrality, mutability, and typicality.

5. Experiment 4

The results of Experiments 1–3 provide evidence for the Aspect Hypothesis. As discussed earlier, the hypothesis potentially provides an account of why formal explanations are
possible when principled connections are involved. Specifically, it allows one to exploit the principle that the existence of a whole presupposes the existence of its parts, and thus the existence of a part is rendered intelligible by identifying the whole of which it is a part. For ease of exposition, we refer to this as the part–whole principle. The present experiment was run to investigate (a) whether participants judge formal explanations that uncontroversially depend on the part–whole principle to be explanatory, and (b) whether formal explanations of k-properties are judged to be as explanatory as the uncontroversial cases. To do this, we compared participants’ judgments of the explanatoriness of responses such as (12a,b) and (13a,b) in response to questions concerning the presence of k- and t-properties in instances of the relevant kinds (12, 13).

12. Why is that (pointing to a dog) four-legged?
   12a. Because it is a dog.
   12b. Because it is a four-legged dog.
13. Why is that (pointing to a barn) red?
   13a. Because it is a barn.
   13b. Because it is a red barn.

The responses in (12b, 13b) explicitly involve a part–whole relation between the property to be explained and the whole referred to in the response. If participants can exploit the part–whole principle to provide explanations, responses of the form given in (12b, 13b) should be judged to be explanatory. Furthermore, responses of this sort should be judged to be equally explanatory for cases in which k- and t-properties are involved because the phrasal identification explicitly identifies both types of properties as an aspect of the complex type identified by the phrase. On the other hand, responses such as (12a), but not (13a), should be judged to be explanatory because, as Experiments 1–3 demonstrate, we represent k-properties, but not t-properties, as an aspect of being a given kind of thing. It is important to note that though (12a) and (12b) both involve representing a part–whole relation that is exploited to provide formal explanations, we are NOT claiming that phrasal types (12b) and nonphrasal types (12a) make use of the same type of part–whole representation. The distinct ways in which the part–whole relation is represented in these cases will be discussed in the general discussion.

5.1. Method

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

5.1.2. Stimuli
The sentences used in the previous experiments were used to generate questions that sought an explanation for a k- or t-property (12, 13). For each question, a response containing an implicit formal explanation (12a, 13a) and an explicit formal explanation (12b, 13b) was generated. Some of the sentences 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 used *can* in order to elicit an explanation for the capacity (e.g., why can that [pointing to a bird] fly?).

5.1.3. Procedure

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

5.1.3.1. Explanation evaluation task: On each trial, participants were presented with one of the stimulus questions on a computer screen, followed by one of the response types (implicit or explicit). Participants were asked to make a judgment as to “the extent to which the answer seems explanatory.” Participants made judgments on a seven-point scale. After participants had made their judgment, they pressed the space bar to receive the other possible response. Participants received the “explicit” response first for half of the questions, and the “implicit” response first for the other half of the questions. The order of responses for a given sentence was counterbalanced across two versions of the experiment. Order of trials was randomized separately for each participant.

5.1.3.2. Prevalence estimation task: Same as Experiment 1.

5.2. Results

The mean ratings given by participants are shown in Fig. 7 and columns 6 and 7 of the Appendix. We performed $2 \times 3 \times 2$ ANOVAS with connection type (principled/statistical),

![Mean Ratings for Experiment 4](image)
explanation type (implicit/explicit), and domain (artifact/natural/social) as the factors and participants’ ratings as the dependent variable.

5.2.1. Connection and explanation types

As predicted, there was a significant interaction between connection and explanation types ($F_1[1,17] = 46.98, p < .001; F_2[1,84] = 206.04, p < .001$). This interaction was due to the fact that implicit explanations were significantly better when principled connections were involved ($M = 5.5$) than when statistical connections were involved ($M = 3.6$) ($F_1[1,17] = 79.35, p < .001; F_2[1,88] = 183.84, p < .001$), whereas explicit explanations were essentially identical for principled and statistical connections ($M = 5.2$ vs. $5.4$) and did not differ in the participant analysis ($F_1[1,17] = .78, p < .389$), but surprisingly, this tiny difference turned out to be significant in the item analysis ($F_2[1,88] = 6.2, p < .015$).

Though the effect of domain was not significant, there was a significant three-way interaction between connection type, explanation type, and domain ($F_1[2,34] = 12.07, p < .001; F_2[2,84] = 8.43, p < .001$). Importantly, the predicted two-way interaction between connection and explanation types was significant in each of the domains (artifact kinds: $F_1[1,17] = 49.73, p < .001; F_2[1,28] = 196.8, p < .001$; natural kinds: $F_1[1,17] = 14.81, p < .001; F_2[1,28] = 20.85, p < .001$; social kinds: $F_1[1,17] = 48.78, p < .001; F_2[1,28] = 196.8, p < .001$).

5.2.2. Prevalence, connection type, and explanation type

A $2 \times 2$ ANOVA with connection and explanation types as the factors was performed on the prevalence-matched subset of the data. The mean ratings are shown in Fig. 8. As was the case with the full data set, there was a significant interaction ($F_1[1,17] = 17.51, p < .001; F_2[1,26] = 25.67, p < .001$). The implicit explanations received significantly higher ratings when they involved principled connections than when they involved statistical connections ($F_1[1,17] = 23.17, p < .001; F_2[1,26] = 22.88 p < .001$). In contrast, the

![Fig. 8. Mean ratings for prevalence-matched stimuli in Experiment 4.](image-url)
explicit explanations were rated as being equally explanatory for both types of connections ($F_1[1,17] = 1.18, \ p < .31; \ F_2[1,26] = 2.19, \ p < .15$). Thus, the prevalence-matched data showed the same pattern of results as the full data set.

A regression analysis with connection-type and prevalence ratings entered as predictors, and the ratings in the implicit condition as the criterion showed that connection type accounted for a significant amount of variance over and above prevalence ($pr = .570, t[86] = 6.43, \ p < .05$). Both of these analyses rule out the possibility that differences between principled and statistical connections in their ability to license formal explanations can be accounted for on the basis of differences in the prevalence of the $k$- and $t$-properties in the stimulus set. Prevalence was also found to account for a significant amount of variance ($pr = .560, t[86] = 6.26, \ p < .05$).

5.3. Discussion

The results of the implicit conditions replicated Prasada and Dillingham’s (2006) finding that principled connections support formal explanations for the presence of $k$-properties in instances of a given kind, and that formal explanations for the presence of $t$-properties in instances of a given kind are not considered very explanatory. Furthermore, the results of the explicit conditions of Experiment 4 provided independent evidence that we can exploit the part–whole principle to provide formal explanations. Thus, it is possible to explain the redness of a barn by citing the fact that it is a red barn, but not by citing the fact that it is a barn. This is because being red is understood to be part of being a red barn, but being red is not understood to be a part of being a barn. In combination with the results of Experiments 1–3, the results of the present experiment suggest that principled connections license formal explanations because we represent $k$-properties as aspects of being a given kind of thing and thus are able to use the part–whole principle to explain the presence of a $k$-property in an instance of the kind by reference to the kind of thing it is.

Some readers may have found it surprising that participants rated the explicit formal explanations (12b, 13b) as being explanatory as they seem to be minimally informative at best and tautologous at worst. That these explanations are not tautologous can be seen by contrasting them directly with ones that are. For example, the response Because it is red, to the query Why is that red? This response is clearly tautologous and thus nonexplanatory. The explanatoriness of an explicit formal explanation such as, Because it is a red barn, can be more easily seen if one compares it to an alternative response one may give, for example, Because there is a big red light shining on it. The formal explanation refers to what the thing is and thus supports the expectation that it will be red in a range of circumstances; the other explanation refers to the external condition responsible for the redness, and thus supports the expectation that the redness will only be present as long as this external condition is operative. As such, even though explicit formal explanations are not terribly informative, they are nevertheless explanatory. The intuition that the implicit formal explanations are better explanations than the explicit formal explanations was confirmed in a ratings task in which participants rated how useful such explanations are (Prasada & Dillingham, 2006). The notions of explanatoriness, usefulness of explanations, and informativeness of
explanations are all important notions that deserve further psychological investigation (see Lombrozo, 2006, 2007; Thagard, 2006).

As with the Prasada and Dillingham’s (2006) results, formal explanations were judged to be significantly better for k-properties than for t-properties across content domains. This difference was slightly smaller, however, for the natural kind items. This slightly reduced effect was largely due to the higher than expected ratings given to the items involving statistical connections. As the findings from Experiments 1–3 demonstrate, we think of k-properties, but not t-properties, to be aspects of kinds of things. Furthermore, the explicit condition of the present experiment shows that we can exploit the part–whole principle to license formal explanations. Given these facts, we suspect that the higher than expected ratings for the statistical items in the natural kind condition is due to participants perceiving a nonarbitrary causal chain between the kind and the t-properties, and thus were more willing to say that the kind of thing the thing is plays a role in explaining why it has the t-property it does. That is, items with statistical connections to a kind in the case of natural kinds may be more likely to be identified as a kairetic (difference making) causal factor (Strevens, 2004). As discussed by Prasada and Dillingham (2006), the formal mode of explanation complements rather than replaces other modes of explanation. We discuss the relation of the formal mode of explanation to other modes of explanation further in the general discussion.

How is the part–whole relation between k-properties and being a given kind of thing that is exploited by formal explanations represented? One possibility is that the concept that represents the k-property is a constituent of the concept that represents the relevant kind of thing in the manner that the concept red is a constituent of the phrasal concept red dog. Alternatively, some other mechanism is required for representing the part–whole relation that is relevant to the Aspect Hypothesis. We propose such an alternative mechanism and argue in its favor in the general discussion. The results of the present experiment suggest that the Aspect Hypothesis along with the part–whole principle provide an account of why and how principled connections license formal explanations. In Experiment 5, we investigate a prediction of the Aspect Hypothesis concerning the nature of the normative expectations licensed by principled connections.

6. Experiment 5

Prasada and Dillingham (2006) showed that participants think that instances of a kind should have their k-properties by virtue of their being the kinds of things they are. The Aspect Hypothesis sheds light on why this should be so. According to the hypothesis, we understand k-properties to be an aspect of being a given kind of thing. If this is the case, then instances of the kind should have their k-properties simply because they are the kinds of things they are and having those (k-) properties is part of being that kind of thing. If they lacked their k-properties, they would be incomplete or have something wrong with them. Not all normative expectations are grounded in such a principle of perfection or completeness. For example, the notion that human beings should floss their teeth every day does not derive its normative force from a principle of perfection. Daily flossing of teeth is not
understood to be part of being a human being. Furthermore, one would not judge someone who does not do so to be incomplete in some way or to have something wrong with them. In this case, the proposition derives its normative force from the fact that daily flossing is good for us/others/society/the planet, etc. As such, it derives its normative force from a principle of beneficence. It is important to note that we are not claiming that having their k-properties is not beneficial to instances of a kind. It is clearly good for instances to have all of their k-properties. It is simply that the normativity that derives from k-properties being beneficial does not predict that instances that lack k-properties should be judged to be incomplete or have something wrong with them.

If principled connections involve representing k-properties as an aspect of being a given kind of thing, then the normative aspect of principled connections should derive from a principle of perfection, and instances that lack a k-property should be judged to be incomplete or have something wrong with them. On the other hand, instances that lack a prevalent t-property should not be so judged. The present experiment tests these predictions of the Aspect Hypothesis.

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

The sentences used in the previous experiments were altered to present scenarios in which participants were asked to imagine an instance of the relevant kind, and then to imagine that it did not possess either a k- or prevalent t-property (14). These scenarios were presented along with a statement that the absence of the property in question meant that the instance in question had something wrong with it or was incomplete in some way as an instance of that kind (14a), and a scale to judge the truth of the statement.

14. Imagine a dog. Imagine that the dog does not have four legs.
14a. The fact that the dog does not have four legs means that there is something wrong with the dog or that it is in some way not complete as a dog.

6.1.3. Procedure

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

6.1.3.1. Truth evaluation task: On each trial, participants were presented with one of the stimulus questions on a computer screen, followed by a statement that the absence of the property in question meant that the instance in question had something wrong with it or was incomplete in some way. Participants were asked to make a judgment as to whether the
statement is true or not. Participants made judgments on a seven-point scale. They were told
that “We are not interested in whether it is socially acceptable to say it is true, or whether,
upon reflection or analysis it really is true. We are simply interested in whether the state-
ment strikes you as true in the first instance.” After participants had made their judgment,
they pressed the space bar to receive the next trial. All participants judged all stimuli. Order
of trials was randomized separately for each participant.

6.1.3.2. Prevalence estimation task: Same as Experiment 1.

6.2. Results and discussion

The mean ratings given by participants are shown in Fig. 9 and column 8 of the Appen-
dix. We performed $2 \times 3$ ANOVAS with connection type (principled/statistical) and domain
(artifact/natural/social) as the factors and participants’ ratings as the dependent variable.

As predicted, there was a significant effect of connection type ($F_1[1,17] = 106.86,$
$p < .001; F_2[1,84] = 504.27,$ $p < .001)$. There was also a small but significant effect of
domain ($F_1[2,34] = 12.03,$ $p < .001; F_2[2,84] = 11.18,$ $p < .001$) and an interaction of con-
nection type and domain ($F_1[2,34] = 19.01,$ $p < .001; F_2[2,84] = 9.14,$ $p < .001$). The inter-
action was due to an effect of domain for items involving principled connections
($F_1[2,34] = 23.10,$ $p < .001; F_2[2,42] = 13.49,$ $p < .001$), whereas there were no domain
differences for the items involving statistical connections. For principled connections, items
involving artifact kinds received higher ratings than those involving natural kinds
($F_1[1,17] = 48.00,$ $p < .001; F_2[1,28] = 41.32,$ $p < .001$) or social kinds ($F_1[1,17] = 29.37,$
$p < .001; F_2[1,28] = 15.64,$ $p < .001$).

Importantly, the effect of connection type was large and significant in each of the
domains (artifact kinds: $F_1[1,17] = 143.74,$ $p < .001; F_2[1,28] = 395.35,$ $p < .001$; natural
kinds: $F_1[1,17] = 63.71,$ $p < .001; F_2[1,24] = 151.90,$ $p < .001$; social kinds: $F_1[1,17] = 69.03,$
$p < .001; F_2[1,28] = 85.70,$ $p < .001$).
A one-way *ANOVA* showed that the effect of connection type remained large and significant for the prevalence matched items ($F_1[1,17] = 47.55, p < .001$; $F_2[1,26] = 57.93, p < .001$; Fig. 10). The regression analysis also showed that connection type accounted for a significant amount of variance over and above prevalence ($pr = .752, t[86] = 10.60, p < .05$). Prevalence was also found to account for a significant amount of variance ($pr = .514, t[86] = 5.56, p < .05$).

The relatively higher ratings of the principled items involving artifacts when compared to those involving natural and social kinds is likely due to four factors. The main factor is that the language used to elicit ratings was best suited to speaking about artifacts. For example, a Mormon who drinks alcohol is more naturally described as *doing* something wrong qua Mormon, rather than having something wrong with him/her qua Mormon. Similarly, the notion of incompleteness is often better expressed via the use of terms such as *immature* or *unripe* rather than incomplete. A second factor that is likely to have dampened ratings for items involving social kinds pertains to the social acceptability of saying that there is something wrong with instances that lack a given k-property. Though our instructions explicitly asked participants to disregard such considerations when making their judgments, it is likely that they nevertheless had some influence on the ratings given. Thirdly, as noted by Prasada and Dillingham (2006), the natural kind principled condition contained two k-properties that we conceive of as being intrinsically negative, even though they may not be negative properties for tokens of the given types to have (fragility [of eggshells]; slowness [of turtles]). It is not surprising that it should be a little odd to say that there is something wrong with an instance that lacks an intrinsically negative property.

It is important to point out that though these factors led to small differences across domains, instances that lacked a k-property were given significantly higher ratings than instances that lacked a prevalent t-property in each of the domains. Furthermore, as the analysis with the prevalence-matched items showed, this difference is not attributable to a difference in the prevalence of k- and t-properties. In sum, as predicted by the Aspect Hypothesis,
instances that lack a k-property are understood to be incomplete or have something wrong with them. As such, the results suggest that principled connections acquire their normative aspect via a principle of perfection and that k-properties are represented as aspects of kinds of things. This conclusion is bolstered by the results of an experiment modeled on Experiment 5 that also included a set of properties that are considered beneficial, but not aspects of being a given kind of thing (e.g., flossing daily for humans). Participants did not judge instances that lacked these beneficial properties as being incomplete or as having something wrong with them, but, as was the case in the present experiment, judged instances that lacked a k-property as being incomplete or having something wrong with them (S. Prasada & D. Bublitz, unpublished data).

7. General discussion

The experiments reported in this paper suggest that representing a principled connection between a kind and a property involves representing the property as an aspect of being that kind of thing. Experiment 1 provided direct evidence that this is the case. Experiments 2 and 3 provided indirect evidence for the hypothesis by showing that k-properties can be used to characterize an arbitrary instance of a kind and are included in informal definitions of kinds of things. Experiment 4 showed that the Aspect Hypothesis can account for the ability of principled connections to support formal explanations. It did so by providing independent evidence that representation of a part–whole relation underlies the possibility of providing formal explanations. Finally, Experiment 5 provided evidence that the normative aspect of principled connections is underwritten by the Aspect Hypothesis and reflects a principle of perfection or completeness. As a consequence, instances of a kind that lack their k-properties are judged to be incomplete or have something wrong with them.

Together these results provide strong evidence for the idea that representing principled connections between kinds and properties involves representing the properties as aspects of being those kinds of things. Furthermore, the results show that it is not an accident that principled connections license (a) formal explanation of k-properties, (b) normative expectations concerning the presence of k-properties, and (c) the expectation that instances will generally possess their k-properties. As discussed above, these three aspects of principled connections follow as a consequence of the Aspect Hypothesis and independently motivated principles. The experiments in Prasada and Dillingham (2006) provided evidence that our conceptual systems distinguish principled and statistical connections in a number of ways; the experiments in the present paper provide evidence that representing principled connections requires representing the k-property as an aspect of the kind in question.

7.1. Clarifying the nature of the Aspect Hypothesis

We can further clarify the nature of the Aspect Hypothesis by considering possible alternatives to it. First, we may consider whether there could be a cognitive system that represents all the properties of principled connections without also representing the k-properties as aspects of the kinds in question. One may call this the No Aspect Representation
Hypothesis. This is a logically possible hypothesis. No logical contradictions seem to be involved in the hypothesis. Though logically possible, the No Aspect Representation Hypothesis seems psychologically impossible or at least very unnatural. Experiment 1 shows that when we represent a principled connection between a kind and a property, we understand that property to be an aspect of being that kind of thing and it is hard to think of any cases in which a principled connection is represented between a kind and a property, but the property is not understood to be an aspect of being that kind of thing.

A psychologically more plausible alternative would be what one might call the Brute Representation Hypothesis. According to this hypothesis, principled connections primitively have a number of properties, including the fact that k-properties are understood to be aspects of the kinds in question. This last property, however, does not have any representational or explanatory priority over the other properties. A disadvantage of the Brute Representation Hypothesis is that, by definition, it provides no explanation as to why principled connections have the properties they do, why formal explanation is possible, or the nature of the normativity involved in principled connections. As discussed above, the Aspect Hypothesis provides answers to these questions and shows how the properties of principled connections may be accounted for on the basis of the Aspect Hypothesis and principles such as the principle of perfection and part–whole principle. Though we have not experimentally sought to distinguish the Brute Representation Hypothesis and the Aspect Hypothesis, the following observations seem to count against the Brute Representation Hypothesis and for the Aspect Hypothesis. The statements in (15)–(17) display an explanatory asymmetry between aspect representation and formal explanation (15a,b), normative expectations (16a,b), as well as the statistical aspect of principled connections (17a,b).

15a. Having four legs is one aspect of being a dog because we can explain the four-leggedness of dogs by reference to the kinds of thing they are (dogs).
15b. We can explain the four-leggedness of dogs by reference to the kinds of thing they are (dogs) because having four legs is one aspect of being a dog.
16a. Having four legs is one aspect of being a dog because dogs should have four legs.
16b. Dogs should have four legs because having four legs is one aspect of being a dog.
17a. Having four legs is one aspect of being a dog because most dogs have four legs.
17b. Most dogs have four legs because having four legs is one aspect of being a dog.

The explanatory asymmetry whereby the statements in (b) sound more natural than those in (a) is not predicted by the Brute Representation Hypothesis but is predicted by the Aspect Hypothesis. As such, these observations complement the data from the experiments in providing evidence for the Aspect Hypothesis.

In the rest of the general discussion, we discuss (a) how the results of the present experiments help elucidate the formal mode of explanation and its relation to other modes of explanation; (b) make a proposal concerning the manner in which the Aspect Hypothesis is represented; (c) discuss the identification of k-properties; (d) discuss the nature of the part–whole relation involved in the representation of kinds and aspects; and (e) discuss directions of research suggested by the present research.
7.2. Formal explanation and other modes of explanation in common sense conception

Prasada and Dillingham (2006) provided some evidence that principled connections support a formal mode of explanation. The results of the present experiments provide further support for this mode of explanation. They also further clarify the ways in which the formal mode of explanation differs from other modes of explanation that have been studied in previous research (e.g., Carey, 1985; Gelman, 1990; Gelman and Bloom, 2007; Gelman & Wellman, 1991; German & Johnson, 2002; German et al., 2004; Gergely et al., 1995; Gopnik & Meltzoff, 1997; Inagaki & Hatano, 2002; Johnson & Solomon, 1997; Keil, 1989, 1994; Kelemen, 1999; Lombozo & Carey, 2006; Opfer & Gelman, 2001; Springer & Keil, 1991, among many others). The results of Experiments 1–4 suggest that principled connections license formal explanations because we represent k-properties as aspects of being a given kind of thing and thus are able to use the part–whole principle to explain the presence of a k-property in an instance of the kind by reference to the kind of thing it is. As such, the formal mode of explanation requires (i) k-properties to be represented as aspects of kinds of things, and (ii) access to the part–whole principle. The causal and teleological modes of explanation can be distinguished from the formal mode of explanation with respect to both their representational requirements and the principles that ground these modes of explanation.

The causal mode of explanation requires that certain properties be represented as the effect of a cause. In the causal representational placeholder version of essentialism, this amounts to representing that which is in the essence placeholder as the cause and the essential property as the effect (Gelman & Hirschfeld, 1999; Gelman, 2003; Medin & Ortony, 1989). On the minimalist version of essentialism, a causal law between the kind of thing something is and its essential properties is represented (Strevens, 2000, 2001). This requires that the kind of thing something is be represented as the cause of its essential properties, which must be represented as effects/products. Both of these versions of essentialism seem to exploit a causal principle such as every thing comes to be (a certain way) from something else. Thus, if a property is represented as something that comes to be (is an effect/product), then there must be something else (cause/producer) that is responsible for its coming to be. On the other hand, the teleological mode of explanation requires that properties be represented as means to ends. In this case, a teleological principle such as things are (as they are) for the sake of an end is needed to ground explanations. Thus, one may explain why dogs have four legs by identifying the legs as the means by which dogs achieve the end of locomotion (walking).9

These considerations help further clarify the manner in which formal explanation differs from the causal and teleological modes of explanation.10 In addition to the differences in the representations and principles exploited by these distinct modes of explanation, one important difference between the formal mode of explanation and the other modes of explanation is that it applies across all content domains. The causal mode, on the other hand, applies only to material (changeable) entities, and the teleological mode is limited to those aspects of the material world for which the notion of ends makes sense (DiYanni & Kelemen, 2005; Keil, 1994; Kelemen, 1999). Because of its domain-generality and its relevance to language,
it is plausible that the formal mode of explanation is available at the earliest stages of development and is part of the logic of kind representations (Prasada & Dillingham, 2006).

It is important to emphasize that the formal mode of explanation complements the modes of explanation investigated in previous research rather than replaces any of these modes. As noted by Aristotle, when talking about living things (and most of our natural kind items were living things), the formal, efficient, and final causes not only coincide, but are identical. Thus, the kind of thing something is plays an explanatory role in formal, efficient (causal), and final (teleological) explanations. What something is, explains why it has certain properties because having those properties is an aspect of being that kind of thing (formal explanation). Furthermore, instances of living kinds come into being via re-production and thus are produced by something of the same kind (efficient explanation), and consequently, so are those properties that are aspects of being that kind of thing. Finally, the production of another instance of the kind is the end (final explanation) of the causal processes that produce instances of the relevant kind. This suggests that with respect to living things, all three modes of explanation are applicable and make crucial reference to the kind of thing something is. Furthermore, if Aristotle is correct, they necessarily explain a single reality from three different perspectives, all of which are needed for a fully satisfactory explanation. This will be the case when we seek an explanation for the existence of instances of kinds of living things and the properties that living things have by virtue of being the kinds of things they are (i.e., their k-properties). If, on the other hand, we consider other properties (e.g., t-properties), these modes of explanation may be distinguished to a greater or lesser extent. Thus, there may be properties that have a causal connection to a kind, but no formal or teleological explanation (e.g., the property of carrying West Nile Virus and mosquitoes), or a teleological connection, but no formal or causal explanation (e.g., wearing collars for dogs). Finally, if we move to domains in which entities are immaterial and unchangeable (e.g., triangles), then only formal explanation applies.

In sum, the formal, causal, and teleological modes of explanation provide distinct ways of understanding things. Furthermore, distinct modes of explanation are differentially relevant to understanding things in distinct content domains (Keil, 1994). The formal mode of explanation, which exploits the part–whole principle and requires that (k-)properties are represented as aspects of being a given kind of thing, is applicable domain-generally and is relevant to various linguistic phenomena (Prasada & Dillingham, 2006). We turn now to have a closer look at how principled connections are represented.

7.3. Representation of principled connections

The experiments reported in this paper present a range of data that suggest that k-properties are represented as aspects of kinds of things. Thus far, however, we have not considered the form of the mechanisms needed to represent principled connections (i.e., represent certain properties as aspects of the relevant kind). We suggested earlier that the part–whole representation that is relevant to the Aspect Hypothesis differs from the part–whole relation encoded between constituents (e.g., yellow) and the phrasal concepts of which they are constituents (e.g., yellow canary). One important difference between the two types of
representation is that whereas tokens of phrasal types must have the properties denoted by their constituents (e.g., every yellow canary must be yellow), instances of a kind can lack their k-properties (e.g., there may be nonyellow canaries). Furthermore, whereas it is clearly impossible to have the concept yellow canary without having the concept yellow and the concept canary, one could certainly have the concept canary without having the concept yellow (Fodor, 1998). These considerations make it clear that being yellow is understood to be an aspect of (part of) being a canary but that cannot require that the concept for the k-property (yellow) is a part of the concept for the kind (canary).11

What is needed is that we represent one aspect of the things that are thought about via the concept canary as being yellow (a property which is thought of via the concept yellow). Thus, there is a part–whole relation between the things that are thought about via the concepts yellow and canary rather than a part–whole relation between the concepts yellow and canary as is the case with the concept yellow and the phrasal concept yellow canary. What is needed is a mechanism for representing a part–whole relation between the things thought about via two concepts without representing a part–whole relation between the concepts themselves. What then is the form of such a representation?

Our proposal draws upon the solution that linguists have developed for handling an analogous representational issue that pertains to the interpretation of pronominal forms. Sentences such as (18) contain two lexical items (John, him) that are nonidentical but which may be interpreted such that they make reference to the same person. On the other hand, the nonidentical lexical items Bill and him cannot be interpreted as making reference to the same person.

18. John\textsubscript{i} thinks Bill\textsubscript{k} likes him\textsubscript{i}.

Consequently, a mechanism is needed to capture whether or not nonidentical lexical items may be given identical interpretations. This is accomplished via the mechanism of coindexation. Thus, though John and him are nonidentical lexical items, they may be interpreted as referring to the same person because they are coindexed. The same mechanism can provide the means for implementing the Aspect Hypothesis. In this case, however, what needs to be established is not the identity of the things thought about by two concepts (e.g., canary, yellow), but the identity of an aspect of the thing thought about via one concept (canary) and the property thought about via the other concept (yellow). The following illustrates the manner in which principled connections may be represented (19).

19. \(K_i \to a_1, a_2, \ldots P_{a_1}\)

In this representation, the \(K\) represents the kind, and the index \(i\) is a variable that can take on indefinitely many values, each representing a distinct instance of the same kind. The indexical elements \(a_1, a_2,\ldots\) provide the mechanism by which we think about aspects of being that kind of thing. Representation of a principled connection involves coindexing one of these elements with the concept \(P\) that represents the property that has a principled connection to the kind. Thus, the notion that being yellow is one aspect of being a canary may be represented in the following manner (20).
The aspect representations \((a_1, a_2, \ldots)\), do not, in and of themselves, represent a specific property. As such, aspect representations are like pronouns (e.g., \textit{him}), which do not, in and of themselves, represent a specific person, but must be coindexed with a representation that does (e.g., \textit{John}). Analogously, the representation of an aspect of a kind can only direct attention to a specific property once it has been coindexed to a representation that represents a property \((P)\) in and of itself. The aspect representations \((a_1, a_2, \ldots)\) may be thought of as parameters, for example, \(a_1\) may be the parameter for the \textit{color} of a canary which gets set by being coindexed with the representation of specific color (e.g., \textit{yellow}). It should be noted that aspect representations do not have an identity or existence that is independent of the kind of representations of which they are a part. In this, they are like parameters (or argument positions in argument structures), but unlike constituents which do have an identity and existence that is independent of their being constituents of a phrase or complex concept.\(^{12}\)

This means it is possible to possess the kind concept (e.g., \textit{canary}) without at the same time also possessing a given k-property concept (e.g., \textit{yellow}). At this stage, the aspect representation simply represents the expectation that this is the kind of thing that may have a principled connection to a property of this sort. After coindexing, the aspect representation is able to direct attention to a specific property that is understood to be an aspect of being that kind of thing.

Such a mechanism for representing principled connections has a number of things to recommend it. First, it provides a mechanism for representing a part–whole relation between the things thought about through the use of two concepts without requiring the two concepts to be in a part–whole relation to one another. For the reasons discussed above, some such mechanism is required. It clearly allows one to have the concept \textit{canary} without also having the concept \textit{yellow}. Consequently, being yellow cannot be understood to be a \textit{condition} for being thought of via the concept \textit{canary}. This leaves open the possibility that an instance of a kind may lack a k-property. In contrast, one cannot have the complex concept \textit{yellow canary} (21) without having both the concept \textit{canary} and the concept \textit{yellow}, and being yellow \textit{is} a condition for something to be thought of via the concept \textit{yellow canary}.\(^{13}\)

\[(21) \text{ [YELLOW \text{ [CANARY}_i \rightarrow a_1, a_2, \ldots]]} \]

By providing a means for representing principled connections, (19) provides the means for specifying what we expect to be true of instances of a kind by virtue of their being the kinds of things they are. Of course, instances of a kind have many properties that are not determined by the kind of thing they are. Consequently, this leaves room for the possibility that a factor other than the kind of thing something is may, in some cases, prevent an instance of a kind from having some of its k-properties. Thus, (19) provides a mechanism that leads us to expect that all instances of a kind will possess their k-properties by virtue of being the kinds of things they are, while allowing for the possibility that some instances may lack k-properties \textit{for reasons other than their being the kinds of things they are}. What is ruled out by (19) is that an instance of the kind could lack being P by virtue of being a K.
This is parallel to the constraints on the interpretation of pronouns in sentences such as (18). The pronoun *him*, by virtue of its structural position in the sentence, may be coindexed with *John*, but not *Bill*, and thus interpreted as referring to the same person as *John*, but not the same person as *Bill*. It is also possible, however, to interpret *him* as referring to someone other than the person *John* refers to on the basis of information other than the pronoun's structural position in the sentence (e.g., on the basis of discourse factors).

Another desirable characteristic of (19) is that the key elements that allow this mechanism to represent principled connections have independent motivation. The key elements are: (a) the interpretation of the index $a1$ as indicating an aspect of an instance of a kind, and (b) the coindexation of aspects of instances of a kind with a k-property concept. These two elements are independently required to capture two very deep intuitions concerning instances of kinds and their properties. One is that no instance of a kind is absolutely simple. No matter how great the unity of a thing, things are always mentally divisible and thus can always be thought to have various parts or aspects. Secondly, certain kinds of properties (e.g., that denoted by *yellow*) seem to be existentially dependent. Put simply, but roughly, instances of certain types of concepts (e.g., *yellow*) seem to presuppose the existence of a subject within which they exist, whereas instances of other types of concepts (e.g., *canary*), do not presuppose subjects in which they exist. Instead, they are understood to be subjects, in and of themselves, within which instances of dependent categories exist. This is a psychologized version of Aristotle's substance–attribute distinction. Whether or not the distinction is philosophically or scientifically defensible, it clearly seems to be reflected in common sense ways of thinking and speaking. The intuition that attributes are always of something, but that things are not (things) of anything and simply are what they are, is robust and must be captured by the mechanisms involved in representing our common sense conceptions. This distinction can be captured via the same mechanisms that are needed for representing principled connections. It is beyond the scope of this paper to develop this claim; however, we hope it is clear that the kind of machinery that was posited for representing principled connections may also be put to such a use.

We also think that the type of mechanism illustrated in (19) can be used to develop an explanation for why it is possible to think and talk about kinds in multiple ways (Prasada, in press). Finally, it seems like a mechanism such as (19) may be needed for grounding many of the primitive generalizations that Leslie (2008) argues to ground our interpretation of generic statements.

We mention these possibilities because we believe an advantage of the account of the representation of principled connections developed above is that it can account for these further facts about the ways in which we think and talk about kinds of things. Whether or not these attempts are ultimately successful, we believe these are the kinds of data that theories of the formal aspect of common sense concepts need to account for. Previous research on conceptual representation has largely focused on the contents of concepts. We would like to suggest that deep and interesting facts about conceptual representation are likely to emerge in the study of the formal characteristics of conceptual representations.
7.4. Identifying k-properties

Before wrapping up, we would like to say a word or two about how k-properties may be identified and studied in future research. Prasada and Dillingham (2006) initially identified k-properties by whether bare plural sentences (Dogs are four-legged) could be paraphrased using a bare plural involving “by virtue” (Dogs, by virtue of being the kinds of things they are, are four-legged). Their judgments concerning these sentences were empirically confirmed and extended in certain ways by participants (Experiment 1A). The rest of the experiments in Prasada and Dillingham (2006) and the present paper show a number of other ways in which our cognitive systems systematically distinguish principled and statistical connections in language and our reasoning. As such, there are now a number of empirical ways in which k-properties may be identified. What is not currently available is a theory of what determines whether a given property of a thing is a k-property of that kind of thing (represented as an aspect of being that kind of thing). The situation is a familiar one. For example, there are various empirical means of distinguishing grammatical and ungrammatical strings of words (sentences and nonsentences), but no complete theory of what makes some strings of words sentences and others not. Such a theory is the goal of research in linguistics and psycholinguistics. Similarly, developing a theory of what makes a property a k-property of a kind must be one goal for research in conceptual representation. As such, a specification of necessary and sufficient criteria for being a k-property must await development of such a theory. The research in this paper and Prasada and Dillingham (2006) provides some constraints on the nature of such a theory. It is likely that such a theory will have to incorporate domain-specific knowledge, perhaps in the form of overhypotheses (Goodman, 1955; Shipley, 1993), in addition to domain-general constraints on the representations of k-properties (see Prasada & Dillingham, 2006).

7.5. Kind and aspect representations

The data from the present experiments suggest that kind representations allow us to think of instances of a kind as not merely possessing spatio-temporal parts, but various other types of parts or aspects (e.g., mechanical parts, functional parts, qualitative parts). Thus, for example, being green, having four legs, having the capacity to ribbit, the capacity to hop, and being slimy are all understood to be aspects of being a single kind of thing—namely a frog. Being green is understood to be an aspect or part of being a frog, but we do not think that being green is all there is to being a frog. Similarly for having four legs, the capacity to hop, ribbit, or being slimy. Of course, we recognize that the specific way in which an instance of each of these properties is related to an actual whole frog is different; nevertheless, in each case, the property is also understood to be only an aspect or part of being that kind of thing (a frog). Johnston (2006) argues that specification of the proper parts of a whole, rather than arbitrary or “fiai” parts, requires specification of a principle of unity. This suggests that kind representations provide a principle of unity. At present, there is no general theory of what kinds of aspects or parts are proper parts of being different kinds of things. The present research points to the need for developing such a theory. The present
research also suggests some intriguing possibilities concerning the nature of the principle of unity embodied by kind representations.

First, the diversity of aspects suggests that things conceived of as instances of kinds may possess a number of distinct forms of unity; however, the unity provided by conceiving of an entity as an instance of a kind cannot be reduced to any of these other forms of unity (spatio-temporal, mechanical, functional, qualitative, ...). An interesting possibility is that kind representations, which have the structure of (19), provide a mechanism for uniting information of different sorts by providing a uniform format for representing information that may be represented in other systems of the mind in very different and incompatible formats. Thus, for example, while the color red and the shape round are likely represented in very different ways within our perceptual systems, kind representations along with property representations within our conceptual systems (19) provide the means for representing both properties as aspects of being a single kind of thing (e.g., a tomato). Consequently, they may be treated in a similar manner in the types of linguistic and nonlinguistic contexts studied in the present paper and Prasada and Dillingham (2006). The uniformity in representation is possible due to the formal nature of aspect representations—representing a property as being an aspect of being a given kind of thing simply amounts to thinking of that property as contributing to being that kind of thing without exhausting what it is to be that kind of thing. The plausibility of this suggestion will have to be determined by future research. Similar suggestions concerning lexicalizable concepts more generally have been made by a number of scholars (e.g., Chomsky, 1996, 2000; Jackendoff, 1983; 1997; Pietroski, 2005). On this view, mechanisms such as (16, 19) may be a conceptual counterpart to nonconceptual mechanisms involved in solving the problem of binding distinct sensory features to yield a unitary percept (see Pylyshyn, 2007) or representing unsorted individuals more generally.

The structure of (19) also embodies another key property of the type of unity we ascribe to things thought of as instances of a kind (i.e., sorted individuals)—this form of unity is intrinsically general. To think of something as an instance of a kind is to think of it as one of indefinitely many things which possess the same type of unity and which together form an abstract unit (a kind) which is also an object of thought. This contrasts with other forms of unity which may be relevant to representing unsorted individuals. So, for example, the spatio-temporal unity of an entity is not intrinsically general. To attribute such a unity to an entity is not to think that its spatio-temporal unity is possessed by indefinitely many things or that these things collectively form an abstract unit. We can, of course, explicitly form the concept of the set of things that have a particular type of spatio-temporal unity, but this is not part and parcel of recognizing a thing’s spatio-temporal unity or characterizing that form of unity. This difference suggests that one way in which the relation of aspect representations to kind representations differs from other part–whole relationships is that, unlike the latter, they are intrinsically general and thus expected to characterize indefinitely many cases.

Finally, the unity a thing has insofar as it is thought of as an instance of a kind differs from the unity that wholes like phrases have. Phrases are constituted of parts that have an existence and identity that is independent of the whole. Aspect representations, on the other hand, do not have an existence or identity that is independent of the kind representations of which they are aspects.
These suggestions concerning the nature of kind and aspect representations will have to be further developed and clarified in future work. The data from the present experiments point to the need for future work to develop a full account of the sense in which we understand certain properties to be an aspect of being a given kind of thing and the ways in which that part–whole relation differs from, or is similar to, other more familiar part–whole relations.

7.6. Conclusions and open questions

Common sense concepts are the mechanisms by which we naturally think about things. These mechanisms allow us to think and talk about things from rich and intricate perspectives (Chomsky, 1996; McGilvray, 1999, 2005; Pietroski, 2005). The experiments in the present paper, along with those in Prasada and Dillingham (2006) reveal one small aspect of the perspectives provided by basic nominal concepts such as dog, table, or artist. Such concepts allow us to think about indefinitely many things as being the same with respect to the kind of thing they are. That is, they allow us to think of things as instances of kinds. Furthermore, they allow us to think of these instances as having certain properties because they are the kinds of things they are. These properties are represented as aspects of being that kind of thing. Thinking about things from this perspective provides the basis for various linguistic expressions and nonlinguistic judgments, including the ones investigated in this paper and Prasada and Dillingham (2006). This perspective is made available through a mechanism such as (19) and differs in important ways from the perspective provided by a mechanism such as (21). Because these mechanisms are formal in nature, they provide a perspective from which we can think about things from different content domains in a similar manner. Future research should investigate how these perspectives may be similar to or differ from the perspectives provided by other types of nominal concepts.

The results of the experiments in this paper suggest that principled connections involve representing k-properties as aspects of being a given kind of thing. They also raise a series of questions, including the following (related) questions: (a) How do we know when to represent a principled connection between a kind and a property? (b) What constraints, if any, are there on what can count as an aspect of being a certain kind of thing? (c) Are some principled connections established more easily than others? (d) Are all principled connections established through the same acquisition mechanisms? (e) How is the formal mode of explanation related to the causal, teleological, and intentional modes of explanation in development? Gelman and Bloom (2007) provided some initial data that bear on the potential relation between causal and formal modes of explanation in development. (f) In what respects are the structure and function of formal explanations similar to or different from that of other types of explanations (Lombrozo, 2006)? (g) How is the normative aspect of principled connections similar to and different from the representation of ideals and idealizations used in science? (h) How is information about principled connections and factual connections accessed and used in the course of sentences processing? Some recent data from a study using event-related potentials are consistent with the idea that processing of principled and factual connections may elicit distinct N400 responses (Prasada et al., 2008). The answers to these questions should deepen our understanding of the formal aspect of common sense conception and how
it relates to other aspects of conceptual understanding and language. More generally, the research reported here is likely to bear on questions concerning the semantics of generics, nonmonotonic reasoning, knowledge representation, and the acquisition and processing of generic language.

Notes

1. This mode of explanation is a psychologized version of Aristotle’s formal mode of explanation (i.e., explanation via the formal “cause”). For further discussion and details, see Prasada and Dillingham (2006) and references cited therein.

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 and that the extent to which the property is associated with the type is a function of the prevalence of the property in tokens of that type.

3. We leave the term aspect undefined and rely on the intuitive interpretation of this term as meaning roughly part as in *not all of*. A more explicit characterization is not needed for present purposes. Neither the theoretical consequences of the Aspect Hypothesis discussed below nor participants’ performance in Experiment 1 relies on anything other than this intuitive interpretation of the term. A more detailed version of the Aspect Hypothesis is developed in the general discussion based on the results of the experiments in this paper and other considerations.

4. Due to an error, one of the stimulus items was repeated (*Bananas are yellow*) and consequently another one of the items was left out (*Bulldozers are yellow*). The data from the second occurrence of the repeated item was not included in the analyses, and thus the analyses were performed on the data of 89 items per participant.

5. For all the experiments in the paper, a parallel set of analyses was also performed on the basis of prevalence estimates provided by the participants who had performed the main task. In all cases but one, these analyses showed the same pattern of results. The one exception was that the item analysis in Experiment 3 was only marginally significant.

6. Following Prasada and Dillingham (2006), 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 extent to which the sentences struck the participants as being true. 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 merely a graded quantitative distinction rather than a qualitative distinction. The data from the prevalence-matched items 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.

7. This possibility was suggested to us by Michael Strevens.

8. Note that this is so even though the normative statement does not involve a mere personal preference, but instead expresses what we might take to be an objective fact.

9. We do not want to claim that our formulation of either the causal principle or the teleological principle is definitive. For present purposes, all that matters is that the two principles can be distinguished and will be formulated along the lines suggested and thus impose distinct representational requirements. The philosophical literature is replete with disagreements about the exact form such principles must have, or even if such principles are needed. Unlike the philosophical literature, we are not interested in normative questions concerning various types of explanations. Instead, we are interested in the psychological question of which modes of explanation we do use in our common sense reasoning and the types of principles and representations these modes of explanation require. For a review of different formulations of the teleological principle within the psychological literature, see Lombrozo and Carey (2006). For alternative formulations of the causal principle, see Bullock, Baillargeon, and Gelman (1982).

10. The intentional mode of explanation is likely to exploit a combination of the representational resources required by the causal-essentialist and teleological modes of explanation with the obvious difference that the properties to be explained will not be essential properties, and the cause of the properties will not be understood to be the essence of that kind of thing, but a mental state of the individual.

11. For a more detailed argument for this point and other arguments why lexical concepts such as canary are unlikely to be constituted of other concepts, see Fodor (1998).

12. One may also think of the aspect representations as placeholders, however, we think the parameter analogy is more appropriate as it seems like once a principled connection is made, it may be fixed once and for all, whereas the placeholder analogy suggests no barriers to revisability, and the argument position analogy suggests that there is no correct value but may be filled by different things on different occasions. As these are only analogies; nothing much hangs on the choice. The crucial point is that before coindexing, the aspect representation does not direct attention to any determinate property.

13. While the mappings between language and conceptual representations requires further investigation, it seems that phrasal expressions (e.g., yellow canary) are mapped onto mechanisms such as (21), whereas nonphrasal expressions such as monomorphic nouns (e.g., canary) and compound nouns (e.g., picnic table, bluebird) map onto mechanisms such as (19), and certain derived nouns such as dancer may be mapped onto either type of structure.

15. We note in passing that non-spatio-temporal wholes are routinely recognized and represented within internalist and conceptual or cognitive approaches to semantics (Chomsky, 1975, 1996, 2000; Jackendoff, 1983; 1997; Lakoff, 1987; McGilvray, 2005; Moravcsik, 1998b; Pietrosi, 2005).

Acknowledgments

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References


Appendix

Stimuli and results for Experiments 1–5. Column 1 contains the stimulus items that were used as a base to generate the items used in the rest of the experiments. These sentences were also used in the prevalence estimation task. Column 2 contains the mean ratings for statements identifying k- and t-properties as aspects of being a given kind of thing (Experiment 1). Columns 3 and 4 contain the mean ratings given to the “‘arbitrary’” and “‘specific’” interpretations of indefinite singular sentences (Experiment 2). Column 5 contains the mean ratings for responses containing k- and t-properties to the question What’s an X? (Experiment 3). Columns 6 and 7 present the mean ratings for the explanatoriness of answers that referred to a phrasal type (Because it is a red barn) or a nonphrasal type (Because it is a barn) in response to questions concerning why an instance of a kind possessed a k- or t-property. The former responses are identified as “‘explicit’” because they explicitly involve a part–whole relation between the property to be explained and the type referred to in the response. The other responses are referred to as “‘implicit’” because the property to be explained in not explicitly a part of the type referred to in the response (Experiment 4). Column 8 contains mean ratings concerning whether an instance of a kind that lacks a k- or t-property has something wrong with it or is incomplete as an X (Experiment 5). Column 9 contains the mean prevalence estimates given by participants who did not complete the judgment task in Experiment 1.

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#### Natural kinds

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#### Social kinds

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**Statistical connections**

**Artifact kinds**

| Barns are red | 4.72 | 2.89 | 5.56 | 3 | 4.72 | 2.89 | 1.5 | 47.67 |
| Bricks are red | 3.67 | 3.67 | 5.5 | 2.94 | 5.78 | 3.78 | 2.5 | 65.11 |
| Bulldozers are yellow | – | 3.28 | 5.28 | 2.33 | 5.22 | 3.33 | 1.61 | 66.94 |
| Cars have radios | 3.5 | 3.56 | 5.22 | 2.56 | 5.83 | 3.61 | 2.94 | 79.11 |
| Clocks have alarms | 5.33 | 3.33 | 5.67 | 3.67 | 5.72 | 4.44 | 2.67 | 54.83 |
| Diapers are white | 3.72 | 3.33 | 5.56 | 3 | 5.94 | 3.22 | 2 | 71.17 |
| Fire trucks are red | 5.39 | 4.61 | 5.61 | 4.11 | 5.44 | 4.39 | 2.61 | 86.17 |
| Glue is white | 3.72 | – | – | 2.61 | 5.67 | 3.89 | 1.5 | 69.56 |
| Hair nets are black | 3.72 | 3.06 | 5.33 | 2 | 5.67 | 3 | 1.22 | 54.44 |
| Rocking chairs are wooden | 4.33 | 3.17 | 5.83 | 3.11 | 5.06 | 3.72 | 1.83 | 66.06 |
| Shower caps are transparent | 3.39 | 2.89 | 5.89 | 2.94 | 5.28 | 2.72 | 1.17 | 51.94 |
| Tables are made of wood | 4.67 | 3.11 | 5.78 | 3.72 | 5.72 | 3 | 1.17 | 58.22 |
| Taxis are yellow | 3.61 | 3.33 | 5.83 | 3.83 | 5.67 | 4 | 1.39 | 66.83 |
| Trampolines are black | 3.22 | 2.94 | 5.61 | 2.72 | 5.72 | 2.67 | 1.39 | 54.28 |
| Wallets are made of leather | 3.94 | 2.83 | 5.94 | 2.89 | 5.56 | 2.94 | 1.17 | 51.00 |

**Natural kinds**

| Bears perform at circuses | 3 | 2.56 | 5.61 | 2.17 | 5.67 | 2.33 | 1 | 27.94 |
| Birds are kept in cages | 3.89 | 3.17 | 5.67 | 2.78 | 4.56 | 3.33 | 1.5 | 31.24 |
| Cats like milk | 4.06 | 4.44 | 5.78 | 2.94 | 5.61 | 4.11 | 2.22 | 72.33 |
| Dogs bark at strangers | 4.89 | 3.39 | 6.28 | 3.83 | 5.39 | 4.44 | 1.5 | 59.72 |
| Dogs wear collars | 4.61 | 3 | 5.72 | 3.28 | 5 | 4.22 | 1.33 | 49.89 |
| Eggshells are white | 5.44 | 3.39 | 5.72 | 3.28 | 5.56 | 4.17 | 1.94 | 68.61 |
| Oranges are grown in Florida | 3.67 | 2.78 | 6 | 4.39 | 5 | 3.17 | 1.44 | 60.94 |
| Pigeons sit on statues | 3.61 | 3.5 | 5.83 | 2.72 | 4.94 | 4.11 | 1.89 | 67.22 |
| Pigs are kept in pens | 4.28 | 3.83 | 5.89 | 3.39 | 5.33 | 4.61 | 1.33 | 72.72 |
| Raccoons eat garbage | 3.61 | 4 | 6.06 | 3.11 | 4.83 | 4.44 | 1.83 | 65.88 |
## Appendix

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