Copredication and Ontological Mutability*

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Abstract

Copredication describes certain forms of expression occurring in natural languages, where seemingly incompatible types of predicate are applied to an object. This typically happens when the object is identified by a polysemous count noun whose possible interpretations span two or more distinct ontological categories (such as 'book', which can be interpreted either as an informational artifact or a physical object). Copredication poses a significant challenge for theories of linguistic meaning because, although many copredication examples seem to be natural and easily understandable, they are very difficult to account for within established semantic theories and formal representations.

The current paper overviews several approaches that have been proposed to account for copredication and identifies some limitations of these. A new approach is then outlined, which is based on a combination of *standpoint semantics* and *coercion*. Some wider consequences of the phenomenon of copredication are then considered. I suggest that it arises from a kind of ontological mutability that is embedded within the way that natural languages are understood.

Keywords

Copredication, Semantics, Ontology, Standpoint Semantics, Semantic Diversity

1. Introduction

In recent years the issue of co-predication has received much attention from researchers in formal semantics and linguistics [1, 2, 3, 4, 5, 6, 7] and its significance in relation to some fundamental properties in ontology design has also been considered [8]. In this paper I investigate the challenge of providing a formal representation and semantics that can account for the phenomenon. Rather than considering copredication from the linguistic point of view, which would require examining a wide range of examples and their interpretation, I will be focusing on fundamental issues of knowledge representation and trying to identify a method that can capture the semantics of some typical examples. I survey several approaches that have previously been proposed and identify advantages and limitations of these.

I shall also be considering whether previous work in the area of supervaluation semantics and standpoint logic [9, 10, 11, 12, 13] could be applied to explain the semantics of copredication. I find that these kinds of approach cannot account for copredication without a significant extension of the framework. However, I go on to suggest that a combination of standpoint

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semantics with a mechanism for type *coercion* may support a plausible theory that avoids some problems of other approaches.

2. The Problem of Copredication

Consider the sentence "There is a book by Quine on my shelf." Following a typical style of converting English into first-order logic, one might propose the following 'naive' classical representation:

$$\exists x[\mathsf{Book}(x) \wedge \mathsf{ByQuine}(x) \wedge \mathsf{OnMyShelf}(x)] \tag{1}$$

However, interpretation of this formula is problematic. The predicate Book can either have the sense of being an informational artifact or the sense of being a physical object. These are surely distinct senses, since when we describe a book as being original or interesting we must be speaking of its informational content, not the physical object; and conversely, when we say a book is heavy or water-damaged, we must be talking about the physical object rather that the information. In the example represented by formula (1), the authorship predicate, ByQuine, applies to a book in the informational artifact sense: Quine originated the content of the book but had no part in creating the physical object; whereas, the predicate OnShelf applies to a book in the physical sense, a material object occupying a particular location. It is this application of two predicates that seem to describe very different kinds of object, to what seems to be a single referent that is called *co-predication*. It typically occurs when there is some ambiguity in a sortal concept word (i.e. a count noun such as) which is used to form the object reference, but can also occur with certain proper names (e.g. names of fictional characters — see [7]) that can be interpreted in different way

The puzzle of co-predication is not so much that one can construct sentences in which copredication occurs. The real mystery is why sentences such as "There is a book by Quine on my self" of "Lunch was delicious but went on forever" [1] make perfect sense and do not even seem unusual.

3. Some Proposed Explanations

A number of possible explanations of copredication have been proposed in the literature. In this section I outline some of the more prominent of these. One should note that only simple versions of the theories are presented here, in order to give an overview of possible approaches. The works referred to give considerably more elaborate accounts.

3.1. Ambiguity Explains All? (No it does not)

An initial response might be just to say that this is easily explained in terms of the ambiguity of 'book': it can be interpreted in the intellectual artifact sense within the context of the 'by Quine' predicate, and in the physical object sense within the context of the 'on my shelf predicate.' But, although this may make some sense as an informal explanation, it does not give any clear idea of how one might specify a coherent semantic interpretation of formula (1). The issue is

not just that Book has two senses but that the quantifying phrase "there is a book" seems to imply the existence of an object that satisfies both of the two predicates 'by Quine' and 'on my shelf'. So the object would somehow have to be an instance of both of the two seemingly disjoint senses of 'book'. This is a very different from what we would normally call ambiguity. Moreover, in ordinary cases of ambiguity, it is expected that they ambiguity gets resolved in the same way throughout a sentence. If this is not the case, the sentence usually seems bizarre or humorous — for example "There were three banks in the village: the two banks of the river and the Barclays bank on the main street." For these reasons, no serious account of copredication suggests that it can easily be explained in terms of the familiar notion of ambiguity.

3.2. Dot Types and Dot Objects

One approach to formulating a semantics that can accommodate such examples is to propose that that books are a type of object that has both a physical and an informational aspect, and that, when a predicate is applied to a book object, it must be interpreted with respect to the aspect appropriate to the type of predicate (authorship applying to the informational aspect and physical properties applying to the physical aspect of book).

The idea of *dot types* compounded from two apparently disjoint types was proposed and elaborated by Asher [1] as a means to specify a semantics that can account for copredication and has also been suggested by Arapinis and Vieu as a means to specify ontological categories necessary to capture certain certain concepts within an formal ontology [8]. Using the formal apparatus of dot types, one may specify, e.g., Info•Phys as a type of compound object that has both informational and physical properties. So the predicate Book could be associated with this type.

Clearly, the introduction of dot types and objects carries significant ontological commitment and would require a fundamental modification of principles that are currently predominant in the design of ontologies.

3.3. Coercion

Another way that one might account for copredications is by some mechanism of *coercion*. As Asher explains, "a coercion is a function from one semantic value or one type to another that is employed when some problem arises in the construction of meaning" [14]. Programmers, will also be familiar with the closely related notion of *coercion* built into many programming languages. For example, a function that primarily operates on strings (e.g. a print function) may also accept a number argument, and if a number is given the function will automatically convert it to a string.

The potential of coercion to explain copredication is fairly obvious. If we consider formula 1, for this to be true we need to find a value that satisfies the three predicates Book, ByQuine and OnMyShelf. Suppose we take the 'primary' type of Book to be book in the physical object sense. Then, if there are any books on my shelf, there will be some instances of Book that are also instances of OnMyShelf. But these physical books cannot by instances of ByQuine which is a predicate applying to informational objects. However, we may propose that within the setting $\mathsf{ByQuine}(x)$ any argument x that is not of type Info will, if possible be coerced into an

object of type Info.

Of course, for this explanation to hold water, we need to have some plausible explanation as to how such a coercion might occur, and for KR purposes we would need some way to implement coercion with the apparatus of a formal language. Although such explanations are clearly not trivial, they certainly seem feasible. For instance, in the case of coercing a physical book object into an informational object we may make use of a relation Manifests(b, c) that holds whenever a physical book b contains a physical inscription encoding the informational content c. If we require that models for our formal language include an assignment specifying the Manifests predicate then this can be used to define coercion as a partial function from physical to informational books. Specifically, one might specify $info(b)$ as a partial function determined by the Manifests relation in cases where there is a unique informational object c, for which Manifests(b, c) is true. Moreover, the fact that not every physical book has information content with a unique author could explain why in some situations copredication does not permit a coherent interpretation.

4. Failure of Supervaluationism and Variable Reference Logic

In this section I consider another popular approach to modelling variable meanings and explain why, unless fundamentally modified, this kind of approach cannot explain copredication phenomena.

4.1. A Quick Introduction to Supervaluationism and Standpoint Logic

A well known approach to variability of meaning, and particularly to accounting for the meanings of vague conceptual terms is *supervaluation semantics* [15, 16]. The idea of this approach is that we consider the interpretation of propositions of a vague language in terms of all acceptable precise versions (*precisifications*) of that language. A proposition is called *super-true* if it is true according to all precisifications. In some versions of supervaluation semantics (e.g. [15]) it is proposed that for a vague language, the truth of a proposition should be equated with its 'super-truth'. One may also consider truth in some but not all precisifications as signifying the potential of being true under some reasonable interpretations of the language (i.e. as being 'true in some sense').

Standpoint Semantics [9, 10, 11] is an elaboration of supervaluation semantics in which different agents or contexts may be associated with different *standpoints* corresponding subsets of the set of all precisifications. This supports the representation of propositions as being true according to all, some or none of the precisifications within a given standpoint. In terms of this semantics one can specify a formal language of *standpoint logic*. This supplements the normal language of classical logic (either propositional or first-order) with standpoint operators: $\Box_*$, $\Diamond_*$, $\Box_{s_1}$, $\Diamond_{s_1}$, $\Box_{s_2}$, $\Diamond_{s_2}$, ..., such that $\Box_{s_i}\phi$ asserts that proposition ϕ is true according to all precisifications in standpoint s_i and $\Diamond_{s_i}$, asserts ϕ is true according to some precisification in s_i. The operators $\Box_*$ and $\Diamond_*$ have a similar interpretation but in relation to the whole set of all semantically acceptable precisifications.

4.2. Supervaluation Semantics Cannot Accommodate Copredication

Unfortunately, when we try to apply supervaluation semantics (or standpoint semantics) to copredication examples, we soon become convinced that any account that follows the usual general principles of supervaluation semantics must fail. The problem is that supervaluation semantics considers the interpretation of a vague sentence in terms of all its possible classical interpretations. In other words in terms of all possible precise interpretations (*precisifications*). If Book has two alternative precise meanings then each precisification must interpret Book as either one or the other — i.e. either an informational artifact or as a physical object. But in any precisification that makes the first interpretation, the predicate OnMyShelf must be false and in any precisification making the second, the predicate ByQuine must be false. Hence, there will be no precisification where all three predicates can be true of any given object.

4.3. Variable Reference Logic Does Not Work Either

Recently, standpoint semantics has been elaborated in order to support a *Variable Reference Logic* (VRL) [12, 13], which, in addition to allowing predicates to be vague, also allows objects to be vague, in the sense that a vague object is one that corresponds to many possible precise versions. Typical cases where such vague objects might be required are in reference to geographic objects such as deserts or mountains, where one may clearly identify that such an object is present and yet not be able to specify a unique spatial extension for the object. Thus vague objects are precise in relation to their *individuation* but indeterminate in terms of other properties (such as exact spatial and material properties).

Unfortunately, although it might at first seem that we can use indeterminate objects to model the referent objects in a copredication situation, this explanation does not work. To fully explain the issue would require quite length exposition of the VRL semantics (see [12, 13]). However, I hope that the following paragraph gives a comprehensible sketch of the difficulty.

The problem is that we still have to decide what kind of objects are instances of Book according to different precisifications of that concept. And since book seems to be polysemous it is very natural to consider that it has an informational sense in some precisifications and a physical sense in others. But this means that, even though the semantics permits indeterminate objects, these objects must be either indeterminate informational objects or indeterminate physical objects, depending on the precise interpretation of book. So we would not have objects that are indeterminate between being an informational object or being an informational object.

The only way to avoid this problem seem to be to allow that there are objects that instances of some precise interpretation of Book, but which are nevertheless indeterminate between being informational or physical objects. Formally, this is perfectly possible. However, the effect would be essentially the same as introducing Info•Phys dot types into the representation. And once we do that, there is no need for any of the other apparatus of standpoint semantics or VRL.

5. Problems with Counting

From what we have seen so far it seems that both the approach using *dot types/objects* and the approach making use of *coercion* might provide reasonable accounts of coercion. However,

there is a further issue that still poses a considerable difficulty to establishing a plausible theory. This issue arises when copredication is combined with some numerical quantification of the number of objects involved in the situation. Consider the sentence: "There are two books by Quine on my bookshelf."

$$\begin{aligned}\exists x \exists y [x \neq y \wedge \mathsf{Book}(x) \wedge \mathsf{Book}(y) \\ \wedge \mathsf{ByQuine}(x) \wedge \mathsf{ByQuine}(y) \\ \wedge \mathsf{OnMyShelf}(x) \wedge \mathsf{OnMyShelf}(y)]\end{aligned}$$

The problem is that determining how many books by Quine are on my self depends upon whether I count in terms of informational artifacts or physical volumes. I might have two copies of the same book, or two book titles contained within the same volume (or some more complex combination of volumes and contents). Thus, a claim regarding the number of books can only have definite meaning once I choose what kind of book object I wish to count. But accepting this leads to a recapitulation of the original problem. Once I choose between informational and physical books, I am no longer dealing with entities that can support both the informational property of the books content originating from a particular author and also the physical property of being a physical object located on a particular shelf.

Neither the dot object or coercion approach provide any obvious way of addressing this numerical quantification issue. In the case of dot objects, the prospects seem quite bad since dot objects combine two aspects into a single object. So it seems hard to envisage that such objects could be counted in different ways. Nevertheless, as outlined in the next section, Gotham [2, 17] has proposed one way that seems to be compatible with at dot object approach.

6. Gotham's Account of Quantification and Counting

Gotham [2, 17] has proposed a somewhat complex semantics that addresses the counting problems associated with copredication. As [1] and [8], Gotham proposes that objects can be of a complex compound type. To address the issue of different counting criteria Gotham also specifies a mechanism by which individuation criteria of different types of entity can be incorporated to form composite individuation criteria taking into account the criteria associated with both of the component types.

Different senses have different individuation criteria giving rise to different counting principles. This difference can be located within the equality relation associated with a particular mode of individuation. According to Gotham the individuation criteria appropriate for counting objects in a given context are induced by the predicates in which they occur. Moreover, compound types are created compositionally when different types of predicate are applied to a quantified variable. Predicates that apply to an informational sense of book will give rise to counting in terms of informational objects and those applying to physical objects will induce counting in terms of physical volumes. And in the case of co-predication involving both informational and physical properties are 'composed' by taking the union of the equality relations for each mode. In the case of books, this means that, when one counts 'informative'

'heavy' books, one should count entities that are distinct both in terms of informational content and physical constitution.

Gotham's theory provides a rather ingenious semantics that directly addresses the counting issues arising from copredication and also gives truth conditions for sentences involving compredication and counting that seem reasonable in relation to a variety of situations. However, there are also situation for which Gotham's truth conditions seem rather strange. For example suppose a writer W has written five novels, which for conciseness we simply call A, B, C, D and E. Now suppose that on my shelf I have 2 copies of novel A and two copies of a collected work containing all five novels. How many books by W are on my shelf?

According to my reading of Gotham,[1] the answer is 3. To see this we number the 4 physical volumes as 1–4. Then we consider the composite pairs consisting of physical volumes and informational novels. These are: $1{\bullet}A$, $2{\bullet}A$, $3{\bullet}A$, $3{\bullet}B$, $3{\bullet}C$, $3{\bullet}D$, $3{\bullet}E$, $4{\bullet}A$, $4{\bullet}B$, $4{\bullet}C$, $4{\bullet}D$, $4{\bullet}E$. We then have to find the maximal size of subset of these combinations such that no two members of that subset are associated either with the same volume or with the same content. There are actually several choices. One of these is: $\{1{\bullet}A, 3{\bullet}B, 4{\bullet}C\}$. I find this very unintuitive. I would say that the number of books is ambiguous between 4 if we mean physical books and 5 if we mean informational artifacts. The fact that it gives specific and quite elaborate truth conditions for interpreting seemingly ambiguous sentences makes me uneasy with Gotham's theory.

7. A New Proposal

Having given an overview of some previous proposals and noting some of their limitations, I now present my own. The idea is that we can account for copredication phenomena by a combination of two interacting modes of semantic articulation:

- There is variability of the meaning, and hence also the type and the individuation criteria, associated with the count noun that specifies the range of quantification. This variability can be captured by a precisification based semantics, similar to that used for Standpoint Logic.
- A coercion mechanism is built into the interpretation of predication and comes into play whenever a predicate is found to operate on an argument that is not if the expected type. This mechanism will convert an argument object to a related object of the required type, on the basis that the given argument uniquely determines an associated object of the required type.

In order to see how these mechanisms would be implemented within a formal representation I make a few fairly modest modifications to the normal first-order logic syntax. (Probably these are not strictly necessary, but I think they make the representation clearer.) Firstly, we associate each quantifier with a count noun, in the fashion of a *sorted* logic. And, keep numerical

[1] Whereas Gotham gives a very precise explanation of how we count objects with compound types, I found his presentation somewhat vague regarding which compound objects should be considered. From his examples, it seems that we consider each pair $\langle v, c\rangle$, such that v is a physical volume and c is an informational work contained within volume v, where each volume may contain one or several informational works.

quantification simple, I will allow a numerical subscript to be added to the existential quantifier. Finally, I add coercion functions within the argument places of each predicate, indicating that the argument should be converted to the required type if possible. Hence, "There are exactly two books by Quine on my shelf" will be represented by:

$$(\exists_2 \,\mathsf{Book} : x)[\ \mathsf{ByQuine}(\mathit{info}(x)) \wedge \mathsf{OnMyShelf}(\mathit{phys}(x))\ ] \tag{2}$$

So how should this be interpreted? We assume a standpoint semantics; but in this case it can be extremely simple, since the only term that exhibits semantic variability is Book, which we assume to have two precise interpretations corresponding to the information artifact and physical object senses of the word. Thus, we have precisifications $\pi_{\mathbf{info}}$ and $\pi_{\mathbf{phys}}$. Since the Book predicate is attached to the existential quantifier, it is the interpretation of Book that determines the counting criteria that will be applicable. Hence, the precisifcations $\pi_{\mathbf{info}}$ and $\pi_{\mathbf{phys}}$ are associated with quantifiying over different kinds of object with different counting criteria. However, whereas with the earlier versions of standpoint logic (and VRL) it was not possible for both ByQuine and OnMySelf to both apply to any object in any precisification, we now have coercion functions as well. Hence, whichever interpretation of Book is chosen, some value for x can potentially satisfy both of the predications $\mathsf{ByQuine}(\mathit{info}(x))$ and $\mathsf{OnMyShelf}(\mathit{phys}(x))$. If we take Book in the physical sense then the *info* coercion function will come into play, whereas for Book in the informational sense, the *phys* function will be needed.

What this means is that in the general standpoint '$*$' comprising all precisifcationsm, i.e. $\{\pi_{\mathbf{info}}, \pi_{\mathbf{phys}}\}$, the formulae $\Box_*(\exists_2 \,\mathsf{Book} : x)[\ \mathsf{ByQuine}(\mathit{info}(x)) \wedge \mathsf{OnMyShelf}(\mathit{phys}(x))\ ]$ will be true provided that for either interpretation of Book we can, using a suitable coercian function, find to instances that satisfy both of the predicates. Morover, in cases where only one of the interpretations of book yields two satisifying instances, we will have the formula $\Diamond_*(\exists_2 \,\mathsf{Book} : x)[\ \mathsf{ByQuine}(\mathit{info}(x)) \wedge \mathsf{OnMyShelf}(\mathit{phys}(x))\ ]$ being true. And furthermore we can specify standpoints $s_{\mathbf{info}} = \{\pi_{\mathbf{info}}\}$ and $s_{\mathbf{phys}} = \{\pi_{\mathbf{phys}}\}$ corresponding to particular agents or contexts in which the interpretation of Book is restricted to one of the two possible interpretations.

8. A Wider View

Copredication may seem like a relatively specific and peculiar oddity of language that only affects certain unusual linguistic constructions. However, after studying it at some length, I have come to the view that it may be more significant than it first appears. Once aware of its possibility, I became more sensitive to its occurrences, and found that shifts in ontological status of referent objects are much more common than I had appreciated. They affect a large number of very common words, including for example: meal, dance, film, celebration, library, nation, political party, to list but a few. Moreover, the ontological shifting that can occur may cover a very large number of distinct ontological categories.

It seems to me that it is actually the ontological shifting and diversity of interpretations that is the deep explanation of copredication and this presents challenges for knowledge representation in general, that are not at all specific to copredication examples. The real issue is that there are many very common natural language words to which we cannot straightforwardly assign any particular 'ontological type'. If we try to make such a stipulation, any semantics based on this

assignment will only explain a very limited subset of possible uses of the word. The concept 'meal' provides a good illustration of this 'ontological mutability'.

8.1. Meal

The word meal is vague in a huge number of ways. There are many considerations relating to 'borderlne' issues, such as the distinction between a few mouthfuls and a meal or whether there could be a meal where nobody actually ate anything (e.g. the dining hall was evacuated due to a fire alarm). But we are now interested only in polysemy relating to fundamental ontological type giving rise to different modes of individuation and counting. I suggest that the following six individuation modes can be distinguished.:

(A) A type of eating event, usually differentiated by time of day it is eaten, but also associated with a range of typical foods:

- "Half board accommodation includes two meals. You can choose either breakfast and lunch or breakfast and dinner. Full board includes four meals: breakfast, lunch, afternoon tea and dinner."

(B) An eating event occurence which can be solitary but often involves multiple people participating in the same meal.

- "The conference programme included two meals: a reception buffet and a formal dinner"

(C) An individual eating event:

- "One pizza and one salad is enough food for three meals."
- "We ate together at the bistro. John loved his meal and we both liked the food, but I didn't enjoy my meal as I kept thinking about the money I had lost."

Here, we could further differentiate senses where we are thinking of the actual food from senses where we are thinking about other aspects of the experience. What is essential to this mode is that the 'meal' count will be the same as the number of people involved.

(D) A physical food portion. That is, a quantity of food prepared for (and usually served to) an individual person during a particular time interval:

- "The students ordered 8 meals between them — 5 pizzas and 3 omelettes. 2 of the students just ordered a beer."
- "The refectory prepares over 500 meals each day. Usually fewer than 20 go to waste."

(E) A physical food ensemble intended for a group of people:

- Three meals had been laid out. One on each of the three tables. Each of the meals was for four people.

(F) A particular food type or collection of food types often eaten together:

- "Pancakes (with blueberries) is one of my favourite meals."

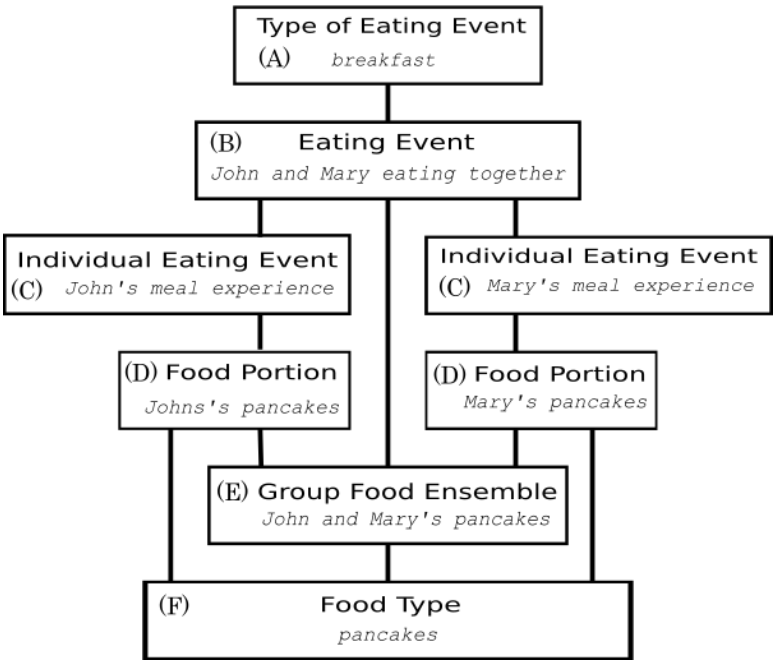

Figure 1: Some senses of 'meal' with different modes of individuation.

- "The menu lists five set meals including two vegetarian meals"

(G) Complex eating event types. One can potentially specify and enumerate a wide variety complex eating event types. Such meal types are listed in certain kinds of menu:

- "The cruise offers three special meals, which you can book as many times as you wish: oysters and champagne in your cabin, tea and cake for two on the poop deck, fish dinner at the captain's table.

Meals individuated by mode (F) have a similar ontological status to those of mode (A) but are more specialised and are typically combined with food specifications akin to mode (F); and they support a counting mode that is distinct from either (A) or (F).

9. Conclusions

Although the current paper is largely exploratory and open ended it does bring to light some difficult issues that confront the task of representation and reasoning using a formal language that has similar expressive capabilities to natural language. I conclude with a couple of general observations:

- Indeterminacy of natural language vocabulary affects involves a number of aspects and affects different elements of semantic structure in different ways.
- Ontological mutability, in the form of shifting (or perhaps merging) of ontological category is revealed in the phenomenon of copredication, but is also pervasive in more subtle kinds of semantic variability.
- Whereas supervaluationist semantics and standpoint theory are good for modelling 'horizontal' variability of linguistic terms (where a term's meaning varies in its range of application but not in its fundamental ontological category); however, it is not good for modelling vertical variability of terms (whose meaning may shift in ontological category event within a sentence).
- Coercion functions are required to understand many constructions found in natural language and may also be useful (perhaps essential) in the design of general purpose Knowledge Representation infrastructure, such as ontologies.

In further work I aim to further develop these ideas and incorporate them within formal languages with the aim of capturing the conceptual flexibility of natural languages in such a way as to be useful for KR-based AI applications.

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