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Csaba Veres

*The University of Melbourne, veres@unimelb.edu.au*

Steve Hitchman

*University of Melbourne, steve@eggconnect.net*

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# USING PSYCHOLOGY TO UNDERSTAND CONCEPTUAL MODELLING

**Dr. Csaba Veres**

Department of Information Systems  
The University of Melbourne  
Tel: +61 3 8344 0711  
Fax: +61 3 9349 4596  
veres@unimelb.edu.au

**Dr. Steve Hitchman**

Department of Information Systems  
The University of Melbourne  
Fax: +61 3 9349 4596  
steve@eggconnect.net

## ABSTRACT

*There have been a growing number of publications suggesting that philosophical ontologies will define a rigorous basis for conceptual modelling, particularly for data modelling methods and notations. An examination of an underlying psychological assumption of the conceptual modelling process is used to show that philosophical ontologies are being used as a 'telescope' to view the products of yet another 'telescope' and this undermines their reliability by being too far removed from the actual modelling process. An ontology of conceptual structure, derived through linguistic analysis provides a psychologically realistic alternative to the philosophical ontologies that is as close to its mental interpretation as possible and is a more promising approach to understanding the modelling process.*

## 1. INTRODUCTION – ONTOLOGIES AND THE REAL WORLD OF MODELLING

There is a growing interest in the information systems community to provide a foundation for conceptual modelling through the use of philosophical ontologies. The best developed of these foundations is described by Wand et al (1999, p.494) who claim that "...Because conceptual models are intended to capture knowledge about a real-world domain, we take the view that the meaning of modelling constructs should be sought in models of reality. Accordingly, we use ontology, which is the branch of philosophy dealing with models of reality, to analyze the meaning of common conceptual modelling constructs." In short, the ontologically sound constructs will be better if they accurately reflect the world. Wand et al base their work on the ontology developed by Bunge (in several texts).

Wand et al (1999, p.497) postulate that "... domain modeling is based upon someone's view of *existing* or *possible* reality ... the notion of a concrete thing applies to anything *perceived* as a *specific object* by someone, whether it exists in physical reality or only in someone's mind. In this light , a bank account is considered a thing, as well as a product that has been designed but not yet produced.

Both are concrete things in someone’s mind”. This is equivalent to a definition of entities that directly reflects the original definition given by Chen (1976) in the original edition of the same journal. Almost all authors referring to Chen’s definition have ignored any interpretive issues and instead taken a positivist stance (Hitchman 1997). However, the paper by Dey et al (1999, p.456), in the same journal issue as the Wand et al (ibid) paper and with a co-author in common, uses this positivist approach with “An entity instance as a “thing” or an object that has a separate identity in the real world.”. This contradicts their previous position, and raises serious questions about the status of entities according to the ontological claims made by Wand et al (ibid).

Wand et al (ibid, p.498) make a distinction between intrinsic properties that depend on one thing only, such as a person’s height, and mutual properties that depend on the existence of two or more things. The ontological constraint suggests that a conceptual model should not represent a mutual property which results from decomposing many to many relationships – such decomposition to a ‘link entity type’ is seen to be an ‘implementation’ construct rather than a conceptual modelling construct. Categories of ‘things’, such as a list of skills (a ‘skill’ entity-type) or types of rental car (‘rental category’ entity-type) would also not be regarded as ‘classes’ of things in this ontology.

To compare the Wand et al (ibid) ontology with a real situation, we can use a transcription of a practitioner modelling session and a diagram reported in Hitchman (2002) The diagram is shown in Figure 1 and the modellers use an ‘I’ notation to indicate that the primary key of, say, skill, is also part of the primary key of worker skill. Using the Wand et al (ibid) ontology assignment cannot be a class since there are no ‘things’ in it – the attributes here are all mutual properties – an assignment only ‘exists’ because of the interaction between the worker, city and project. Similarly ‘worker skill’ has only mutual properties and exists because a skill is used on an assignment.

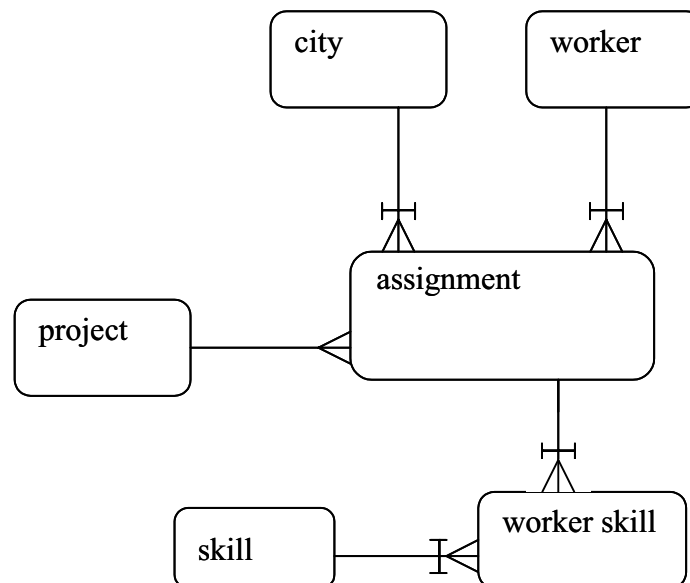


Figure 1. Practitioner modeller’s perception of a scenario (from Hitchman 2002)

However, it is clear from the transcription of the modelling session that the practitioners *perceive* as a *specific object* in their mind both ‘worker skill’ and assignment as ‘things. For example:

“So, you’re now saying that assignment is current assignment”

“No, because they can have several current ones but assignments could now only be current assignments and not assignments over time”

“A worker has a number of skills, does that mean a worker used a skill set on a particular project assignment ?”

“If you are a new employee with seven skills on just one project only using two skills how do you know what the others are ?”

“So, this thing here (*pointing to worker skill on the diagram*) each one of these is one skill being used on one project”

In the last example the practitioners are talking either about their perception of ‘worker skill’ as an idea in their mind, or more probably about ‘worker skill’ as a row in a table in a database.

The problem in attempting an ontological definition of these concepts is that this definition needs to include the way that the concepts are used, interpretively, during a conversation. Such interpretations will conflict with ontological rules, such as mutual properties – such rules do not appear to apply to conversations or minds. There is no problem for these practitioners in talking about either assignment or ‘worker skill’ as a ‘thing’ – these are ‘things’ that help the practitioners understand the scenario. The basic claim of Wand et al (ibid) and others, is that the entity-type construct is unnecessarily overloaded because their ontology necessitates considering concepts like assignment and ‘worker skill’ as different sorts of concepts to those of ‘worker’ or ‘project’. However, there is clearly no particular problem for the practitioners in considering either of these concepts in constructing language about the scenario in order to make sense of it. Whilst we might consider that ‘skill’ and ‘assignment’ are in some way different to ‘worker’, these concepts can be used in the same way during a conversation designed to make sense of the situation

## 2. WHY ONTOLOGIES MAY NOT HELP

The reason for the difficulty in applying an ontology to a modelling session conversation is that the ontologically sound constructs are the result of using a particular ‘telescope’ to view the world. Using modelling constructs is another sort of, perhaps, microscope, used to view the same world. There is no reason to suppose that using the results of what can be seen through one telescope, in order to define the building of a microscope picture will be successful. (This analogy is based on the argument in Mingers, 2001 concerning the use of different paradigms.) If a particular philosopher believes that mutual properties are ‘what is there’ but a group of practitioners is happy to believe that rows in a relational database are ‘things’ then the ontology has a problem, especially if the ontology might allow that “the notion of a concrete thing applies to anything *perceived* as a *specific object* by someone, whether it exists in physical reality or only in someone’s mind”. Further, there is no reason to suppose that ‘mutual properties’ as a way of thinking are going to be either useful or better when a team of modellers design a database in the context of a full understanding of how that database works. To imagine that ‘conceptual modelling’ of data takes place without knowledge of databases would be rather like trying to design a bridge and pretend that reinforced concrete and steel did not exist.

Yet in spite of these seemingly self evident facts, Wand et. al. (ibid) emphatically claim that a notational system which conforms to an acceptable ontology is somehow to be preferred to one which does not: an ontologically well founded notation will avail itself to interpretation more readily and clearly than one which does not. Perhaps the idea is that, if we provide a notation that encourages modelers to adhere to ontologically sound principles, then they will abandon their somewhat naïve practices. The reason for this is that models “... are intended to capture knowledge about a real-world domain ...”, so the best way to define the meaning of the constructs is with reference to an independently argued and well thought-out model of reality. At this point the use of the ontology seems to move away from interpretive and takes a more positivist stance. But there is a strong, unarticulated assumption behind this move.

The assumption revolves around the question of **why** an ontologically inspired model should be easier to interpret and use by humans? Why **can’t** we make up arbitrary modeling constructs divorced from conceptualizations of reality, and expect people to use those? The assumption is that the human interpretive system is tuned to the entities which make up the world humans live in, and is therefore

more efficient in thinking about things it expects to find in the real world. If the modeling notation reflects the entities that exist in the world, humans will find it easier to use. This is certainly not an outlandish claim, and there is no shortage of evidence from cognitive science to support it (e.g. Gigerenzer and Hoffrage 1995, Pinker 1997, Cosmides 1989, Jackendoff 1983, Shepard 1987). These authors argue from various sources that cognitive mechanisms have evolved as a means to deal with the information processing demands of the environment, and as a result our cognitive mechanisms are highly specific, and tuned to the contingencies one encounters in real world environments. For instance, in a series of fascinating studies Lida Cosmides (e.g. Cosmides, 1989) and her colleagues have argued that the pattern of response errors on the classic Wason selection task can be explained by reasoning mechanisms tuned to detect cheaters in social scenarios. They argue that we have poor facilities for abstract reasoning, but that we solve swiftly and effectively those problems which fit with the sorts of scenarios that lead to the evolution of the specific reasoning mechanisms we have. Reasoning is tuned by evolution to solve specific problems which were significant in our evolutionary history, in the real world.

Such claims support the idea that a “good”, realistic ontology of the world should capture those elements in the world with which we ought to be particularly adept: the real things that exist in the world we evolved in. The critical use for an ontology on this view is that it accurately captures the entities that exist in the world, and therefore tells us about the entities to which we are best tuned for interpretation. The implication, then, is that a notation that also contains these entities should be one that is also highly interpretable. The best way to model reality is the way reality really is.

The assumption seems quite sensible and harmless. If we have good reason to believe that the world contains certain entities, which are accurately described in our ontology, AND we suppose that the mind deals best with entities that really exist in the world that the mind inhabits, then we should expect the mind to prefer notational systems that represent the sorts of entities our ontology informs us about.

But - there is a problem. What if the human mind did not evolve to encode the entities in the world in this simple and straightforward way? That is, Wand et. al. (ibid) have assumed that there is a one-to-one mapping between entities in the world and the way we think about them. But what if instead, we were designed to capture certain non-intuitive generalizations that might obtain in the world. Thus, interpretation could involve processing events which are not obvious from simply looking at the world. For instance, consider the way we think about a hierarchically ordered set of entities, like the class of animals. The class of “animals” belongs in a hierarchical ordering which goes from "living thing" through “animal”, "mammal", and the various species like "cat" and "dog", through "burmese", "siamese" and so on. At each stage the categories become more specific, and branch in several different directions. An ontology for such a tree could be easily constructed. But an ontology would not tell us how people use their knowledge of this ontology. What do people think when they are shown a picture of my siamese/domestic shorthair cross, Mini? Do they think they are looking at a "living thing", a "siamese/domestic shorthair", a "mammal", or a "cat"? To answer this question, Eleanor Rosch (e.g. Rosch 1978) has conducted a series of experiments to argue that people prefer to think in terms of a "basic-level category" in such hierarchically organized domains. That is, there is a level of representation at which people perceive the difference between different members in the hierarchy to be most diagnostic, and they tend to categorize novel objects at this level. Quite simply, when people see the picture of my Mini, they say “boy, what a gorgeous cat”. An ontology of the world could not tell us this: it would tell us what sorts of things we think about, not HOW we think about them, or which are the important ones. This is why it is difficult for the Wand et al (ibid) ontology to claim that the idea of an ‘assignment’ is in some way incorrect in modelling – they have no grounds for claiming that psychologically, such entities are not “real”.

The point, then, is that there is a forgotten link between a philosophically derived ontology and a notational system based on that ontology; the human mind. It is the mind that was responsible for constructing the philosophical ontology, and it is the mind that uses modeling notations in information systems. An ontology is a view of the world as described through a human construction. It is a

projection derived from the philosopher's perception about the nature of the world. Similarly, a notational system is a projection of the way we think a domain can be represented. If it is by virtue of the correctness of an ontology that we can claim veridicality for a notation then we are mistaken, for we are simply using one projection to evaluate another.

This is a rather strong claim. It is therefore doubly important to note that fortunately the question is an empirical one. We can empirically investigate mental structure. It might turn out that Bunge's ontology captures precisely the way in which we mentally encode and process information about the world. The ontological constructs could map directly onto the mental representations that encode them. In this case the present theoretical claim would become vacuous since the generalizations from the study of mental representations would be isomorphic to those derived from the study of ontologies. The empirical claim, therefore, is simply that this is not true: there is something important beyond an ontology of "reality" in describing the meaning of conceptual modeling constructs.

To summarize, we suggest the possibility that Bunge's ontology fails to capture certain deep underlying regularities of the human cognitive architecture responsible for comprehending the world, with the consequence that certain important interpretive patterns are missed. The suggestion is that we would be better served in studying the cognitive components which are responsible for interpreting reality, and to use what we know about the processes responsible for interpretation to inform us about the use of notational systems. The claim is that the best way to model reality is not the way it "really is", but the way we think it is.

### 3. A PSYCHOLOGICAL ONTOLOGY

To pursue the theoretical aims, it is necessary to specify a useful theory of conceptual structure. This is no easy task. There is an enormous volume of work published around the central themes of meaning, concepts and interpretation. This is more a problem than a blessing, as the cognitive psychologist Johnson-Laird once remarked, "the less that is known about something, the more that is written." In this paper we will therefore argue that a theoretical framework proposed by the linguist Ray Jackendoff is the most useful for our purpose. Jackendoff argues that the formal properties of language, and language use, can inform us directly about the nature of conceptual structures. We should note that Linguistics is a discipline that is perhaps *the* paradigm example of a success story in the cognitive sciences, and therefore a prominent theory from the field has surface validity at least.

The theory was discussed at length in the book "Semantics and Cognition" which was described by the psychologist Lila Gleitman as "... almost for the first time, we have a book that suggests plausible bridges between theories of lexical semantics and theories of cognitive and perceptual processes, presented in a way specific enough to do us good."

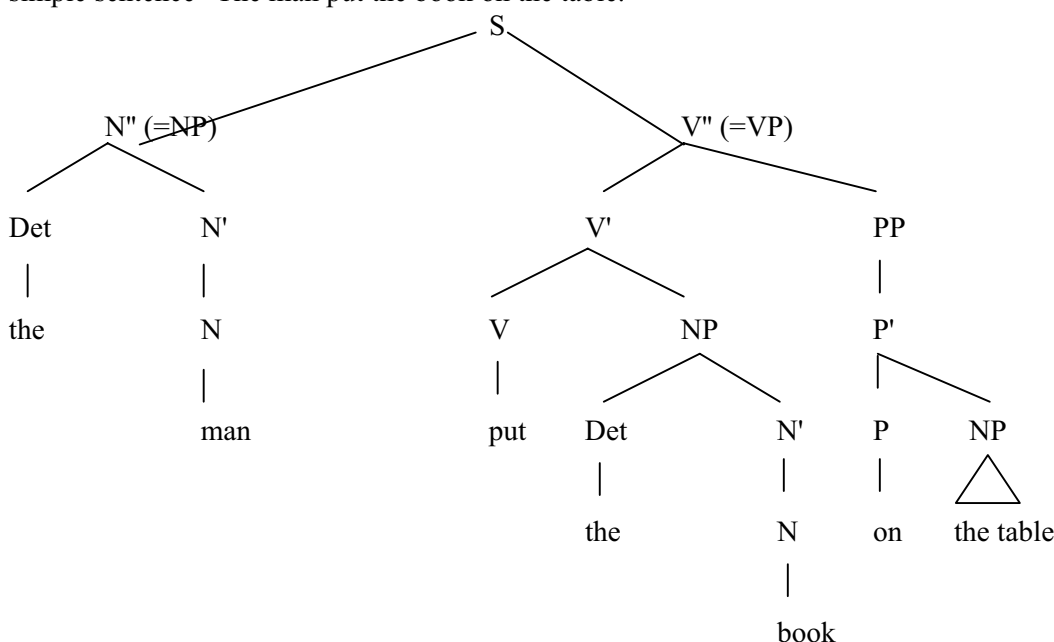
In the book, Jackendoff (1983) hypothesized that the properties of linguistic structure could provide direct evidence for the properties of conceptual structure. Language is taken to be a communicative stream designed for the transmission of messages ("designed" by natural selection, Pinker and Bloom 1990). The computational components of language are organized in a modular fashion, and during real time processing various different sub tasks are managed by different sub systems (e.g. Fodor 1983, Forster, 1987). Thus, the way speech sounds are organized follow specialized rules of phonology which are separate from the rules of syntax that determine the way groups of speech sounds, packaged into lexical units, combine to form sentences. The modularity of syntax can be demonstrated in many ways, but one intuitively appealing demonstration involves subject-verb agreement errors (e.g. Bock, et. al. 1999). The observation is that people routinely produce errors like: "The key to the cabinets are in my pocket." They do this in both spoken and written language. It can be shown experimentally that the rate of errors is not affected by semantic or conceptual facts, but simply by the syntactic markings carried by the lexical items. They say "are" instead of the correct "is" in the above example because of the proximity of the syntactic marker for plural in "cabinets". Error patterns are best explained by the way such markers might propagate in a syntactic structure.



Jackendoff (1983) argues that the complex and elegant rules of syntax, while modular in nature, are nevertheless not arbitrary with respect to conceptual structures. That is, certain aspects of the way we structure syntactic elements is determined by conceptual structure. The suggestion is not dissimilar to the dual notions of interface and implementation in object oriented design. If the syntactic module describes an implementation, it can have many self contained rules and methods, but it must also present an interface which is understood by external information processors. In this case, the common interface between conceptual and syntactic structure impose certain conditions on the data types in both syntax and semantics. Let us consider more specifically the way this correspondence works. The reader should keep in mind the main point while considering the following technical discussion: syntactic structures inform uniquely on the nature of conceptual structures. Important distinctions in syntax tell us important properties of mind.

Universal grammar allows certain categories of lexical items. The four major ones are verbs (V), nouns (N), adjectives (A), and adpositions (P; prepositions or postpositions depending on whether they precede or follow their complements) (Chomsky, 1988). Although there are more minor categories, the basic elements of the lexicon fall within these four categories. In addition, each of these basic categories has a projection of which it is the head: verb phrase (VP), noun phrase (NP), adjective phrase (AP), adpositional phrase (PP). Thus, for instance, “speak English” is a VP in which the verb “speak” is the head, and its complement is an NP, the single noun “English” in this example.

Jackendoff (1983) further argues that corresponding to each lexical category there is a major phrasal category, which maximizes the possible modifiers of the lexical category. The major phrasal category corresponding to N is NP, to A is AP, and to V is S. This final stipulation states that a sentence S is the major phrasal category for a V. To illustrate the relation between these constituents, consider the simple sentence “The man put the book on the table.”



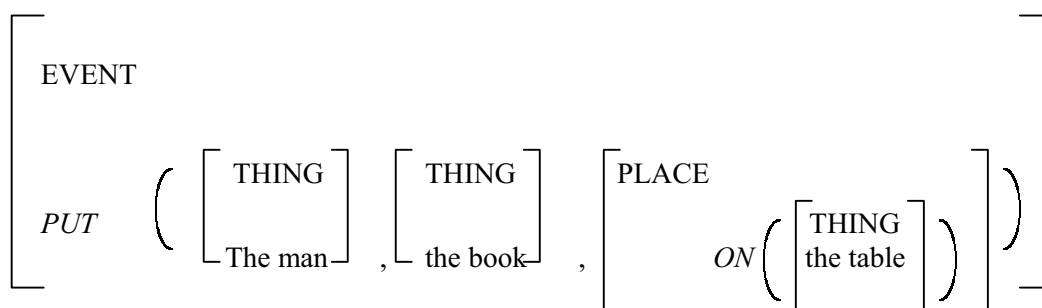
With this very basic overview of syntactic theory in hand, we are ready to consider the relevant aspects of Jackendoff’s theoretical claims.

The crucial point is that there are mapping rules which allow major syntactic categories to map onto conceptual ones. The fundamental component of such a conceptual system is the vocabulary or the basic representational elements of the system: the “conceptual parts of speech” which define the ontology of mind. Jackendoff argues that “... every major phrasal constituent in the syntax of a sentence corresponds to a conceptual constituent that belongs to one of the major ontological categories.” The identity of the conceptual constituents themselves is given with reference to the

lexical head of the phrase.

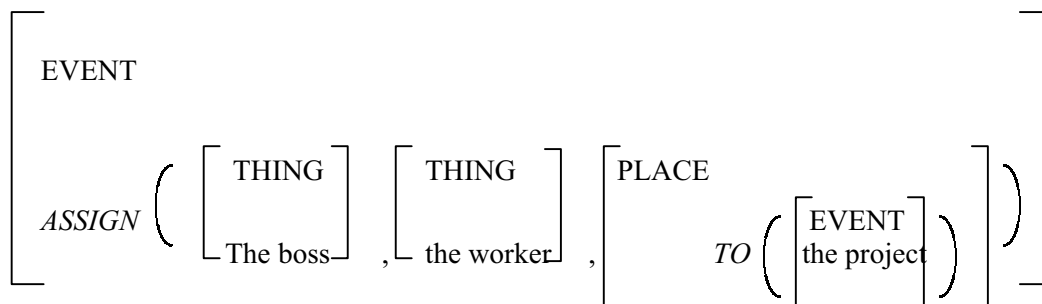
Consider once again our example, “The man put the book on the table”. The major conceptual constituents are given by the S, two NPs, and a PP, which collectively form the sentence. The head of S is the verb “put”, which expresses a semantic function that maps its arguments onto an [EVENT]. The lexical items “man” and “book” correspond to [THING]s. Finally, the PP has as its lexical head the word “on”, which maps into a [PLACE].

The major conceptual constituents can be thought of as the range of functions that are defined by the lexical head of major phrasal constituents. In other words, the head of a syntactic constituent corresponds to a function in conceptual structure that maps its arguments into a conceptual constituent. Returning to our example, “put” is seen as a function which maps its arguments ([THING],[THING],[PLACE]) into an [EVENT], “man” and “book” are zero place functions (constants) that map into [THING], and “on” is a one place function mapping a reference object (“the table”, which is itself a [THING]) into a [PLACE]. As a first approximation, then, the following represents the conceptual structure of the sentence “The man put the book on the table.”



An important property of this representation is that while the conceptual constituents differ in their identity, they are treated equivalently by many processes in conceptual structure. With this assumption, Jackendoff is able to make generalizations about linguistic facts that seem to ignore the differences in conceptual type. For instance, there is a similarity of meaning between “The train went from Paris to Rome” and “The meeting went from 9 to 5”. Or, as another example, restrictive modification seems to work similarly for [things], [events], [properties], and [paths]: “red hat”, “quickly dropped”, “quietly obnoxious”, and “straight down”. That is, in some respects, there is NO DISTINCTION TO BE MADE BETWEEN CONCEPTUAL CONSTITUENTS OF DIFFERENT TYPES.

But given this, consider the following sentence, which could be taken from the example at the beginning of this paper: “The boss assigned the worker to the project”. The syntactic similarity of this sentence with the one above is clear. But more importantly, we would argue that the conceptual structures for the two sentences are also similar, except perhaps that a “project” is (perhaps) an [event] rather than a [thing].





But the specific identity of the conceptual constituent is not significant for our purposes. What is important is that table and project both map onto equivalent conceptual constituents, albeit with different names. An [Event] can serve in the same way as [Thing] in conceptual structure, contrary to philosophical ontologies.

We make a similar point concerning the notion of an “assignment”, which as we have seen, Wand et al (ibid) deny an independent existence. According to our view, an “assignment” would map onto a conceptual constituent (an [event] perhaps) just as readily as a “worker” or a “table”. There is therefore no mystery about why modelers perceive “assignment” as an object in their minds.

#### 4. CONCLUSION

It should be clear that the proposal in this paper is twofold. First, there is a claim that the ontology which forms the foundation of modeling notations should be a psychological one. Second, it is claimed that the ontology should itself be defensible through empirical investigation. To this end, it was suggested that Jackendoff’s proposals were particularly useful since he uses language as a novel and exacting source of evidence. Language serves as a telescope: it is a measuring instrument which allows us to “see” the hidden and secret components of conceptual structure and is the medium for data modelling. It is these language components which show us the most direct and straightforward means of constructing and interpreting conceptual models. Happily, our deliberations thus far suggest that modelers intuitions about the sorts of entities that can be represented, seem justified on psychological grounds. We should therefore resist prescriptive ontological claims. Finally, we are currently engaged in experiments to test the usefulness of new modeling constructs constructed from a theory about the nature of conceptual structures. We eagerly await the results.

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