

Language Games, Natural and Artificial

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Abstract

Natural languages are the ultimate knowledge representation languages. Everything that can be expressed in any artificial language or notation can be expressed with equal precision in a natural language. For many applications, however, artificial languages can be more concise or better tailored to the requirements. A key to understanding the relationships between natural languages and artificial languages is Wittgenstein's theory of *language games*: the semantics of a natural language consists of the totality of all possible language games that can be played with a given syntax and vocabulary, but an artificial language is designed for a single language game. The lexical ambiguities of natural languages result from the option of using and reusing the same words in multiple ways in multiple games. Those ambiguities can be eliminated by restricting the discourse to a single language game or a limited set of closely related games called a *sublanguage*. This talk will present examples that illustrate these points, discuss their implications, and suggest an approach that can relate Wittgenstein's insights to current research in linguistics and knowledge representation.

From Enthusiasm to Disillusionment

At the beginning of his career, Ludwig Wittgenstein, like many of the early AI researchers, thought he had found the key to solving the problems of understanding language and reasoning. In his first book, the *Tractatus Logico-Philosophicus*, he presented an elegant view of semantics that directly or indirectly inspired the theories of formal semantics and knowledge representation that have been implemented over the past 40 years: An elementary proposition expresses an atomic fact (Sachverhalt) about a pattern of relationships among objects in the world (Verbindung von Gegenständen); a compound proposition is a boolean combination of elementary propositions that can describe interrelated patterns of objects; every pattern of objects that exists in the world can be described by some proposition, elementary or compound; and everything that can be said can be clearly expressed by some proposition about such patterns. His conclusion was the famous one-sentence Chapter 7, which conveniently dismissed all exceptions: "Whereof one cannot speak, thereof one must be silent."

The *Tractatus* inspired Rudolf Carnap's version of logical positivism and Alfred Tarski's model-theoretic semantics.

One of Tarski's students, Richard Montague, extended model theory to handle intensional verbs, such as *believe*, *want*, or *seek*. Montague (1967) summarized the underlying philosophy:

It has for fifteen years been possible for at least one philosopher (myself) to maintain that philosophy, at this stage in history, has as its proper theoretical framework set theory with individuals and the possible addition of empirical predicates.

Montague's individuals correspond to Wittgenstein's objects, and Montague's grammar (1970) maps a *fragment* of English to patterns of individuals in an elaborate construction with multiple worlds instead of the single world of Wittgenstein and Tarski.

Around the same time, Bill Woods (1968, 1972) and Terry Winograd (1972) were implementing model-theoretic systems for talking about moon rocks and the blocks world. Winograd's thesis adviser, Marvin Minsky, was also a technical adviser for the movie *2001*, which featured the HAL 9000, a computer that not only spoke and understood English, but could also read lips, interpret human intentions, and conceive plans to thwart them. When the movie appeared in 1968, Minsky claimed it was a conservative prediction about AI technology in 2001.

Although Wittgenstein and Winograd had a strong influence on later developments, both of them became disillusioned about a decade after their early successes. After Wittgenstein published his first book, which he believed had solved all the solvable problems of philosophy, he went to teach school in an Austrian mountain village. Unfortunately, his pupils didn't think or speak the way his theory predicted. It was impossible to find any truly atomic facts that could not be further analyzed or viewed from an open-ended number of different perspectives. Winograd also became discouraged by the difficulty of generalizing and extending his early system, and he later published a harsh critique of his own and other methods for translating natural languages to formal knowledge representations (Winograd & Flores 1986). Today, no AI system has any ability that can remotely compare to the HAL 9000, and textbooks based on Montague's approach are illustrated with toy examples that more closely resemble Montague's fragment than the

English that anybody actually reads, writes, or speaks.

The logician Hao Wang (1986), who earned a PhD in philosophy from Harvard and spent many years working as an assistant to Kurt Gödel, became disillusioned with the set-theoretical constructions of his former thesis adviser:

Quine merrily reduces mind to body, physical objects to (some of) the place-times, place-times to sets of sets of numbers, and numbers to sets. Hence, we arrive at a purified ontology which consists of sets only.... I believe I am not alone in feeling uncomfortable about these reductions. What common and garden consequences can we draw from such grand reductions? What hitherto concealed information do we get from them? Rather than being overwhelmed by the result, one is inclined to question the significance of the enterprise itself. (p. 146)

In support of this view, Wang quoted a personal letter from Clarence Irving Lewis, the founder of the modern systems of modal logic, about the state of philosophy in 1960:

It is so easy... to get impressive 'results' by replacing the vaguer concepts which convey real meaning by virtue of common usage by pseudo precise concepts which are manipulable by 'exact' methods — the trouble being that nobody any longer knows whether anything actual or of practical import is being discussed. (p. 116)

Barbara Partee (2005), one of the pioneers of formal semantics who taught Montague's theories to several generations of students, made the following observation about their limitations:

In Montague's formal semantics the simple predicates of the language of intensional logic (IL), like *love*, *like*, *kiss*, *see*, etc., are regarded as symbols (similar to the "labels" of [predicate calculus]) which could have many possible interpretations in many different models, their "real meanings" being regarded as their interpretations in the "intended model". Formal semantics does not pretend to give a complete characterization of this "intended model", neither in terms of the model structure representing the "worlds" nor in terms of the assignments of interpretations to the lexical constants. The present formalizations of model-theoretic semantics are undoubtedly still rather primitive compared to what is needed to capture many important semantic properties of natural languages.... There are other approaches to semantics that are concerned with other aspects of natural language, perhaps even cognitively "deeper" in some sense, but which we presently lack the tools to adequately formalize. (Lecture 4)

Partee's remarks are consistent with the criticisms of Winograd, Wang, and Lewis. Formal semantics has not yet captured the "real meanings" of words in their "intended interpretation", and it is not clear how it could contribute to a realistic synthesis that is linguistically, logically, psychologically, and computationally sound.

If the *Tractatus* had been an accurate theory of natural language semantics, the early systems by Woods and Winograd could have evolved into the HAL 9000 to vindicate Minsky's prediction. Children, however, rapidly learn to associate words with the things and actions they see and do without analyzing them into atomic facts or evaluating Montague's functions from possible worlds to truth values. The following sentence was spoken by Laura Limber at age 34 months and recorded by her father, the psychologist John Limber (1973):

When I was a little girl, I could go "geek, geek" like that; but now I can go "This is a chair."

In this short passage, Laura combined subordinate and coordinate clauses, past tense contrasted with present, the modal auxiliaries *can* and *could*, the quotations "geek, geek" and "This is a chair", metalanguage about her own linguistic abilities, and parallel stylistic structure. The difficulty of simulating such ability led Alan Perlis to remark "A year spent in artificial intelligence is enough to make one believe in God" (1982).

Wittgenstein's Alternative

Although Wittgenstein rejected his earlier theory of semantics and related theories by other logicians, he did not reject everything in the *Tractatus*. He continued to have a high regard for logic and mathematics, and he taught a course on the foundations of mathematics, which turned into a debate between himself and Alan Turing. He also retained the picture theory of the *Tractatus*, which considered the pattern of relationships in a sentence as a "picture" of relationships in the world. What he abandoned, however, was the claim that there exists a unique decomposition of the world into atomic facts and a privileged vantage point for taking pictures of those facts. A chair, for example, is a simple object for someone who wants to sit down; but for a cabinet maker, it has many parts that must be carefully fit together. For a chemist developing a new paint or glue, even the wood is a complex mixture of chemical compounds, and those compounds are made up of *atoms*, which are not really atomic after all. Every one of those views is a valid "picture" of a chair for some purpose.

In the *Philosophical Investigations*, Wittgenstein showed that ordinary words like *game* have few, if any common properties that characterize all their uses: Competition is present in ball games, but absent in solitaire or ring around

the rosy. Organized sport follows strict rules, but not spontaneous play. And serious games of life or war lack the aspects of leisure and enjoyment. Instead of unique defining properties, games share a sort of *family resemblance*: baseball and chess are games because they resemble the family of activities that people call games. Except for technical terms in mathematics, Wittgenstein maintained that most words are defined by family resemblances. Even in mathematics, the meaning of a symbol is its use, as specified by a pattern of rules or axioms. A word or other symbol is like a chess piece, which is not defined by its shape or physical composition, but by the rules for using the piece in the game of chess. As he said,

There are *countless* — countless different kinds of use of what we call 'symbols,' 'words,' 'sentences.' And this multiplicity is not something fixed, given once and for all; but new types of language, new language games, as we may say, come into existence, and others become obsolete and get forgotten.

As examples of the multiple language games, he cited

Giving orders, and obeying them; describing the appearance of an object, or giving its measurements; constructing an object from a description (a drawing); reporting an event; speculating about an event; forming and testing a hypothesis; presenting the results of an experiment in tables and diagrams; making up a story, and reading it; play acting; singing catches; guessing riddles; making a joke, telling it; solving a problem in practical arithmetic; translating from one language into another; asking, thanking, cursing, greeting, praying.

None of these language games could be explained in the terminology of the *Tractatus*. In fact, Sentence 6.54 of the *Tractatus* classifies its own language game as senseless: "My propositions are elucidatory in this way: he who understands me finally recognizes them as senseless..."

Wittgenstein's hypothesis of language games has not been universally accepted, partly because formalists don't want to admit defeat and partly because his definitions were not sufficiently precise to enable linguists and programmers to implement them. One drawback is that the English translation *language game* suggests a kind of competition that is not as obvious in the original German *Sprachspiel*. An alternative term, *sublanguage*, is already widely used by linguists, it is free of misleading connotations, and many of its applications fall within the range of examples Wittgenstein discussed. For the remainder of this article, the word *sublanguage* will be used as the common generalization of Wittgenstein's language games and the semantically restricted dialects described by Kittredge and Lehrberger (1982).

In the preface to the *Philosophical Investigations*, which was published shortly after his death, Wittgenstein admitted its disorganized structure, especially in comparison with his elegant first book: "I should have liked to produce a good book. This has not come about, but the time is past, in which I could improve it." Although Wittgenstein's later philosophy isn't as precise and crisp as his earlier philosophy, the difference is partly a result of the subject matter: a theory that recognizes the complexity and diversity of life is never going to be as tightly organized as a theory that ignores recalcitrant evidence, but it has a chance of being more realistic.

A Search for Simplicity Amidst Diversity

Any new theory of semantics should be sufficiently simple that it could explain how an infant might learn language and sufficiently powerful that it could support sophisticated discourse in the most advanced fields of science, business, and the arts. Some formal theories have the power, and some statistical theories have the simplicity. But an adequate theory must be able to support both and show how a child can grow from a simple stage to a more sophisticated stage without relearning everything from scratch. As Israel (1993) said,

A complete theory of a programming language must include an account, at some level of abstraction, of the 'psychology' of the machines that execute the language. Just so, a complete theory of a natural language must include an account, at some level of abstraction, of the virtual machines in the heads of its users: *us*.

That account must also support stages of competence from infancy to adulthood. Each stage should enable the speaker to communicate effectively by means of sublanguages appropriate to that level. Each stage should also build on the earlier stages by adding new skills, not by replacing the skills used at the previous stage.

The greatest strength of natural language is its flexibility and power to accommodate any sublanguage ranging from cooking recipes to stock-market reports and mathematical formulas. A very flexible syntactic theory, which is also psychologically realistic, is *Radical Construction Grammar* (RCG) by Croft (2001). Unlike theories that draw a sharp boundary between grammatical and ungrammatical sentences, RCG can accept any kind of construction that speakers of a language actually use, including different choices of constructions for different sublanguages:

Constructions, not categories or relations, are the basic, primitive units of syntactic representation.... the grammatical knowledge of a speaker is knowledge of

constructions (as form-meaning pairings), words (also as form-meaning pairings), and the mappings between words and the constructions they fit in. (p. 46)

RCG makes it easy to borrow a word from another language, such as *connoisseur* from French or H_2SO_4 from chemistry, or to borrow an entire construction, such as *sine qua non* from Latin or $x^2+y^2=z^2$ from algebra. In the sublanguage of chemistry, the same meaning that is paired with H_2SO_4 can be paired with *sulfuric acid*, and the constructions of chemical notation can be freely intermixed with the more common constructions of English syntax.

The form-meaning pairings of RCG are determined by language-specific or even sublanguage-specific *semantic maps* to a multidimensional *conceptual space*, which "represents conventional pragmatic or discourse-functional or information-structural or even stylistic or social dimensions" (Croft, p. 93). Although Croft has not developed a detailed theory of conceptual structures, there is no shortage of theories, ranging from those that avoid logic (Jackendoff 1990, 2002) to those that emphasize logic (Sowa 1984, 2000). The versions that avoid or emphasize logic represent stages along a continuum, which an individual could traverse from infancy to childhood to adulthood. Each stage adds new functionality to the earlier stages, which always remain available; even the most sophisticated adult can find common ground in a conversation with a three-year-old child. Following are the basic elements of logic, each of which builds on the previous elements:

1. Every natural language has basic constructions for expressing relational patterns with two or three arguments, and additional arguments can be added by constructions with prepositions or postpositions.
2. The logical operators of conjunction, negation, and existence are universal. Other operators are more problematical, but the first three are sufficient to support first-order logic.
3. Proper names, simple pronouns, and indexicals to extralinguistic phenomena are universal, but complex mechanisms for anaphora take some time to learn, and some languages have only rudimentary versions.
4. Metalanguage is supported by every natural language, and it appears even in Laura Limber's remark at age three. Metalanguage supports the introduction of new words, new syntax, and the mapping from the new features to older features and to extralinguistic referents.
5. Simple metalanguage can be used even without embedded structures, but the ability to encapsulate

any expression as a single unit that can be embedded in other expressions provides enormous power.

6. When combined in all possible ways, the above features support the ability to define modal operators and all the intensional verbs and structures of English. Sowa (2003) defined a family of *nested graph models* that require only those features and showed how they could support a wide range of intensional logics as special cases, including Kripke models, Montague models, Barcan models, and various temporal models. None of these special cases need to be built into the human "virtual machine", as Israel called it, but any of them could be defined as needed.

In addition to the ability to represent any logic and its model theory, a general framework must also support reasoning methods. The most primitive and the most general is analogy, which by itself supports case-based reasoning. Sowa and Majumdar (2003) showed how induction, deduction, and abduction could be treated as more disciplined special cases of analogy. Analogy can be extended to mappings between heterogeneous sensory modalities and from those modalities to linguistic constructions — a means of supporting Wittgenstein's older and later pictures theories as well as Croft's semantic maps. The semiotics of Charles Sanders Peirce has attracted increasing attention in all branches of cognitive science, and Goguen (1999) has developed a method of *algebraic semiotics*, which supports a version of *blending* for generating metaphors.

Finally, the most primitive in evolutionary terms, the earliest in the stages of learning, and still the most frequent use of language by everyone is in spontaneous conversation in every sublanguage or language game from the most casual to the most sophisticated. Many, if not most of the utterances in such conversations do not consist of full sentences, but during the course of a conversation, fragmentary contributions to the conceptual structures are proposed, corrected, revised, and elaborated. The question of how new information is related to previous conceptual structures, which is central to conversation, is also fundamental to every aspect of language understanding and reasoning. Any adequate theory of language must bring such issues to the forefront, not relegate them to footnotes or afterthoughts.

In summary, Wittgenstein started with an abstract, mathematical view of language and later replaced it with a view that emphasized the purpose of linguistic activity in relation to other people and the environment. Although he rejected the goals of his earlier study, he applied many of the same analytical tools in novel ways. New approaches to the study of language are making a similarly radical readjustment of goals and methodologies, while continuing to use the well-developed tools and techniques of the older

theories. A promising combination could include: a highly flexible theory of syntax, such as RCG; a theory of conceptual structures that supports a progression of stages from simple relational forms to more complex logic; reasoning methods that start with analogy as primitive and define more disciplined logical methods as special cases; and open-ended families of sublanguages that use restricted versions of syntax, semantics, and reasoning for various applications. Purpose or intention is fundamental to the structure and even the existence of every utterance, and the relationship of purpose to perception, emotion, and action must be central to any theory of semantics.

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