Fenstad, Jens Erik: Grammar, Geometry, & Brain. CSLI Lecture Notes. CSLI 2010. 111 Pages.

In this small book logician and mathematician Jens Erik Fenstad addresses some of the most important foundational questions of linguistics: What should a theory of meaning look like and how might we provide the missing link between meaning theory and our knowledge of how the brain works? The author's answer is twofold. On the one hand, he suggests that logical semantics in the Montague tradition and other broadly conceived symbolic approaches do not suffice. On the other hand, he does not argue that the logical approach should be discarded; instead, he opts for a methodological pluralism in which symbolic approaches to meaning are combined with geometric ones such as Conceptual Spaces [9] and discusses ways in which these geometric accounts could be hooked up with connectionist frameworks and dynamic systems approaches in neurophysiology. The book is divided into three chapters to be summarized in the following paragraphs.

In the first chapter Fenstad addresses the history of linguistic theory and what one might call the traditional convictions of linguistics. The historical part comprises an overview of the early development of grammar and logic, briefly mentioning works of thinkers like Plato, Aristotle, Boethius, Dionysius Thrax, Apollonius Dyscolus, the modistae, Thomas of Erfurt's Grammatica Speculativa, and the Port Royal logicians. The author then jumps to the rise of modern linguistics and semantics. Concerning syntax, linguists like Saussure, Bloomfield, and Jespersen are acknowledged, yet not discussed in great detail. Turning to semantics, Fenstad draws a line from the work of Tarski, Ajdukiewicz and Łesniewski of the Lvov-Warsaw school over Reichenbach, Bar-Hillel, and Curry to Montague. Apart from roughly laying out the historical development, one of his main points of this part is that often contingencies played a role in the success or failure of semantic and linguistic programs. For example, Fenstad argues that although Curry's work already contained all the potential for this kind of semantics, Montague succeeded in spreading Curry's and his own ideas partly because Barbara Hall Partee helped popularize his work.

In the second part of the chapter, Fenstad discusses, amongst other things, the connection between syntax and semantics, which following [12] he characterizes as a mapping from a 'computational module' representing the syntactic domain to a 'conceptual module' representing meaning. This mapping is achieved by a 'connecting sign': a projection rule in the Chomskian tradition, and in the tradition of categorial grammar the application of shifted types that reduce to base types which reflect the underlying combinatory model structure. For instance, a shifted verb entry such as $love'(P)(x)$ defined as

$P(\lambda y.love^*(x, y))$, where *love** denotes a relation between two individuals, in a simple example allows one to retain the main distribution patterns of generalized quantifiers and proper names while in the meantime keeping the underlying higher-order logic term *love** conventional of type *eet* (or, $\sigma\iota\iota$ in the notation of Church and Henkin). The reader who would expect to hear more about extensions of Applicative Categorial Grammar such as [15, 2, 13], in which most type-shifting principles are provable, or more about standard analyses like [20] will be disappointed, for the discussion instead turns to some work with which the author himself was involved: using attribute value structures as situation schemata and embedding these into lexical functional grammar. Taking a look at a relatively detailed example based on [8] it is argued that attribute value structures constitute a qualitative shift from defining the syntax-semantics interface as a homomorphism between two algebras to a constraint-based view of the relationship between form and meaning and that this latter view is more fruitful. The chapter ends with a very brief and somewhat detached discussion of language technology in order to illustrate that grammar and meaning is an interdisciplinary matter.

The second chapter primarily deals with geometric approaches to meaning such as Gärdenfors's Conceptual Spaces [9]. One aim of this chapter is to show that symbolic/logical approaches ought to be supplemented by geometric ones. Why? To make the point, the author resorts to the theory of the evolution of culture and cognition of [4]. (The interested reader might take a look at [5] for an overview.) According to Donald, the evolution of cognition is divided into four phases: episodic, mimetic, mythic, and theoretical culture. These correspond to different stages of the biological and cultural evolution from the homo erectus to the homo sapiens. Now Fenstad's point is that logical approaches based on first-order logic basically structure their domain as a large flat database, as relations are interpreted over Cartesian products of the total domain. Such a database structure suffices for simple models at the level of theoretical culture, but for an integrated understanding of discourse in context Donald's other levels need to be modeled as well. As Fenstad lays out, such models require more structure—geometrical and topological approaches as for example Gärdenfors's Conceptual Spaces illustrate. While it would be possible to axiomatize these structures in higher-order logics it is well-known that these lack completeness and compactness with standard models and in fact higher-order logic is barely used for axiomatizing geometric or topological concepts. Fenstad does not mention such axiomatizations by the automated theorem prover community, but nevertheless he has a point. Linguists and logicians doing truth-conditional semantics do not use much structure and, as one might add, many linguists presume Henkin models anyway. As Fenstad further lays out, refinements and extensions such as situation theory, possible worlds semantics, event and temporal logics, and partial models serve their purpose but do in practice not overcome the lack of structure in the models. As he puts it, "[f]ormal semantics must proceed beyond the equation 'model = data base' in order to serve as a link between language and mind" [p. 33], and "...meaning is a conceptualization in a cognitive model, not truth conditions in possible worlds." [p. 47] Perhaps surprisingly, he mentions reciprocals and locatives as examples of linguistic phenomena that require geometrical models; vagueness and similarity measures are not mentioned at this place and only addressed very briefly later.

After this critical discussion, a short introduction to Conceptual Spaces is given. A Conceptual Space is an n-dimensional metric space where each dimension represents a quality like loudness, hue, or color saturation and dimensions may also have weights. Individual objects are vectors and concepts regions in that space. Not only can distance measures account for the similarity of objects and concepts in this kind of model, Gärdenfors also suggests to require a natural concept to be represented by a convex region, i.e. a region such that the points on the line segment between any two points in it are also in it, and points out that if conceptual spaces are arranged in a Voronoi tessellation, their centers can be taken to represent prototypes. Fenstad concurs and, going one step further than Gärdenfors, considers possible links between Conceptual Spaces and dynamic systems used in modeling brain dynamics such as attractor neural networks in [1]. The idea here is that "...prototypes are the attractors of the system and the concept [...] corresponds to a domain of attraction in the energy surface of the system." [p. 50] Thom's semiotics based on Catastrophe Theory [22, 23] is discussed as another possible way to provide a missing link between dynamic models of the mind/brain and symbolic computation. The gist of this chapter is that Conceptual Spaces and other broadly-conceived geometric models of meaning could serve as a mediator between symbolic computation and brain dynamics, potentially encompassing several or even all of Donald's levels of cognitive evolution.

In the third and last chapter, Fenstad explores in more detail possible ways to provide the missing link between the geometric representations of the conceptual system and the dynamics of the brain. The chapter starts with Chomsky's question whether there is a Universal Grammar and how language might have evolved. The author does not give any definite answer to the question of the innateness of UG, but instead lays out work by mathematical biologist Nowak and his co-workers [18, 19] who show by means of dynamic evolutionary models how syntactic structures might have evolved and even provide an explicit threshold that indicates within the model when it becomes evolutionary advantageous to use signals with syntactic structure rather than single signal communication. Fenstad then addresses reductionism and the question of hard AI, writing that "[it] is generally accepted that an understanding of consciousness and self-awareness is basic for any 'final' theory of language and meaning." [p. 72] Will we be able to write "equations for consciousness" some day, as [3] has suggested? Based on [7] Fenstad answers that in non-linear complex dynamic systems "we see new phenomena emerge" and "...we may be have both upwards and downwards causality." [ibid.] Leaving this matter aside, the author then returns to the question of modeling at the mid-level by mapping from brain dynamics to geometric representations. Two suggestions are laid out in some more detail than others mentioned: Optimality and Harmony Theory [21] and an account based on Control Theory by [6]. It would take too much space to go into the details of these theories and Fenstad also summarizes them only cursorily. His general suggestion is as follows: Encode the representational form of meaning in attribute-value matrices, for example instances of situation schemata, and interpret these in suitable geometric models. Then link them to brain dynamics using whatever methodology seems suitable. Possible candidates for providing the missing link are for instance mean field theory, dynamic systems theory, control theory, and optimality theory.

What to make of this book? It is best described as a 'subjective literature overview.' As such, a reader cannot expect rigid argumentation or the level of detail of a textbook. None of the theories mentioned are discussed at great length and some parts of the book presume prior familiarity with the theories *and* their mathematical underpinnings. Moreover, the literature is not laid out in a systematic way but rather whenever the author deems it appropriate. There are also a few omissions that some logicians, semanticists, and philosophers might bemoan. Axiomatic and proof-theoretic semantics are not considered, seminal work in dynamic semantics such as [11, 10] and recent work by van Benthem and other researchers of the Amsterdam school of dynamic logics are barely mentioned. Hyperintensional logics such as [16, 17] where meanings (senses) are algorithms and alternative semantic foundations such as trope theories with topological semantics [14] are not discussed either. Of course, it would not be reasonable to expect a complete literature survey in such a small book, but in light of these omissions Fenstad's critique on the 'flat database' approach of logic must be taken with a grain of salt. Another point worth mentioning is that not much ink is wasted on philosophical issues. Not everybody will consider this a shortcoming, but it can be misleading at times. For example, semantic internalism seems to be presumed throughout the book without mention, although many contemporary semanticists in the Montague tradition are social externalists about meaning. To give another example, the author considers it obvious that talking about the brain as a computer is merely meant as a metaphor [p. 89], whereas to many computationalists (including some connectionists) this talk is not metaphorical at all—in their view the mind/brain *is* a computer.

These are minor shortcomings in an overall concise, inspiring and interesting book that feels a bit like a 'popular science book for experts.' Fenstad has managed to jam together a wealth of information and common and uncommon references on less than a hundred pages that will make the book interesting to philosophers, linguists, cognitive scientists and anyone else working on meaning, concept systems, and the connection these have with the brain. The mathematical modeling perspective advocated in this book is in a stark and welcome contrast to certain foundational views about truth-conditional meaning that are in the reviewer's opinion less fruitful and still encountered frequently in philosophical semantics and the philosophy of language. Logic is *a* tool, but not *the* tool for doing semantics. To end with Fenstad's own words, the hope is that "...someone from the next generation, well-trained in the mathematical sciences, will read the text and be encouraged to apply their particular skills to the complex problems of language, meaning, and the brain." [p. VII]

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