Cognitive State Semantics and the Condition of the Sign

NathanielChristen

Linguistic Technology Systems,

December 5, 2016

Abstract

Start with the question of conditions of possibility for language to exist: how spoken, written, or inscribed signs differ from other kinds of things, enough to establish language as something that exists in the world. Language is a regime of multiple conversation partners, an ambient surrounding where they share actions, perceptions, and foci of attention, and a common posit of structured rules. If communication is successful, each sign's referent is isolated, collectively/phenomenologically, from a (canonically spatiotemporal) reality that extends beyond it. My goal here is to sketch this process with the help of formal and Computational linguistic theories, but keeping in sight a cognitive nuance and intersubjectivity that is (thankfully) an essential, unavoidable part of human language. I will incorporate technical models mostly from Link Grammar and Type-Theoretic Semantics, understanding the latter as possibly layering on the former to complete a syntax/semantic pairing. I propose both cases for and limits on formal theories' applicability for Cognitive Linguistics/Humanities/Phenomenology, through the lens of the Philosophy of Science — arguing how Phenomenology and Cognitive Linguistics, while distinct traditions, can work powerfully in consort.

> On connaît la célèbre affirmation de Claude Lévi-Strauss: "les sciences humaines seront structurales ou ne seront pas". Nous aimerions lui en adjoindre une autre: "les sciences humaines seront des sciences naturelles ou ne seront pas". Evidemment, sauf à en revenir à un réductionnisme dogmatique, une telle affirmation n'est soutenable que si l'on peut suffisamment généraliser le concept classique de "naturalité", le généraliser jusqu'à pouvoir y faire droit, comme à des phénomènes naturels, aux phénomènes d'organisation structurale.

— Jean Petitot, *Syntaxe Topologique et Grammaire Cognitive*

> The nature of any entity, I propose, divides into three aspects or facets, which we may call its form, appearance, and substrate. In an act of consciousness, accordingly, we must distinguish three fundamentally different aspects: its form or intentional structure, its appearance or subjective "feel", and its substrate or origin. In terms of this three-facet distinction, we can define the place of consciousness in the world.

— David Woodruff Smith, *Mind World*

One of the well-recognized questions in semiotics and philosophy is the relation of language to other sign-systems — whether the "structural laws" of Natural Language are different in kind from the norms of other sign-systems, and whether we possess truly innate language faculties. There should be no question that people are instinctively communicative; but a generally Chomskyan linguistics holds that we separately have cognitive abilities primed for language's unique structures. Cognitive Linguists, by contrast, dispute the syntax/semantics distinction and therefore undermine suppositions of a distinct faculty of (or modeled by) grammar, referring instead to general communicative and cognitive-enactive patterns which coalesce into language competence, insofar as children are raised in environments where language and the social interactions it enables are crucial parts of their world. A priority for this cognitive viewpoint is then to model how this

adaptation may occur: how language ability can evolve out of communicative and interactive needs, emerging from prelinguistic dialogic and perceptual experience [37]. Preliminary to such a theory are representations of language structures which can be defended based on their reflecting general cognitive (situational, perceptual) construals, but also have a degree of formality comparable to models based on abstract, logico-mathematic structures — including computational-linguistic frameworks, if these can be persuasively associated with cognitive-linguistic analyses.

Here I will consider Dependency Grammar (more precisely Link Grammar [29], [2]), as one branch of computational model, precise enough to guide concrete Natural Language Processing implementations, but (I will argue) potentially encapsulating some cognitive themes. Dependency Grammars employ syntactic formalisms that emphasize word-to-word relations; they are often contrasted with Phrase Structure Grammars, which put more emphasis on the nested, hierarchical structure of phrases [63], [35]. Dependency Grammar has several variants, including Link Grammar, and Extensible Dependency Grammar, which differ in the precise graph structures used to analyze word-to-word links

[18], [17], [49]. Phrase-Structure approaches also have many offshoots, like Head-Driven Phrase Structure Grammar (HPSG), Lexical-Functional Grammar, and Sign-Based Construction Grammar [33], [41], [57]; [16]; [9]. These various methods often address the same language phenomena; in particular, phrase structure can be implicit in word-to-word linkage, and vice-versa [36]; [81]. So one question is whether inter-word "links" or phrase "hierarchies" are "better" for revealing linguistic structure in the sense that they produce more compelling notations, computational implementations, and/or theoretical expositions. I will not explore this controversy in depth, but I will make some brief arguments for the relative merit of the link-grammar methodology.

My larger concerns are with the limits and ramifications of formal models that suggest cognitive patterns. I want to avoid both an eliminative metaphysics that reduces cognition to a computational metaphor — mind as computer, or perhaps a decentralized network of computer-like facilities — and also a disciplinary prejudice to reject formal models *a priori*. From a humanistic perspective, it can seem reductionistic — even dehumanizing — to ignore emotion, ethics, society, subjective experience, and personal identity, in any worldview about reason and consciousness. On the other hand, many areas of academia and (especially) industry evince a sincere faith in Artificial Intellience simulating progressively more human-like behavior. This has led to useful technologies — better search engines, Optical Character Recognition (to automatically deposit checks, for example) — but it also offers up the question of whether real human behavior is just a totality of narrow mental abilities, or something more holistic. Meanwhile, technology need not *reproduce* cognition to be a window on cognitive-perceptual processes: 3D and Virtual Reality, for example, employ geometric calculations to represent shape, contour, color, texture, opacity, transparency, and lighting; the experiential realism of the resulting graphics implies retroactively that the mathematics built in to Computer Generated Imagery resonates with conscious experience — as a formal model of the world as encountered by the senses if not as a reproduction of how sense-data is intellected into consciousness.[1] At the same time, we are still aware that computer graphics

[1] Relatedly, reconstructing three-dimensional geometry, for instance from photographs, can be a valuable technology and shed light on mechanisms of human vision, without any presumption that computers have phenomenological "sight-experiences". I think this suggests how a mathematical and/or algorithmic process which takes givens in one form (like a photographic bitmap) and creates a (by some theory) equivalent representation in another form (like a 3D mesh or richer 3D scene

are not fully real; the further experiential gap to bridge, the failure of this mathematical system to create *entirely* virtual reality, may also hold lessons about mind and consciousness GiuseppeRiva [58].

Whether in vision and graphics, or in language and search engines, technology gives us solutions which are useful but imperfect. I believe therefore that we should neither reduce consciousness and cognition as "nothing but" computational activity ("implemented" in the brain somehow), but nor accept a disciplinary programme where formal/computational methods are pro-forma jettisoned. Even granting that a "human" layer of meaning saturates language and thought and is beyond the realm of mechanical processing — not as a practical limitation on software (not enough memory, not enough parallelism) but something more entrenched and Ontological — this dualistic partition of the realm of (for example) language and meaning, into the functional and tractable and the emotive and expressive, can have the ironic effect of reaffirming a fairly reductionistic status quo (in the marketplace of ideas as well as services).

Cultural topics like art and literature are the most obvious examples where faith in the explanatory completeness of AI strains credulity, but they are also (with some justification) deemed tangential to the important research interests of those who do science or create products under the AI umbrella. It is more productive to apply both humanistic and formal/computational perspectives to the same phenomena; and there is a rich humanities tradition — including braches of linguistics, or Philosophy in the "Naturalizing Phenomenology" tradition (taking this term from the collection edited by Jean Petitot, Barry Smith, and David Woodruff Smith, who are also leading examples of the kind of hybrid scholarship I'm denoting) — which is sensitive to interpretive and experiential nuance but also accepts the occasional role for formal, mathematical models [52]. It is fascinating to explore "gendered" spatial experience in the context of Impressionistic painting, for example [55]; but approaching an arguably similar topic from the perspective of sentence-construction [14] allows greater comparison with mathematical grammars: at what level of formal description can issues of gender and of first-person spatial experience become causally relevant, or expressible in the terms of the theory? How should we think about computational and/or neuroscientific understandings of human reason, relative to the social, experienced world? Is consciousness (with all its personal and collective layers, its forming "a" world) an emergent property of microscale cognitive activity, by analogy to how electricity is an emergent property of electrons? Or is first-person reality fundamentally different from, if perhaps informed by, the world disclosed to us through rational cognitive-perceptual syntheses of sense-data and of situations?

The human mind is such an everpresent topic in almost any intellectual pursuit — since after all mind is the very medium of science and philosophy — that no one single cognitive, humanities, or neuroscience discipline can be realistically expected to exhaust its subject matter. So there is nothing intrinsically wrong with humanists seeing mind through its manifestation in culture and politics, or personal and collective identity, while cognitive scientists see mind through its manifestation in intelligent behaviors, functionalities, neural network architecture, and other formally analyzable organizations. The problem has emerged as the mind-as-computer motif migrates from a useful fiction in a specific academic community to a powerful cultural and industrial meme, and the scholarship best positioned to know its limitations — general humanitistic and cultural studies,

notation), shows intelligent behavior, with useful affordances for human ends that are worth pursuing even apart from any clues to cognitive process — but that systems exhibiting the appropriate intelligent *behavior* also need not be deemed *intelligent* per se, or sentient or conscious.

for example — have limited counterbalancing theoretical resources, acquiescing to a disciplinary core which in "science of mind" marginalizes, rather than engages with, those same humanities. Responding to "mind as computer" calls for extending cultural perspectives from macroscale to microscale, from art and politics to "everyday speech" and the single sentences, single speech-act, single moment of cognition — which is not necessarily discouraged in humanities scholarship but is not prioritized either, outside perhaps of relatively low-profile fields like Sociolinguistics.

More to the point, the terminology and theoretical instincts which would allow humanists to approach cognitive-scientific questions from a social or cultural (or even political) perspective does not seem to typically emerge in the humanities culture — one can criticize the use of quasi-mathematical models for mental processes on the grounds that a mind/computer metaphor is mostly an illusion, but a consequence of this outright disengagement is a gap in methodology that prevents the more formal and more interpretive perspectives from ever being set in contrast. More practically, the same scholarship community which rightly questions an uncritical faith in computation and its industry, also must operate in the world the faith has created. So while promoting a philosophy which challenges both the goals and actions of "the" IT industry, this community still falls back on Facebook and other social networking sites, on Apple or Microsoft and other hardware and software providers, on Google and other search engines and cloud architectures — in other words, *using* these products and services rather than critically *engaging* them. By separating (say) Computational Linguistics from the kind of interpretive language study which is the norm in the humanities, these disciplines fail to encircle in their interdisciplinary reach the expertise relevant to engaging the IT world critically, neither accepting their paradigms nor just ignoring them. There are few critiques of the commercial and societal norms of the internet, for example, which also propose solutions with enough engineering specificity to outline practical implementations.

In fact, the most quotidian language, visual perception, and premeditated activity, reflects both formal and social/personal structures and so provides a foundation for the humanistic and scientific attitudes to cooperate — but a simplistic rejection of scientific reductionism, as does reductionism itself, forecloses rather than solicits such collaboration. It is against this backdrop that scholarship like Jean Petitot's, embracing both detailed mathematical models and complex Husserlian phenomenology, speaks to our larger intellectual institutions. All science joins theories with a measure of explanatory autonomy, differentiated from other theories by virtue of scale or topic. But these differences need not be antagonistic — Analytic or "Continental" Philosophy; Science or Humanities; Formal or Informal Logic; literary studies and "philosophy of language" or formal/computational linguistics. More formal and more interpretive analyses can co-exist, expanding our understanding of their target phenomena because, not in spite of, differences in method, just as analyses from multiple scales of resolution can supplement rather than undermine one another. Semantics has both formal and informal dimensions: conventionalized in semantic norms, schema prime users to manipulate linguistic structures against a situational background, a situationality that may demand introspective/interpretive ways of study but a manipulation which, to be communicatively effective, needs a clarity and repeatability that can be formalized. Semantic layers are abstract tools, but they offer a tableau of forms and combinations which users adapt, concretely, to each context. The deep potential of language, I believe, comes from the perpetual

combination of the abstract/formal and the concrete/phenomenological.

The phenomenological dimension of language is the experiential surround that provides an ambient context for all communication; it has an analogous background in the "plane" of articulation, from which individual signifiers must be cognized. So on a plane of language and of reality words and referents must be intended apart, partially, from these two notions of surrounding. (Dis/)continuity in the plane of reference brings consciousness to a mereo-logic [23], [64] that language-cognition can then reshape into syntax and semantics [8]. Like a footprint, whose very existence depends on both material continuity and visual break, for each sign there must be a blend of continuity and discontinuity, both around the sign and its referent. Attending to a mereologically ordered world, we need innate theories warranting criteria for seeing things as both individuals and as causally/behaviorally constrained by and from a whole. These criteria include structural consideration of the whole, and it is often in structural terms that the blend of autonomy and linkage for each part is realized (using the word "linkage" suggests Link Grammar here, but I also believe such partonomic balance is a primordial structuring principle of almost any organized system). Attunement to structured organization therefore warrants the perceptual and mental isolation of particular foci of attention [78], [79]. As this plays out on planes of articulation alongside general situation awareness, the structures of discourse — its division into distinct signs and their structural interrelationships — and that of patterns we identify in our surroundings, that provide a context of discourse, play off one another.

A central theme in Cognitive Linguistics is that language meaning depends on situational understanding, and by extension on mental schema of spatial, temporal, and functional organization — not only how environments are arranged, but how they are causally and physically determined [54], [70]. The objects around us are not just blobs of matter, but usually have a constructed purpose, socially sanctioned meaning, nostalgic weight, and other aspects of non-perceptual significance. The difference between *pour water* and *spill water* is the person's deliberate intentions in relation to natural forces and tendencies (such as that of water to fall downward). To "apply paint" to something, compared with to "cover" with paint, suggests different spatial configurations; to *fill a glass with water*, versus *pour water into* the glass, suggests both different spatial details and maybe different rationales. These are alternatives in emphasis, not necessarily in actuality: those pairs of alternatives could describe identical state of affairs. But they direct conversants' attention in different ways, they choose one or another part of a scene as a reference frame, and suggest different "takes". These are driven by *semantic* variations — the choice of verbs like *pour* versus *fill*, *pour* versus *spill*, or *apply* versus *cover*. But semantic and syntactic rules work in federation, relative to context: for example, different verbs take different prepositions in different situations. Pour *into* vs. fill *with*. To join "pour" with *with* places emphasis elsewhere — onto the device which enables the pourer to do the pouring. So the grammatic and semantic norms of a language jointly offer a terrain of options from which speakers assemble combinations invoking those aspects of situations that they wish to emphasize.

In short, grammar is language's substitute for *visual* or *physical* resemblance-to-structure. Take Ronald Langacker's "landmark"/"trajector" model: one (very general) manner of spatial gestalt, subject to either intuitive, reflective analysis or to formalization ([6], [77]). "That boat crossing the lake": *boat* (trajector)

perceived against *lake* (landmark), which provides context; together they produce a mental model; a figured spatial relationship. This is communicated, not by visual or kinaesthetic effect,[2] but by the more abstract effects of intentions signaled, both via exact words ("crossing" paints a different picture than would *across*, *on*, *by*; still more so, *at the bottom of*), and morphosyntactic tropes (like the form *x* `r` *y*; where "`r`" here means one from many spatial relations, taking *trajector* to the left and *landmark* to the right). *Landmark* and *trajector* are anchors around which both syntactic and semantic selections are organized.

Language needs both abstract laws and cognitively-mediated construals of ambient situations. The abstract laws are shaped by the situations, not directly — it is that extra indirection which cleaves language from other sign systems — but derivatively: language rules are optimized for conversants to mold linguistic possibilities into selection-spaces, which then become raw materials for representations of situational context. Each choice of word and form adds a piece to a representational complex, and the sum of those pieces — be this a sentence, a conversation turn, or an entire discourse — is a language act that hews to the structure of a situation, as the speaker wants to emphasize it. Here I take this perspective as a working hypothesis on the origins of linguistic structuration as such. It is a philosophical claim on the nature of signs and signification, not a specifically linguistic claim. Over the next two sections I will try to sustain this theory as a paradigmatic sketch and fill in some details, building up a picture of first syntax and then semantics which can meet formal criteria but culminate in a picture of language consistent with this cognitive starting-point.

There is also another level where questions of the degree of formalizability proper to Cognitive Linguistics take on a "semiotic" dimension, one where explanatory strategies investigated by a Philosophy of Science become relevant. In its connotations, the very term "Cognitive" suggests both a scientific dimension and also a level or focus of analysis which is more high-scale, more experience-focused, in contrast to neuroscience or an experimental psychology. Cognitive Grammar, Cognitive Linguistics, Cognitive Phenomenology all imply a telos of analysis which is neither as physically oriented as the biological study of mind nor as speculative as a Philosophy of Mind. Our intuition of this "spectrum" of disciplines, from the more natural-scientific to the more philosophical, can hopefully be made more precise by treating them rigorously as different modes of "science" broadly understood — clarifying their methodologies, their understanding of what are disputable claims and what are claims' warrants, of what kind of empirical or interpersonal observations or discussions serve as support (or refutation) for theories. In many such analyses, the nature of "scientific language", or "theory" languages, has intrinsic importance — the metaphysical commitments of a theory being expressed in the kind of language it develops and how technical terms are understood to abstractly or empirically refer.

Philosophy of Science has a semiotic dimension: how do theory languages internally propose a word-to-world correspondence, so that the symbols of an equation, the extension of a natural-kind term, or the diagram of a system, can be given a meaningful interpretation in terms of the world we experience? The reference of the term "Natural Selection", for example, in rigorous biological science, is very different from the reference of the term "electron" or "electromagnetism" in physics. Much of the complex Ontological position of Cognitive Science vis-à-vis both science and consciousness can be explored through the lens of semiotics — when a

[2] At least in prose — poetry, which can bring back a semiotics of raw visual layout and auditory effect, is an exception that proves the rule.

Cognitive Linguist (for example) writes of "cognitions", or "Understanding", or conversants' mutual play of *attention*, or speaker's *framing* of situations, or *dispositions* to accept or reject a grammatic construction, the lurking metatheoretical question is what *cognition*, *understanding*, *attention*, *framing*, and *disposition* actually *are*, and how specific or hypothetical tokens of these phenomena are believed to refer to something (a "thing" or process or something more ephemeral) in the world. Cognitive Science can develop a rigorous methodology without implying that there is a realm of "cognitions" that may be paired one-off against brain states or any other physical correlate (even if in a more global sense there is a mental/physical causal determinism or supervenience). Metatheoretic principles like the supervening of one class of properties on another (property-identity in the subvening class necessarily propagating to identity in the supervening class — no mental difference without physical difference) are actually, I believe, the "semiotic" principles of disciplines' theory-language media, often stipulated and curated by decentralized consensus rather than explicit construction.

So, with this in mind, I will use Dependency Grammar as a case study in Cognitive Grammar, and then use Cognitive Grammar as a case-study in a theory-language which is neither wholly physical/scientific nor wholly interpretive/humanistic. I will start by outlining Dependency Grammar in contrast to phrase-structure approaches; then try to generalize from grammar to semantics and suggest how link-grammar formalisms capture some Cognitive-Linguistic semantic principles; and then explore how the mixture of cognitive and formal analysis reveals an overlap (neither total nor vacuous) between the range of relevant cognitive phenomena which have some fashion of "reductive" analysis. To put it very briefly, some cognitive processes have formal/systematic reductions and some do not, or at least not obviously and tractably — which makes reductionism neither wholly right nor wholly wrong. I will speculate on the implications of this partiality in conclusion.

1 Link Grammar and Cognitive Grammar

The emergence of Dependency Grammar as a *computational* approach has some broad implications. The historical preference for phrase-structure foundations — among those who actually build Natural Language Processing code libraries, in disciplines related to Artifical Intelligence — arguably reflects how phrase structure more cleanly models a theory of linguistic meaning and signification based on "symbolic logic" — a theory that the *meaning* of a complete and self-contained linguistic expression is the logical state of affairs which it asserts or in other ways connotes. Correlated with this assumption is the idea that phrase structure logically transforms its constituent parts; so from the word "students" we can form the phrase "many students" to designate a kind of plurality — a plural set but also, more specifically, a set which is reasonably large relative to some context. In the hierarchical model presented by these norms, phrases subsume the roles of individual words and represent discrete semantic units with respect to still larger phrases.

It is certainly true that one role for phrases is to satisfy a semantic niche — often a place occupied in other (or even the same) language with single words, or vice-versa. The French "laisse tomber" translates the English "drop", for example; and "parliamentarian" is a more exotic version of "Member of Parliament". There is

no evident pattern for when a single concept is conveyed, in one language or another, by a single word or a multi-word phrase. Moreover, the meanings of phrases are influenced by semantic conventions no less than are individual words, and they are not solely a product of phrase constituents. Semantics is guided by what people need to talk and write about often; when events in a linguistic community call for some fairly rigid and repeatable designation for an important concept, the resources of language adjust to provide that role, either through a complete neologism, or a lexical variant — a new usage; or the entrenchment of a phrase. In current events, the expression "Syrian Refugees" recurs when discussing people displaced by the Syrian civil war, and potentially other interrelated conflicts also; convention seems to allow that nominal "Syrian" Refugees don't have to be Syrian nationals. The meaning of the phrase is fixed by its niche in familiar discourse more than by its literal form. Phrases exhibit conventionalization and usage pressures analogous to single words; which lends credance to the notion that phrases subsume the role of single words, and that the semantic contribution of words to sentences is determined through the phrases where they occur.

On the other hand, it is well established that words' contributions are not *wholly* subsumed by their surrounding phrase-structure. The famous joke about the Holy Roman Empire — or its reprise in the current line that the Islamic State is neither Islamic nor a State — point to evidence that as language-users we still hear the individual words outside their phrase context. To subsume a word into a phrase is also to suggest a particular semantic (and pragmatic, real world) interpretation, one which conversants may challenge.[3]

Arguably, joking or titular cases like "Holy Roman Empire" can be relegated to thematic margins, especially if we accept formal-logical construals of what semantics is all about, with an *a priori* contrast between Semantics and Pragmatics, the former rooted in *states of affairs* and only the latter addressing rhetoric and usage. Counter to this counter-argument, however, we can observe that different phrases imply different degrees of "autonomy" to their constituents, and different degrees of coherence or unification into a single idea. Some phrases act as direct substitutes for single concepts (like "Member of Parliament") where it seems mostly historical accident that a phrase rather than a word emerged as the most popular; but many other phrases have more complex usage scanarios, including everyday expressions that don't have special rhetorical or sociolinguistic conventions that would make them tangential to semantic or syntactic analysis proper. Moreover, many of these examples are similar to those used by Cognitive Grammar to challenge the syntax/semantic distinction and argue for "morphosyntactic" models as reciprocating cognitive formations, not abstract language-rules.

For example, in Langacker's *Foundations of Cognitive Grammar*, the sentence

- Three times, students asked an interesting question

is used to demonstrate how grammatical principles follow from cognitive "construals" of the relevant situations, those which language seeks to describe or takes as presupposed context.[4] In particular, Langacker argues that "students" and "question" can both be either singular or plural: syntax is open-ended here, with neither form more evidently correct. Langacker uses this example to make the Cognitive-Linguistic point that we assess

[3] How literally to take phrases is a notorious source of political controversy: recall debates about the relevance of Afghanistan for Iraq, in US policy, and Rudy Giuliani saying "There *is* Al Qaeda in Iraq — it's called, 'Al Qaeda in Iraq'".

[4] For example, [40, pp. 119 and 128], discussed by [11, p. 189], and [50, p. 9].

syntactic propriety relative to cognitive frames and conversational context. In this specific case, we are actually working with two different cognitive frames which are interlinked — on the one hand, we recognize distinct events consisting of a student asking a question, but the speaker calls attention, too, to their recurrence, so the events can also be understood as part of a single, larger pattern. There are therefore two different cognitive foci, at two different scales of time and attention, a "split focus" which makes both singular and plural invocations of "student" and "question" acceptable.

Supplementing this analysis, however, we can additionally focus attention directly on grammatical relations. The words "student" and "question" are clearly linked as the subject and object of the verb "asked"; yet, contrary to any simple presentation of rules, no agreement of singular or plural is required between them (they can be singular and/or plural in any combination), Moreover, this anomaly is only in force due to the context established by an initial phrase like "Three times"; absent some such framing, the singular/plural relation would be more rigid. For example, "A student asked interesting questions" would (in isolation) strongly imply *one* student asking *several* questions. So the initial "Three times" phrase alters how the subsequent phrase-structure is understood while remaining structurally isolated from the rest of the sentence. Semantically, it suggests a "space builder" in the manner of Gilles Fauconnier or Per Aage Brandt [22]; [12], but we need to append Mental Space analysis with theory of how these spaces influence syntactic acceptability, which would seem to be logically prior to the stage where Mental Spaces would come in play. "Three times" triggers agreement norms on word-to-word links in *other* phrases to be suspended and also alters their morphosyntax-to-semantics (there are understood to be three questions, for example, despite *question* being singular in morphology and article). This complex interplay of phrase-structures is hard to accommodate from the grammar-hierarchy perspective. There seems to be no way to break down this example sentence into a tree-like phrase hierarchy wherein each phrase, considering the semantic concept which it is apparently tasked to put into words, can be seen to function in isolation. The mapping of the sentence to a logical substratum would be more transparent with a sentence like "Three students asked interesting questions"; that sentence is a more direct translation of the facts which the original sentence conveys. But this "more logical" sentence has different connotations than the sentence Langacker cites; the original sentence places the emphasis elsewhere, calling attention more to the idea of something temporally drawn-out, of a recurrence of events and a sense of time-scale. The "more logical" sentence lacks this direct invocation of time scale and temporal progression.

We can say that the "Three students" version is a more direct statement of fact, whereas Langacker's version is more speaker-relative, in the sense that it elaborates more on the speaker's own acknowledgment of belief. The speaker retraces the steps of her coming to appreciate the fact — of coming to realize that the "interesting questions" were a recurrent phenomenon and therefore worthy of mention. By situating expression relative to cognitive process rather than to the facts themselves, the sentence takes on a structure which models the cognition rather than the states of affairs. But this shift of semantic grounding from the factual to the cognitive also apparently breaks down the logical orderliness of the phrase structure. "Three times", compared to "three students", leads to a morphosyntactic choice-space which is "underdetermined" and leaves room for speakers' shades of emphasis.

This is not an isolated example. Many sentences can be provided with similar phrase-structure complications, particularly with respect to singular/plural agreement.

- Time after time, tourists (a tourist) walk(s) by this building with no idea of its history.
- The streets around here are confusing; often people (someone) will ask me for directions.
- Student after student came with their (his/her) paper to compain about my grade(s).
- Student after student — and their (his/her) parents — complained about the tuition increase.

On a straightforward phrase-structure reading, "Student after student" reduces to an elegant equivalent of "Many students", with the rhetorical flourish abstracted away to a logical form. But our willingness to accept both singular and plural agreements (his/her/their parents, grades, papers) shows that clearly we don't simply substitute "Many students"; we recognize the plural as a logical gloss on the situation but engage the sentence in a more cogntively complex way, recognizing connotions of temporal unfolding and juxtapositions of cognitive frames. The singular/plural underdeterminism is actually a signification in its own right, a signal to the listener that the sentence in question demands a layered cognitive attitude. Here again, syntactic structure (morphosyntactic, in that syntactic allowances are linked with variations in the morphology of individual words, such as singular or plural form) serves to corroborate conversants' cognitive frames rather than to model logical form.

This is not to say that phrase-structure paradigms are refuted by these examples. Cases like these can be accommodated by layering new structural rules, such as allowing exceptions for singular/plural agreement in the presence of certain "lead-in" phrases like "Three times". It is not even accepted that these examples clearly favor inter-word relations (as language formalization, in preference over phrase-structure trees) — cases like "Student after student" have also been used *against* Dependency Grammar on the argument that there is not a clear "single" word, in that phrase, which should be seen as linking with words elsewhere in the sentence [48, pp. 400-401], [47, p. 2]. It seems arbitrary to select either "student", or "after", as "the" representative of the phrase to link with — for example — the verb "complained"; on that argument, the least arbitrary analysis is to treat the phrase as a whole as a single unit for purposes of grammatic linkage. In short, both paradigms have potential problems with these example. Considering "Student after student" as an encapsulated phrase leaves the singular/plural flexibility in the continuation of the sentence unexplained ("Many students compained about ?his grade" is clearly dubious, so "Many students" is not a direct substitution). But bracketing the phrase when decribing the sentences' "linkage" leads to an apparently arbitrary choice when it comes time to notate the subject/verb linkage for "complained". I will address this particular ambiguity later; but for now I'll just point out that a simplistic reading of both Dependency and Phrase-Structure ideas seems to run aground.

To reiterate, the goal of this analysis is not to defend Dependency and critique Phrase-Structure Grammars, respectively. It is however instructive to consider how such a case might be rehearsed, because doing so brings some metatheory to the fore which is worth examining.

1.1 Comparing paradigms

How, then, would a comparative assessment of Dependency and Phrase-Structure Grammars proceed? One approach is to focus on practical applications: computational-linguistic paradigms find expression in code libraries, which can be judged empirically — comparing libraries' speed, accuracy, ease of use, and how readily can they be modified in light of new research. Arguably, however, the quality of a code library does not automatically reflect the accuracy of its underlying linguistic paradigms (as opposed to the skill, foresight, and resources of its programmers); not to mention that more complex analyses of human language may be both more correct and also harder to express in code. There is, in any case, no apparent consensus amongst linguists and programmers that one or another language theory has proven computationally preferable. Alternatively, in lieu of computational standoffs, another approach to theory-comparison. The prior examples may give Dependency Grammar an edge here. The internal structure of phrases seems to lend specificity and nuance to their meaning in ways that get lost when trying to replace phrases with logico-semantic equivalents; phenomena which may settle in the explanatory orbit of word-to-word-relation models more than phrase-hierarchy models. "Student after student" is not losslessly substitutable with "Many students"; the former phrase has a temporal and multi-tier cognitive implication which the latter discards. The second phrase is compatible with "Many students" complaining *at one time*, as well as drawn out over time; the former phrase appears to clarify that the second kind of situation is the intended meaning, Of course, in context, the two phrases may be understood to have similar meanings; but this is a product of how the linguistic structure relates to its presumptive conversational context, not to an intrinsic semantic equivalence. I will now consider these and other examples to discuss the dependency/phrase-structure contrast in a little more detail.

The contrast between the phrases "Student after student" and "Many students" cannot be based on "abstract" semantics alone — how the evident temporal implications of the first form, for example, are concretely understood, depends on conversants' mutual recognition of a relevant time frame. The dialog may concern a single day, a school year, many years. We assume that the speakers share a similar choice of time "scale" (or can converge on one through subsequent conversation). *Some* time-frame is therefore presupposed in the discursive context, and the first phrase invokes this presumed but unstated framing. The semantics of the phrase are therefore somewhat open-ended: the phrase "hooks into" shared understanding of a temporal cognitive framing without referring to it directly. By contrast, the second phrase is less open-ended: it is consistent with both a more and less temporally protracted understanding of "many", but leaves such details (whatever they may be) unsignified. The factual circumstance is designated with a level of abstraction that sets temporal considerations outside the focus of concern. The second phrase is therefore both less open-ended and also less expressive: it carries less detail but accordingly also relies less on speaker's contextual understanding to fill in yet more detail.

Clearly the two phrases are therefore semantically different; but notice also that the semantic properties of the first phrase are due explicitly to its internal structure. The temporality implicatures could be expressed in a more "purely" semantic fasion with a choice of wording, like "a procession of students complained". This would rely on the conventional meaning of "procession" (or maybe "stream" or "sequence") to provide the expressive "time" dimension. But the "Student after student" phraseology achieves this effect more economically and with

more “oomph” because the internal repetition in the phrase itself effectively models the recurrence it seeks to feature semantically. Here linguistic form actually does reproduce factual structure, like a syntactic version of onomatopoeia. This fact of internal structure clearly can only be fully modeled by taking seriously the exact composition of the phrase, not treating the phrase-structure as a convention fully subsumed by a semantic role.

In addition, aside from the expressive detail which depends on the actual phrase structure (which therefore cannot be summarized away), this inner structure also governs morphosyntactic possibilities over all. “A procession of students” captures a similar temporal progression but also fully absorbs “student” in a plural guise, and “A procession of students complained about ?his grade” is straightforwardly ungrammatical. In Langacker’s “Three times” example, the inter-word “linkage” captures the aforementioned complexities in a reasonably non-arbitrary way. “Student” is linked as subject-to-verb with “asked”, and as subject-to-object with “question”. It is true that these link-pairs seem to violate agreement norms, but there is nothing in the Link Grammar paradigm — which practices Dependency Grammar with a rather detailed and intricate inventory of inter-word relations, or “links” — mandating that *all* link-pairs exhibit forced agreement (like singular/plural). Agreement, when it applies, is a property *of* link pairs. There is also an implicit (cross-phrasal) link between “student” and “Three” — clarifying that, considered in its entirely, the sentence is about three students precisely — and the presence of this kind of link alters how the other links connecting to the word “student” are assessed. In particular, this latter link stipulates that the word “student” is being simultaneously understood in both a plural and a singular sense, so it permits singular *and* plural link forms which, more commonly, could only be singular *or* plural. So link grammar can offer an elegant analysis of singular/plural “underdeterminism”, expressed in the same underlying graph-context terminology as most other link-grammar theorizing. It would be unfair to use this as a case against Phrase Structure grammars without a detailed presentation of how these grammars would handle such a case in turn, but I’d argue that link grammar accommodates this complex example with relatively little departure from its underlying theoretical and notational or presentational commitments.

While my previous examples contrasted Phrase Structure and Dependency Grammars in terms of their resources for explaining sentences with unusual semantic patterns but relatively clear meanings (in context), another form of comparison can address actual ambiguity. Consider

- The Maple Leafs failed to win in overtime for the first time this year.
- The Maple Leafs failed for the first time this year to win in overtime.

The first can mean either that the Leafs had won *all* or *none* of their prior overtime games. From a phrase-structure perspective, we have to image that “to win in overtime” can “migrate” so we hear it as in the second version of the sentence. For more inter-word grammars, the alternation is simpler: “for”, initiating the phrase “for the first time”, can be linked with either *failed* or *win* — notationally, it amounts to the presence or absence of one graph-edge, when the syntax is represented as a graph with inter-word labels for link kinds. This could be a distinction without a real difference, since choosing which inter-word link to recognize triggers linking in the rest of the phrase along with it. But perhaps reflecting on how we process the ambiguity — realizing that there are two competing parses and deciding which is the one intended — we picture the alternatives more as

"horizontal" options for connecting threads across the sentence, more so than a "vertical" organization where we hear "for the first time" as "contained" in a larger phrase. My own feeling is of exploring competing relational patterns more than exploring different ways that the phrases can be nested inside each other.

That being said, how much of our sense of ambiguity (or clarity, for that matter) is driven by meaning, not form? The "double parse" just examined does not always generalize to similar cases:

- The Maple Leafs failed to win two consecutive games for the first time this year.

The reading as in "this is the first time they failed to win two consecutive games" makes no sense — unless you've won every game, but perhaps the first, you've at some point lost after a win. Is this case anomalous, where a syntactic ambiguity idiosyncratically fails to yield logically plausible readings? The ambiguity is found in *failed to make the playoffs for the first time since 2013*, and many *for the first time this season* cases, like *beat the Habs*, *sell out the arena*, *score a goal in the first period*. But "failed to score a goal" is almost surely read that they *did* score in every prior game. Do we hear the construction as intrinsically ambiguous, and reject one reading only when it is clearly flawed pragmatically?

If we believe that language understanding unfolds in a predictable operational sequence, then we should assume that both parses are deemed plausible, and semantic considerations only retroactively eschew one reading (if they do so at all). This would explain why in many cases the ambiguity persists enough to cast the practically intended meaning in doubt. But that account does not consider the temporality of language itself: the hearer does not know in advance that a trailing phrase like "for the first time this season" is coming, and starts to make sense of the sentence up to there; once then hearing or reading the addendum, the audience instinctively has to interpret the final phrase as deliberately inserted to modify an already-complete idea. On this analysis, the addendum is initially approached as a performative detail, something said for a reason on its way to being determined — it is not structurally necessary to make the sentence well-formed. Perhaps we then try to fit the last phrase into the sentence both syntactically and semantically, together, triggered by a pragmatic phenomenon (the speaker's choice to add on to a seemingly complete thought) which then becomes logically prior to both syntax and semantics. If this is plausible, it supports an inter-word relational model because we are forming a picture of language structure relationally, assimilating new words and phrases to those already heard by linkings referring back in time, rather than waiting until we are sure we have a complete sentence and then treating it as a static structure to vertically reconstruct.

The examples I have used so far may also imply that a choice of phrase structure is always driven by semantic connotations of one structure or another; but seemingly the reverse can happen as well — speakers choose a semantic variant because its grammatic realization lends a useful organization to the larger expression. There are many ways to say "many", for example: *a lot of*, *quite a few*, not to mention "time after time" style constructions. Whatever their subtle semantic variations, these phrases also have different syntactic properties: *Quite a few* is legitimate as standalone (like an answer to a question); *A lot of* is not, and *A lot* on its own is awkward. On the other hand the "of" in *A lot of* can "float" to be replicated further on: "A lot of students, of citizens, believe education must be our top priority" sounds more decorous than the equivalent sentence

with the second "of" replaced by "and". If the cadence of that sentence appeals to the speaker, then such stylistic preference will influence taking "A lot of" as the "many" variant of choice. So speakers have leeway in choosing grammatic forms that highlight one or another aspect of situations; but they also have leeway in choosing rhetorical and stylistic pitch, where they may favor a syntax on "aesthetic" grounds. Both cognitive framings and stylistic performance should be factored in when reconstructing what compels the choice of one sentence over alternatives.

Real-world language is indeed a performance, which can take twists and turns: speakers sometimes modify sentences mid-stream, observing the reaction of their listeners or just "thinking aloud". And, as my Leafs examples touched on, the addressee of a sentence, also, responds to language as an unfolding process. The consequences of this temporality may be more pronounced in some dialogues compared to others; but theories and representations of language should be judged in part by how comfortably they incorporate the temporality of enunciation, even while this is only sometimes analytically relevant. The relative temporal position of words and phrases belongs to a genre of inter-word relations that are overlayed against semantic and phrase-constructing relations. As an SVO (Subject-Verb-Object) language, for example, English speakers expect in a typical sentence for the subject to appear near the start, followed by a verb and then a direct object. Hearers need to recognize when a sentence is following a different script (a question, say), but once confident in the SVO order addressees are poised to link the object "slot" to the verb, and the verb to the subject; expectations which condition how the progressing sentence is received. Semantically, however, the (transitive) verb is like an operator which requires both subject and object to produce a propositional meaning: from this perspective the subject-object link and its temporality is less relevant, and the "head/dependent" links between the verb (as the "functional" part of speech) and both nouns are more important — because these links represent how the verb "produces" propositional content once its requisite nouns are known. The verb in a signifying sense "depends" on these nouns, but in a formal model we can also understand the dependency relation in reverse, since the verb is the "active" operator, taking ideas that have more substantial out-of-context meaning — nouns *qua* linguistic delegates for things and concepts — and producing a new (propositional) idea. The primordial dynamics of language is the mental transition from concepts to propositions, which then call for more concepts as elaboration, a cycle (a "propositional cycle" of speech-performances, perhaps) that repeats itself, sentence after sentence.

Verbs and other "composite" Parts of Speech drive this cycle; they are operators that transform concepts more immediately than they are concepts themselves. As such, nouns — the clearest representatives of pre-linguistic concepts, those forged from acquaintance with things and classes of things in the world — depend on verbs and other "operators" to draw them in to propositional forms. This provides a cognitive justification for a notion of "dependence", manifest in certain formal language models, that may seem removed from the direction of dependence usually presented in Dependency Grammar. These formal models — like Type-Theoretic semantics — can be seen as targeting transitions from surface grammar (where for example SVO order, or its alternatives, is essential) to a semantics as it initiates abstracting from immediate linguistic givens. Notice, moreover, how framing the syntax-to-semantics transitions in the above terms involves contrasting two different aspects of inter-word links — distinguished by the salience of implied temporality, which is present in (say) verb-object links modeling initial reception of a sentence, but abstracted from links modeling semantic structure seen as

functional organization wherein a series of "function-like" Parts of Speech converge through phrase-formation onto a complete idea. How this contrasting emphasis on inter-word link kinds marks different aspects or stages of language understanding arguably comes to our attention more clearly in a theoretical set-up that is built around inter-word links from the outset. So, consequently, I cite this as one final argument for Dependency Grammars overall.

I will discuss the "functional" dimension of Part of Speech and phrase modeling in greater detail later; which means the following elaboration of a syntax-to-semantics transition, to which I now turn, will be cut short. But it is worth sketching an outline of theory for this transition to complete my current review of "inter-word" grammar, insofar as the points in its favor which I have reviewed here also anticipate how these grammars may serve as one tier in multi-layered theory unifying syntax and meaning.

1.2 From Link Grammar to Type Theory

One consequence of my analyses so far, should they be accepted, is that grammar needs to be approached holistically: the grammatic structure of phrases cannot, except when deliberate oversimplification is warranted, be isolated from surrounded sentences and still larger discourse units. Semantic roles of phrases have some effect on their syntax, but phrases are nonetheless chosen from sets of options, whose variations reflect subtle semantic and syntactic maneuvers manifest at super-phrasal scales. The constituent words of phrases retain some autonomy, and can enter into inter-word and phrasal structures with other words outside their immediate phrase-context. We can still apply formal models to phrase structure — for example, Cognitive and Applicative Grammar (CAG) considers phrases as "applications" of (something like) linguistic or cognitive "functions", in the sense that (say) an adjective is like a *function* applied to a noun, to yield a different noun (viz., something playing a noun's conceptual role) [20]. "Functional" and (by extension) Type-Theoretic notions of Part of Speech (POS) and phrase-structure provide a rigorous foundation for the crucial syntax-to-semantics transition, in building an overall theory of Natural Language. But we should not read POS/applicative transformations — conceptual modulations dictated by POS "operators", like (for an adjectival example) *Syrian refugee* from *refugee* — too hastily as a purely semantic correlation within a space of denotable concepts — *such that* the new concept wholly replaces the contained parts, which then cease to have further linguistic role and effect. Instead, applicative structures represent shifts or evolutions in mental construal, which proceed in stages as conversants form cognitive models of each others' discourse. Even if phrase structure sets landmarks in this unfolding, phrases do not wholly subsume their constituents; the parts within phrases do not "vanish" on the higher scale, but remain latent and may be "hooked" by other, overlapping phrases. This argument rests on a vantage point from semantics as well as syntax; therefore, I will discuss it briefly at present (I return to this analysis at greater length in the next section).

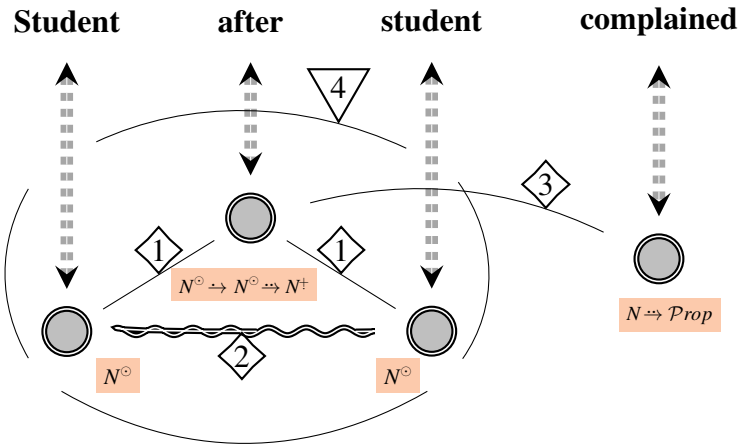
Consider the effect of "Many students complained". Propositionally, this appears to say essentially that *students* complained; but, on hermeneutic charity, the speaker had *some* reason to say "many". The familiar analysis is that "many" suggests relative size; but this is only half the story. If the speaker chose merely *students complained*, we would hear an assertion that more than one student did, but we would also understand that there

were several occasions when complaints happened. Adding "many" does not just imply "more" students, but suggests a mental shift away from the particular episodes. In the other direction, saying *a student complained* is not just asserting how at least one student did so, but apparently reports one specific occasion (which perhaps the speaker wishes to elaborate on). In other words, we cannot really capture the singular/plural semantics, or different varieties of plural, just by looking at the relative size of implied sets; we need to track how representations of singleness or multitude imply temporal and event-situational details. So *a student complained* focuses not on the numeric count of one, but on a singular event (unlike "*only one* student complained"); *students complained* focuses not on the plural measure of students involved, but on the fact that a certain type of event happened several times. *Many students complained* focuses not on sheer number (unlike *a large number of students complained*), but rather on the implication that complaints were widespread enough to represent a significant sample, perhaps a majority sentiment, among the student body. The semantics of the former two forms seems to focus attention on the *events* of complaining, while the *many students* construction seems to focus more on their suggesting a prevailing attitude. "Students complained" seems to single out each event as distinct, even though there are several of them; whereas *Many students complained* seems to construe the events as each resembling the other, to the point where they partly lose their individuality. "Isolated events", in the English idiom, are those which are atypical; as we cognitively shift from the events as discrete to recurring patterns, they become suggestive of a larger state of affairs. By implication, if many students complained, many other students may be unhappy; the extent of students' unrest is no longer measurable by the multiplicity of the complaining-events.

Against this backdrop, *Student after student complained* captures both dimensions, implying at once a widespread unrest among the student body and also temporal recurrence of complainings. To motivate further discussion, Figure 1 shows a Depency-style destructuring, along with (relatively simple) type annotations. Formal models of syntax and semantics often borrow notation from formal language theory, including POS notations lifted and repurposed from functional programming languages.[5] Such presentation can help us picture the "flow" of ideas building up to a complete sentence, formally represented via Type Theory (where sentences reveal a type hierarchy culminating in a self-contained idea, that is, a proposition); more informally we can picture a similar "conceptual" flow tracing how listeners come to make sense of the language they encounter enunciated by speakers. So, in Figure 1, a type model for "after" could be written: `after` :: $N^{\odot} \dot{\to} N^{\odot} \dot{\Rightarrow} N^{+}$ (using $N^{\odot}$ and N^{+} to mean singular and count-plural nouns, respectively) — but with the special case that the "argument" to *after* is repeated in both positions, suggesting an unusual degree of repetition, something frustratingly recurrent: *He went on and on*; *Car after car passed us by*; *Time after time I got turned down*. Although I have no problem treating these constructions as idiomatic plurals, I also contend (on the premise of phrase-overlap) that the dependent constituents in the ——`after`—— construction can be hooked to other phrases as well (which is why "and [their/his/her] parents" can also be singular, in this case). I dwell on this example because it shows how type/functional accounts of phrase structure can be useful even if we treat phrases more as frames which overlay linguistic structure, not as rigid compositional isolates. Each "students" variation

[5] A note on notation: I adopt the Haskell convention (referring to the Haskell programming language and other functional languages) of using arrows both between parameters and before output notation, but for visual cue I add one dot above the arrow in the former case, and two dots in the latter: $Arg_0 \dot{\to} Arg_1 \dot{\to} \cdots \dot{\Rightarrow} Result$. I use N for the broadest designation of nouns (the broadest noun type, assuming we are using type-theoretic principles), with extra markings for more specific types (in principle similar notation could be adopted for verbs, propositions, and so on).

Figure 1: Dependency-style graph with argument repetition



- ♦ 1 Head/dependent relation
- ♦ 2 Argument repetition (——`after`—— idiom)
- ♦ 3 Propositional completion ($V :: N \dashrightarrow \mathcal{P}rop$)
- ▼ 4 Phrase (modeled as applicative structure), typed as N^{+}

uses morphology and inter-word agreement (or even potentially lack thereof) to nudge cognitive attention in one direction or another, toward events or the degree to which events are representative of some global property (here of a student body), or both. The $N^{\odot} \dashrightarrow N^{+}$ transformation is not *the* morphosyntactic meaning, but instead the skeleton on which the full meaning (via cognitive schema) is designed, its hints solicited.

If this analysis has merit, it suggests that a CAG approach to phrases like *many students* or *student after student* (singular-to-plural or plural-to-plural mappings) should be understood not just as functions among POS types, but as adding cognitive shading, foregrounding or backgrounding cognitive elements like events, or like typicality in some context. In other words, *many students* is type-theoretically $N \dashrightarrow N$ or $N^{+} \dashrightarrow N^{+}$; but, in more detail, it adds a kind of cognitive rider, attached to the mapping, which focuses cognition in the subsequent discourse onto *events* (their recurrence and temporal distribution); similarly "student after student" has a "rider" suggesting more of a temporal unfolding. The different phrasings represent different speakers' intentions, to make the sentence more "about" the events or, conversely, more about their temporality. The second form implies not only that many students complained, but that the events of these complainings were spread out over some stretch of time. Each such functional application (mappings between Parts of Speech understood as linguistic types) produces not only a resulting POS "type", but also a reconfiguration of cognitive attitudes toward the relevant situation and context. The point is not that *cognitive attitudes* (which presumably are very metaphysically complex things) are neatly encapsulated by formalizable configurations of language, but that — even if we choose to be skeptical of formalization in this metaphysical terroir — formal theory can isolate the *triggers* which *start* listeners on the path to correctly parsing speakers' intensions.

A formal (e.g., Type-Theoretic) model of semantics may in fact be only a very incomplete story of semantics — may *not*, really, represent the observations and thought processes through which people understand meanings — but rather portray linguistic data that *do* catch listeners' attention and *do* compel listeners to complete the

idea, taking speakers' motives and situation into account. The formal structure on this account does not carry *the* meaning, but affords a mutually acknowledged layout which conversants fill out via empathy and situational awareness. Notwithstanding its incompleteness, the formal structure is still indispensable, because it conditions how the hearer *does* proceed to reconstruct speakers' communicative goals. It is the solid ground from which listeners depart toward the hazier goal of "reading others' minds". Language users have many ways to craft each sentence, and one task for linguistic analysis is to model the space of choices which are available in a given situation; to represent what ideas and effects are invoked by one selection over others. Listeners use this information instinctively, we can argue, as a pointer (usually, but not necessarily, one deliberately created by the speaker) to the thoughts intended within the utterance.

Sentences — and, in general, complete ideas (or beliefs, desires, requests, and so forth), represented in language — have constraints on conceptual coherence, which give rise accordingly to constraints on word and grammatic choice. Listeners recognize these constriants and observe how speakers design sentences around and conformant to them. Conceptual constraints (what makes a proposition a self-contained idea, for example) yield linguistic equivalents (such as, the fact that different kinds of verbs need different numbers of direct and/or indirect objects to yield a proposition). The latter, linguistic-proper constraints can be approached from different directions and scales — for example, from the sentence level "down", or the word level "up".

Suppose a cashier says, *I am missing quarters*. The statement's direct object is evidently (to be in a state involving) "missing quarters", which — although *quarter* is a conventional count-plural noun, the concept being a familiar physical object — as a phrase involves a kind of ascription of state or condition. For a type annotation we might refer to this as an $N_{\mathfrak{C}}$, or a noun capturing a condition, a subtype or variant of nouns; giving this type to the phrase by account of the lexical properties of "missing". On the other hand, the verb *to be* generally takes as its direct object a noun or noun phrase that also might be called "ascriptive" (or as I am expressing it $N_{\mathfrak{C}}$) — though see [28, pp. 57-58] for elaboration and exceptions — so progressing "down" from the "root" of the sentence we again find a need for an $N_{\mathfrak{C}}$ construction at this point. From the perspective of temporal unfolding, which I have also considered in previous examples, the *missing* certainly appears to be an incomplete idea, with the utterance's verb and subject already known, so the listener (if one were to arbitrarily freeze the discourse at that moment) is anticipating a word to complete a direct object of *to be*. So, in sum, different directions (root-to-leaf, lead-to-root — picturing the sentence as a tree — or before-to-after, picturing it as an unforlding performance) all appear to converge on the recognition of the phrase "missing quarters" as having a "type signature" like $N_{\mathfrak{C}}$: this captures its conceptual role, and its syntactic contibution to completing larger units of the discourse. That implies additional that, since "quarters" is a straightforward count-plural, *missing* is a "function-like" Part of Speech that "converts" a count-plural noun to an $N_{\mathfrak{C}}$, which (according to my recommended symbolization) would be written something like $N^{+} \dashrightarrow N_{\mathfrak{C}}$.

The "type" machinery so far may not appear to add much to a common-sense conceptual survey of the sentence, but notice that the same type pattern can be identified in more complex examples, such as if the cashier had said *I am out of quarters*. The single word (*missing*) is then replaced by a word-pair, which has a more complex "type model" since each individual word, as well as the pair, should be assigned a type. Notice

that *out* often expresses state or condition, viz., $N_{\mathfrak{C}}$, which means that *out of* can be described via *of* converting *out* (which is already $N_{\mathfrak{C}}$) into a type like that of *missing*, which has a function-like type signature *yielding* $N_{\mathfrak{C}}$: that is, $\texttt{of} :: N_{\mathfrak{C}} \dashrightarrow (N^{+} \dashrightarrow N_{\mathfrak{C}})$ (note that the "output" type is function-like, so the "out arrow" $\dashrightarrow$ marking appears twice). This is a rather complex annotation, but it seems to capture a pattern that recurs in a number of cases:

- I'm tired of politicians.
- I'm sick of (getting) bad news.
- I'm out of sorts.
- I'm lost (at a loss) for words.
- I'm excited by the news.

Most of these sentences support an interpretation identical to $N_{\mathfrak{C}} \dashrightarrow (N^{+} \dashrightarrow N_{\mathfrak{C}})$ for *out of*; in some the N^{+} is replaced with a singular noun or noun-phrase. The type analysis can help capture the similarities across these cases, however, providing both a kind of notational "package" for the relevant similarities and also pointing to a formal strategy for discerning this pattern when it occurs, something rigid enough to work in a computational module. On the other hand, the formal similarities belie a wide conceptual range: the mental operations which take us from "politicians" to our fatigue with them, are only remotely comparable to thinking from "words" to our being momentarily speechless. Certainly grammatic or coarse-grained semantic modeling like $N_{\mathfrak{C}} \dashrightarrow (N^{+} \dashrightarrow N_{\mathfrak{C}})$ does not by itself explain or convey the contrasts in these alternatives in conceptualization — but, the paradigm I am assuming here is that many levels of linguistic analysis do not need to "capture" meaning, but rather capture the simplified schema which we as language users find *in* language and which *starts* a conceptual process, without directly *modeling* that process.

In taking my argument up to here, I am necesarily switching to functional and type notions that are more semantic than syntactic, so they already anticipate extensions to Dependency Grammar proper and therefore to my main emphasis in this section. I have, nevertheless, tried to argue that separating syntax from semantics can be at most provisional. Inter-word "link pairs" are vehicles for expressing syntactic rules (like singular/plural agreement) but are also a ground level for semantic analysis, since we can explain how semantic nuances are carried, in specific sentences, by the actual link-pairs in evidence (violations to agreement norms, for example), which is one venue for contrasting the sentence that *was* enunciated against its sibling options that were *not* chosen. These semantic nuances in turn can be given cognitive interpretations, revealing a syntax-to-semantics-to-cognition pattern which I am sketching here through perspectives such as Link Grammar and Type Theory. But returning one last time to the initial syntactic stage of analysis, my tactics for contrasting Dependency and Phrase-Structure paradigms rest on an implicit and to this point mostly unstated picture of how theories should be evaluated. While a comparable suite of assumptions is probably fairly consistent across perspectives, it is still worth making a little more explicit.

1.3 Explanation and Formality

Both Dependency and Phrase Structure grammars presuppose that the fundamental exposition and achievement of their theory involves formal transformation of linguistic givens, resulting in a more complex data structure which, to the extent that the theory is correct and useful, models something of the inner structure of language

(*qua* abstract formal system and/or cognitive phenomenon). The "data structure" might be a phrase-structure "tree" or a graph-like dependency "linkage", but while these representations have different form they share certain criteria: they are formally describable systems which allow some structures but reject others; they are rigorous enough to be given a mathematical (e.g., algebraic) definition; and they can be expressed in computer code which builds these structures out of Natural Language artifacts, can verify that an instance of the relevant data structures satisfies the system rules, and can execute operations which modify the structures. The phrase trees or word-link graphs are "formal substrata" which encapsulate Natural Language patterns but also are rigidly mathematical and computational. How thoroughly these substrata capture linguistic meaning, is therefore directly relevant to questions of whether and in what degree natural language itself, as social and cognitive, is also formal and computational.

Translating NL content into (say) a linked-grammar graph does not make software capable of "understanding" language. If Dependency Grammar is a reasonable foundation for linguistics in general, then properly parsing sentences into their auxiliary graphs is, at most, a step in the direction toward "understanding". Even this may beg the question of what constitutes a "correct" parse: when writing real-world code, language engineers appear to rely principally on their own intuitions, based on their familiarity with the underlying theory, the idea they have of what a *correct* "re-presentation" looks like (for link grammar, of the correct collection of link types between the various words). They then add code to ensure that this representation is indeed identified by the software in specific examples, and try to do so in such a way as to generalize to other examples. This methodology can be gleaned from observing internet chat sites and other informal research venues; one can witness developers painstakingly constructing systems which "work right" in the sense of producing the interpretation for each sentence which corresponds with what the human linguists perceive, even for sentences which the software has never encountered before. The code is considered reliable the more that new sentences are "correctly" parsed. Again, "correctly" here means, conformant to linguists' own interpretations; insofar as these are subjective, such conformance is not conclusive evidence that the transformational algorithms are "correct".

In order to assess linguistic "competence" (or whatever computational ability may simulate it), it is needed to check specific "behavior" and compare it to some expectation. The gold standard for linguistic behavior is just participating in a linguistic community, judged by the community at large as fully competent and included. Unfortunately, however — at least for those who want to profit from Artificial Intelligence — achieving true "language-like behavior" may be impossible. Scholarship therefore has to turn toward more limited notions of competence, such as representational transformation of sentences — but since each theory has its own picture of what sentences should be transformed *into*, the justification of competence measures can be circular. It is the theory which dictates how the software should act, and the software is deemed "intelligent" if it acts accordingly. We can be skeptical of such non-theory-neutral conceptions of "intelligence". Nonetheless it does count in theories' favor if they both propose accounts of language structure which are independently defensible and also can produce computing systems that reliably and without external direction map language onto those structures. Language-like behavior then involves producing a transformed representation of language embodying a particular theoretical conception of linguistic "deep structure".

It would serve Computational-Linguistic theories still further to create systems that demonstrate behavior which is "language-like" on terms less wedded to their own hypotheses. More satisfying definitions of linguistic behavior would involve intuitions of language users in general, not just language experts. For example, document classifiers — which typically use statistical analysis to predict which topic will be deemed most relevant for documents like news stories and technical articles — again illustate a kind of transformational representation, converting Natural Language to a formal data structure (in this case a relatively simple one, naming one or multiple topics from a predefined list). In this case however a broad user public can provide feedback on how well the system performs. For another example, artificial translators map language onto formal structures but then attempt an opposite map, translating the formalized representation into natural-seeming expressions in a different language. This case is different in that formal representation is an intermediary rather than end point of the transformation, but like document classifiers it is a kind of behavior whose effectiveness can be judged by a large community of speakers. People who interact with text "chat" bots, or talking robots, and feel that the experience is similar to talking with another person, are also providing evidence of more complete and larger-scale language-like behavior. Again, though, it is not now and may never be possible to engineer intelligent behavior to this level of perfection. Existing language AI platforms are flawed but useful, which suggests both that formal re-presentation is an important step toward language understanding but also that attempts to use these formalisms as a springboard to more holistic behavior — like automated translation, but also extracting practical information, or gleaning emotion and sentiment — are missing something essential. Doing useful things with or gleaning useful insight from the re-presentational target structures appears to be a separate problem from that of generating them — which calls into question the degree to which the target structures sufficiently encapsulate linguistic meaning, even if they reveal structures which are essential to linguistic meaning.

This does not have to mean that Natural Language Processing is basically impossible, only that more modest criteria of "correct" NLP systems need to be adopted. This is complicated by the fact that artifical language behavior can be flawed but meaningful: "Urine shift one step forward" is an awkward English sentence but its meaning seems clear enough (an example from a shopping center men's room in New York's Flushing, Queens Chinatown). We have an intuition that some expressions are "incorrect" but not so completely off-base that they fail to signify anything at all — but in this case we need criteria for how a linguistic performance can be both incorrect *and* nonetheless coherent.

These issues influence any theory which approaches linguistic competence from the viewpoint of formal re-presentations, and therefore effectively all branches of Computational Linguistics. The reigning assumption appears to be that transformational representation which converts language to theory-regulated data structures, for which in many cases the transformation achieved by mechanical algorithms matches that intuited as most accurate by human experts, serves as *prima facie* evidence of something like computationally-engineered "intelligent (language) behavior". This leaves room for language-like behavior to productively replicate dimensions of language understanding while also being very incomplete: language-like relative to experts' opinions on deep linguistic structure, not real-world communication. Structures like link grammar graphs can be essential formal substrata that linguistic expression relies on to achieve communication, without being the

sole medium of this expression.

My arguments so far have used Link Grammar as a representative example of "transformational representation" where a computational system can be judged to reveal some level of language competence, some kind of "language like behavior", insofar as it translates natural language expressions to data structures conformant to Dependency Grammar (and particularly Link Grammar) theory. As I also just argued, performance vis-à-vis structural transformation may be only tangential to human language, so whatever theory is built up needs a separate, more philosophical or metatheoretical analysis to consider how the theory is purported to engage with its phenomena. But I now take this as a starting point for pivoting the discussion from grammar to semantics; and will defer until after that any speculating on philosophical implications of the theory thus extended.

2 Link Grammar and Type Theoretic Semantics

From one perspective, grammar is just a most top-level semantics, the primordial Ontological division of language into designations of things or substances (nouns), events or processes (verbs), qualities and attributes (adjectives), and so forth. Further distinctions like count, mass, and plural nouns add semantic precision but arguably remain in the orbit of grammar (singular/plural agreement rules, for example); the question is whether semantic detail gets increasingly fine-grained and somewhere therein lies a "boundary" between syntax and semantics. The mass/count distinction is perhaps a topic in grammar more so than semantics, because its primary manifestation in language is via agreement (*some wine* in a glass; *a wine* that won a prize; *many wines* from Bordeaux). But are the distinctions between natural and constructed objects, or animate and inanimate kinds, or social institutions and natural systems, matters more of grammar or of lexicon? Certainly they engender agreements and propriety which appear similar to grammatic rules. "The tree wants to run away from the dog" sounds wrong — because the verb "want", suggestive of propositional attitudes, seems incompatible with the nonsentient "tree". Structurally, the problem with this sentence seems analogous to the flawed "The trees wants to run away": the latter has incorrect singular/plural linkage, the former has incorrect sentient/nonsentient linkage, so to speak. But does this structural resemblance imply that singular/plural is as much part of semantics as grammar, or sentient/nonsentient as much part of grammar as semantics? It is true that there are no morphological markers for "sentience" or its absence, at least in English — except perhaps for "it" vs. "him/her" — but is this an accident of English or revealing something deeper?

To explore these questions it is first necessary to consider how a grammar theory can be extended to and/or connected with a formal or, to some measure, informal semantics. Here I will present one approach to make this extension vis-à-vis Link Grammar.

Insofar as grammatic categories do provide a very basic "Ontological" viewpoint, it is reasonable to build semantic formalization on top of grammar theories. Link Grammar, for example, explicitly derives "link types" — species of word-to-word relations — by appeal to "Categorial" grammars which define parts of speech in terms of their manner of composition with other, more "fundamental" parts of speech [34], [59]. The most

primordial grammatic categories are generally seen to be nouns and "propositions" (self-contained sentences or sentence-parts which assert individual states of affairs), and categories like verbs and adjectives are derived on their basis. For example, a verb "combines" with a noun to produce a proposition. *Students* is an abstract concept; "Students complained", tieing the noun to a verb, tethers the concept to an assertorial flesh, yielding something that expresses a belief or observation. Meanwhile, Categorial Grammar models not only the semantic transition from abstract to concrete, but surface-level composition: in English and other SVO language for example the verb should immediately follow the noun; in German and all SVO languages the verb tends the come last in a sentence, and can be well apart from its subject. The semantic pattern in the link is how the verb/noun pair yields a new semantic category (propositions) whereas the grammatic component lies in how the link is established relative to other words (to the left and not the right, for example, and whether or not the words are adjacent).

Assuming that surface-level details can be treated as grammar rules and abstracted from the semantics, we can set aside Categorial Grammar notions like connecting "left" vs. "right" or "adjacent" (near) vs. "nonadjacent" (far). With this abstracting, Categorial Grammar becomes similar to a Type-Theoretic Semantics which recognizes, in Natural Language, operational patterns that are formally studied in mathematics and computer science [42], [56], [45]. A verb, for example, *transforms* a noun into a sentence or proposition (at least an intransitive verb; other kinds of verbs may require two, or even three nouns). In some schematic sense a verb is analogous to a mathematical "function", which "takes" one or more nouns and "yields" propositions, much like the "square" function takes a real number and yields a non-negative real number. To make this analogy useful, it is necessary to clarify how "types" in a mathematical or computational context may serve as appropriate metaphors for syntactic and/or semantic groupings in language.

2.1 Types, Sets, and Concepts

Most Computer Science rests on types rather than (for example) sets, because abstract reasoning about data types requires some abstraction from practical limitations about how particular values may be digitally encoded. Types can be defined as sets of both values and "expectations" [10] (meaning assumptions which may be made about all values covered by the type); alternatively, we can (perhaps better) consider types as *spaces* of values. Types' extensions have internal structure; there can be "null" or "invalid" values, default-constructed values, and so forth, which are "regions" of type-space and can be the basis of topological or Category-Theoretic rather than set-based analyses of type-extension. Also, expectations intrinsically include functions which may be "called on" types. There is definitional interdependence between types and functions: a function is defined in terms of the types it accepts as parameters and returns — rather than its entire set of possible inputs and outputs, which can vary across computing environments. These are some reasons why in theoretical Computer Science types are not "reduced" to underlying sets; instead, extensions are sometimes complex spaces that model states of, or internal organization of comparisons among, type instances.

An obvious paradigm is organizing type-extensions around prototype/borderline cases — there are instances which are clear examples of a type and ones whose classification is dubious. I will briefly argue later, however,

that common resemblance is not always a good marker for types being well-conceived — many useful concepts are common precisely because they cover many cases, which makes defining "prototypes" or "common properties" misleading; this reasoning arguably carries over to types as well. Also, sometimes the clearest "representative" example of a type or concept is actually not a *typical* example: a sample letter or model home is actually not (in many cases) a real letter or home. So resemblance-to-prototype is at best one kind of "inner organization" of concepts' and types' spaces of extension. Computer Science develops other pictures of types' "state space", reflecting the trajectory of symbols or channels which hold type instances, which at different moments in time become initialized — acquiring a value obtained from a *constructor* function (one "type space region" is then demarcated by which values can be direct results of constructors) — then possibly subject to change in the value they hold, and finally (often) transitioning to a state where the held value is no longer "valid".[6] Type *spaces* have potentially complex patterns of regions and equivalence classes of inter-value mappings (in the sense of behavioral equivalence relative to code analysis, testing, or security) — the *conceptual* properties of types are expressed in the *internal structuration* of their associated state-space. Putting this in mathematical language, an in-depth treatment of types cannot work "in the Category" of sets, even for basic type-extension, but rather (for instance) the Category of Topological Spaces. This represents a more sophisticated picture of type extension than (for example) resemblance-to-prototype, which as a model of extension-structuration may apply in some cases but is a flawed picture in general.

Moreover, with respect to "expectations", these in a particular case may be more precise than what is implied by the type itself — it is erroneous to assume that a proper type system will allow a correct "set of values" to be stipulated for each point in a computation (the kind of contract enforced via documentation and unit testing). So state-space in a given context can include many "unreasonable" values, implying that within the overall space there is a "reasonable" subspace, except that this subspace may not be crisply defined. A value representing someone's age may be assigned a type for which a legal value is, say, 1000 years, which is obviously unreasonable — the conceptual role served by the *particular* use of a type in some context can be distinct from the entire space of values exhibited by the type. It is possible to construct types which are narrowed down to more precise ranges, but in many cases this is unnecessary or poorly motivated: while 1000 years is clearly too large for an age, it would be arbitrary to specify a "maximum allowed" age (recall that assuming a "maximum allowed" year of 1999 — so that the year in decimal only required two digits — led to costly reprogramming of archaic legacy code during Y2K). In this kind of situation programmers usually assign types based on properties of binary representation — what number of binary digits is optimal for memory and/or speed, even if this allows "absurd" values like 1000 years old. Run-time checks, rather than type restrictions, may be used to flag nonsensical data and prevent data corruption. In these scenarios, types represent a compromise between *concepts*, which can be fuzzy and open-ended, and *sets*, which conceptually are nothing more than the totality of their extension.[7]

[6] Managing the "lifetime" of values from many types, especially "pointer" types (that hold a numeric value representing the current memory address of some other value), has been a notorious source of programming errors, especially in older computer languages. Of late, also, data types often need to be designed to minimize the risk of data corruption, theft, and malicious code. For these reasons, Cybersecurity takes particularly interest in studying types' extensions and transitions between different values (morphisms within a type space) to formally describe states or state-transitions which are security vulnerable.

[7] Nevertheless, there is interesting (and potentially practically useful) research in how formal type-constructions model conceptual organization: for example, Gärdenfors Conceptual Space Theory has seen formal implementations [1], and it is very interesting to juxtapose scientific and mathematical treatments of Conceptual Spaces (as in [69] or [24]) with mathematical (e.g., topological) thoeries of data types [21], [60].

These examples demonstrate that type extensions have internal patterns of organization, and that the nature and significance of these patterns vary considerably and often reflect conceptual structures which types are used to formally represent. Sets, concepts, and types represent three different primordial thought-vehicles for grounding notions of logic and meaning. To organize systems around *sets* is to forefront notions of inclusion, exclusion, extension, and intersection, which are also formally essential to mathematical logic and undergird the classical interdependence of sets, logic, and mathematics.[8] To organize systems around *concepts* is to forefront practical engagement and how we mold conceptual profiles, as collections of ideas and pragmas, to empirical situations. To organize systems around *types* is to forefront "functions" or transformations which operate on typed values, the interrelationships between different types (like subtypes and inclusion — a type can itself encompass multiple values of other types), and the conceptual abstraction of types themselves from the actual sets of values they may exhibit in different environments. Sets and types are formal, abstract phenomena; whereas concepts are characterized by gradations of applicability, and play flexible roles in thought and language. The cognitive role of concepts can be discussed with some rigor, but there is a complex interplay of cognitive schema and practical engagements which would have to be meticulously sketched in many real-world scenarios, if our goal were to translate conceptual reasoning to formal structures on a case-by-case basis. We can, however, consider in general terms how type-theoretic semantics can capture conceptual structures as part of the overall transitioning of thoughts to langauge.

A concept does not merely package up a definition, like "restaurant" as "a place to order food"; instead concepts link up with other concepts as tools for describing and participating in situations. Concepts are associated with "scripts" of discourse and action, and find their range of application through a variegated pragmatic scope. We should be careful not to overlook these pragmatics, and assume that conceptual structures can be simplistically translated to formal models. Cognitive Linguistics critiques Set-Theoretic or Modal Logic reductionism (where a concept is just a set of instances, or an extension across different possible worlds) — George Lakoff and Mark Johnson, prominently, argue for concepts' organization around prototypes ([38, p. 18]; [31, p. 171, or p. *xi*]) and embodied/enactive patterns of interaction ([38, p. 90]; [31, p. 208]). Types, by contrast, at least in linguistic applications of type theory, are abstractions defined in large part by quasi-functional notions of phrase struture. Nevertheless, the *patterns* of how types may inter-relate (mass-noun or count-noun, sentient or non-sentient, and so forth) provide an infrastructure for conceptual understandings to be encoded in language — specifically, to be signaled by which typed articulations conversants choose to use. A concept like *restaurant* enters language with a collection of understood qualities (social phenomena, with some notion of spatial location and being a "place", etc.) that in turn can be marshaled by collections of allowed or disallowed phrasal combinations, whose parameters can be given type-like descriptions. Types, in this sense, are not direct expressions of concepts but vehicles for introducing concepts into language.

Concepts (and types also) are not cognitively the same as their extension — the concept *restaurant*, I believe, is distinct from concepts like *all restaurants* or *the set of all restaurants*. This is for several reasons. First, Concepts can be pairwise different not only through their instances, but because they highlight different

[8] Recent work in mathematics, however (partly under the influence of computational proof engines and foundations research like Homotopy Type Theory) shows that type and/or Category theory may replace sets as a groundlevel for logico-mathematical reasoning (if not notation) in the future [30] (It is worth pointing out that despite their similar ordinary meanings, mathematically *type* is much different from *Category* even though these respective theories can be usefully integrated).

sets of attributes or indicators. The concepts "American President" and "Commander in Chief" refer to the same person, but the latter foregrounds a military role. Formal Concept Analysis considers *extensions* and "properties" — suggestive indicators that inhere in each instance — as jointly (and co-dependently) determinate: concepts are formally a synthesis of instance-sets and property-sets [82], [5], [80]. Second, in language, clear evidence for the contrast between *intension* and *extension* comes from phrase structure: certain constructions specifically refer to concept-extension, triggering a mental shift from thinking of the concept as a schema or prototype to thinking of its extension (maybe in some context). Compare these sentences:

- Tigers in that park are threatened by poachers.
- Young tigers are threatened by poachers.

Both sentences focus a conceptual lens in greater detail than *tiger* in general, but the second does so more intensionally, by adding an extra indicative criterion; while the former does so extensionally, using a phrase-structure designed to operate on and narrow our mental construal of "the set of all tigers", in the sense of *existing* tigers, their physical place and habitat, as opposed to the "abstract" (or "universal") type. So there is a familiar semantic pattern which mentally transitions from a lexical type to its extension and then extension-narrowing — an interpretation that, if accepted, clearly shows a different mental role for concepts of concepts' *extension* than the concepts themselves.

There is a type-theoretic correspondence between intension and extension — for a type $\mathcal{T}$ there is a corresponding "higher-order" type of *sets* whose members are $\mathcal{T}$.[9] If we take this (higher-order) type gloss seriously, the extension of a concept is not its *meaning*, but a different, albeit interrelated concept. Extension is not definition. "Tiger" does not mean *all tigers* (or *all possible tigers*) — though arguably there are concepts *all tigers* and *all restaurants* (etc.) along with the concepts *tiger* and *restaurant*. Concepts, in short, do not mentally signify sets, or extensions, or sets-of-shared-properties. Concepts, rather, are cognitive/dialogic tools. Each concept-choice, as presentation device, invites its own follow-up. *Restaurant* or *house* have meaning not via idealized mental pictures, or proto-schema, but via kinds of things we do (eat, live), of conversations we have, of qualities we deem relevant. Concepts do not have to paint a complete picture, because we use them as part of ongoing situations — in language, ongoing conversations. Narrow concepts — which may best exemplify "logical" models of concepts as resemblance-spaces or as rigid designators to natural kinds — have, in practice, fewer use-cases *because* there are fewer chances for elaboration. Very broad concepts, on the other hand, can have, in context, too *little* built-in *a priori* detail. (We say "restaurant" more often than *eatery*, and more often than *diner*, *steakhouse*, or *taqueria*). Concepts dynamically play against each other, making "spaces" where different niches of meaning, including levels of precision, converge as site for one or another. Speakers need freedom to choose finer or coarser grain, so concepts are profligate, but the most oft-used trend toward middle ground, neither too narrow nor too broad. *Restaurant* or *house* are useful because they are noncommittal, inviting more detail. These dynamics govern the flow of inter-concept relations (disjointness, subtypes, partonymy, etc.).

Concepts are not rigid formulae (like instance-sets or even attributes fixing when they apply); they are

[9] Related constructions are the type of *ordered sequences* of $\mathcal{T}$; unordered collections of $\mathcal{T}$ allowing repetition; and stacks, queus, and deques (double-ended queues) as $\mathcal{T}$-lists that can grow or shrink at their beginning and/or end.

mental gadgets to initiate and guide dialog. Importantly, this contradicts the idea that concepts are unified around instances' similarity (to each other or to some hypothetical prototype): concepts have avenues for contrasting different examples, invoking a "script" for further elaboration, or for building temporary filters ("Let's find a restaurant that's family-friendly"; allowing such one-off narrowing is a feature of the concept's flexibility). No less important, than acknowledged similarities across all instances, are well-rehearsed ways vis-à-vis each concept to narrow scope by marshaling lines of *contrast*, of *dissimilarity*. A *house* is obviously different from a *skyscraper* or a *tent*, and better resembles other houses; but there are also more nontrivial *comparisons* between houses, than between a house and a skyscraper or a tent. Concepts are not only spaces of similarity, but of *meaningful kinds of differences*.

To this account of conceptual spaces we can add the conceptual matrix spanned by various (maybe overlapping) word-senses: to *fly*, for example, names not a single concept, but a family of concepts all related to airborn travel. Variations highlight different features: the path of flight (*fly to Korea*, *fly over the mountain*); the means (*fly Korean air*, *that model flew during World War II*); the cause (*sent flying (by an explosion)*, *the bird flew away (after a loud noise)*, *leaves flying in the wind*). Words allow different use-contexts to the degree that their various *senses* offer an inventory of aspects for highlighting by *morphosyntactic* convention. Someone who says *I hate to fly* is not heard to dislike hand-gliding or jumping off mountains.[10] Accordant variations of cognitive construal (attending more to mode of action, or path, or motives, etc.), which are elsewhere signaled by grammatic choices, are also spanned by a conceptual space innate to a given word: senses are finer-grained meanings availing themselves to one construal or another.

So situational construals can be signaled by word- and/or syntactic form choice (locative, benefactive, direct and indirect object constructions, and so forth). Whereas conceptual organization often functions by establishing classifications, and/or invoking "scripts" of dialogic elaboration, cognitive structure tends to apply more to our attention focusing on particular objects, sets of objects, events, or aspects of events or situations. *Conceptual* is more abstract and belief-oriented; *Cognitive* is more concrete and phenomenological. Concepts organize our "background knowledge" [67]; cognitions allow it to be latent against the disclosures of material consciousness [65], [66], [83], [32]. So the contrast between singular, mass-multiples, and count-multiples, among nouns, depends on cognitive construal of the behavior of the referent in question (if singular, its propensity to act or be conceived as an integral whole; if multiple, its disposition to either be divisible into discrete units, or not). Or, events can be construed in terms of their causes (their conditions at the outset), or their goals (their conditions at the conclusion), or their means (their conditions in the interim). Compare *attaching* something to a wall (means-focused) to *hanging* something on a wall (ends-focused); *baking* a cake (cause-focus: putting a cake in the oven with deliberate intent to cook it) to *burning* a cake (accidentally overcooking it).[11] Words'

[10] People, unlike birds, do not fly — so the verb, used intransitively (not flying *to* somewhere in particular or *in* something in particular), is understood to refer less to the physical motion and more to the socially sanctioned phenomenon of buying a seat on a scheduled flight on an airplane. The construction highlights the procedural and commercial dimension, not the physical mechanism and spatial path. But it does so *because* we know human flight is unnatural: we can poetically describe how the sky is filled with flying leaves or birds, but not "flying people", even if we are nearby an airport. Were "flying people" used jokingly, it would be in bad taste, like "cat all over the driveway" from Pinker [54] (page 119) and Langacker's "Nouns and Verbs" [39] (page 67).

[11] We can express an intent to bake someone a cake, but not (well, maybe comedically) to *burn* someone a cake ("burn", at least in this context, implies something not intended); however, we *can* say "I burnt your cake", while it is a little jarring to say "I baked your cake" — the possessive implies that some specific cake is being talked about, and there is less apparent reason to focus on one particular stage of its preparation (the baking) once it is done. I *will* bake a cake, in the future, uses "bake" to mean also other steps in preparation (like "make"), while, in the present, "the cake *is* baking" emphasizes more its actual time in the oven. I *baked your cake* seems to focus (rather unexpectedly) on this specific stage even after it is completed, whereas *I baked you a cake*, which is worded as if the recipient did not

senses mutate in relation to the kinds of situations where they are used — why else would (at least as I just read it, in the footnote) *bake* mean "make"/"prepare" in the past or future tense but "cook"/"heat" in the present? These variations are not random assortments of polysemous words' senses: they are, instead, rather predictably distributed according to speakers' context-specific knowledge and motives.

I claim therefore that *concepts* enter language complexly, influenced by conceptual *spaces* and multi-dimensional semantic and syntactic selection-spaces. Concepts are not simplistically "encoded" by types, as if for each concept there is a linguistic or lexical type that just disquotationally references it — that the type "tiger" means the concept *tiger* ("type" in the sense that type-theoretic semantics would model lexical data according to type-theoretic rules, such as *tiger* as subtype of *animal* or *living thing*). Cognitive schema, at least in the terms I just laid out, select particularly important gestalt principles (force dynamics, spatial frames, action-intention) and isolate these from a conceptual matrix. On this basis, we can argue that these schema form a precondition for concept-to-type association; or, in the opposite logical direction, that language users' choices to employ particular type articulations follow forth from their prelinguistic cognizing of practical scenarios as this emerges out of collections of concepts used to form a basic understanding of and self-positioning within them.

In this sense I called types "vehicles" for concepts: not that types *denote* concepts but that they (metaphorically) "carry" concepts into language, as a bus carries people into a city. "Carrying" is enabled by types' semi-formal rule-bound interactions with other types, which are positioned to capture concepts' variations and relations with other concepts. To express a noun in the benefactive case, for example, which can be seen as attributing to it a linguistic type consistent with being the target of a benefactive, is to capture the concept in a type-theoretic gloss. It tells us, I'm thinking about this thing in such a way that it *can* take a benefactive (the type formalism attempting to capture that "such a way"). A concept-to-type "map", as I just suggested, is mediated (in experience and practical reasoning) by cognitive organizations; when (social, embodied) enactions take linguistic form, these organizing principles can be encoded in how speakers apply morphosyntactic rules. So the linguistic structures, which I propose can be formally modeled by a kind of type theory, work communicatively as carriers and thereby signifiers of cognitive attitudes. The type is a vehicle for the concept because it takes part in constructions which express conceptual details — the details don't emerge merely by virtue of the type itself. I am not arguing for a neat concept-to-type correspondence; instead, a type system provides a "formal substrate" that models (with some abstraction and simplification) how properties of individual concepts translate (via cognitive-schematic intermediaries) to their manifestation in both semantics and syntax.

Continuing with benefactive case as a case study (no pun intended), consider how an ontology of word senses (which could plausibly be expressed by types and subtypes) can interrelate with the benefactive. A noun as a benefactive target most often is a person or some other sentient/animate being; an inanimate benefactive is most likely something artificial and constructed (cf., *I got the car new tires*). How readily hearers accept a sentence – and the path they take to construing its meaning so as to make it grammatically acceptable – involves interlocking morphological and type-related considerations; in the current example, the mixture of benefactive

know about the cake ahead of time, apparently uses "bake" in the broader sense of "made", not just "cooked in an oven".

case and which noun "type" (assuming a basic division of nouns into e.g. animate/constructed/natural) forces a broader or narrower interpretation. A benefactive with an "artifact" noun, for example, almost forces the thing to be heard as somehow disrepaired:

- I got glue for your daughter.
- I got glue for your coffee mug.

We gather (in the second case) that the mug is broken — but this is never spelled out by any lexical choice. It is implied indirectly by benefactive case along with notions of classification, on the grammar/semantic border, that have a potential type-theoretic treatment. It is easy to design similar examples with other cases: a locative construction rarely targets "sentient" nouns, so in

- We're going to Grandma!
- Let's go to him right now.
- Let's go to the lawyers.
- Let's go to the press.

we mentally substitute the person with the place where they live or work. Morphosyntactic considerations are also at play: *to the lawyers* makes "go" sound more like "consult with", partly because of the definite article (*the* lawyers implies conversants have some prior involvement with specific lawyers or else are using the phrase metonymically, as in "go to court" or "to the courts", for legal institutions generally; either reading draws attention away from literal spatial implications of "go"). "Go to him" implies that "he" needs some kind of help, because if the speaker just meant going to wherever he's at, she probably would have said that instead. Similarly, the locative in *to the press* forces the mind to reconfigure the landmark/trajector structure, where "going" is thought not as a literal spatial path and "press" not a literal destination — in other words, the phrase must be read as a metaphor. But the "metaphor" here is not "idiomatic" or removed from linguistic rules (based on mental resemblance, not language structure); here it clearly works off of formal language patterns: the landmark/trajector relation is read abstracted from literal spatial movement because the locative is applied to an expression (*the press*) which does not (simplistically) meet the expected interpretation as "designation of place". We need to analyze syntactic details like noun case and forms of articles, but also finer-grained (though not purely lexicosemantic) classifications like sentient/nonsentient or spatial/institutional.

One way to engage in classification in this kind of example is just to consider subtyping: divide nouns into sentient and non-sentient, the former into human and animal and the latter into artifacts and natural things, and so forth. But other options are less blunt. For example, notions like sentient/nonsentient can be construed as "higher-order types", meaning that for broadly-hewed types like nouns or verbs, there are sentient (and non-sentient) variants, just as for a type $\mathcal{T}$ there are mass-plural and count-plural collections of $\mathcal{T}$, ordered and unordered $\mathcal{T}$ collections, and so on. Subtyping, higher-order types, inter-type associations and various other formal combinations are options for encoding grammatic and semantic classification in something like a formal type theory. The key properties of type systems are not only meanings atttached to individual types but notions of functionality (according to the central notion that a type system includes "function" types which are mappings between other types; in Category Theory, any formal type system is "Cartesian Closed", meaning that

if $\mathcal{T}_1$ and $\mathcal{T}_2$ are types, there is necessarily a type $\mathcal{T}_2^{\mathcal{T}_1}$ of functions between them). So if adjectives, say, are most basically $N \dashrightarrow N$ (they modify nouns and yield noun-role phrases), we can then consider how adjectives should be modeled when their modified nouns are associated with or attributed sentience, mass-plural, or any other variation (whether via subtyping or some other association). How these "variations" are modeled in accord with one single type is less important than how they "propagate" via applicative structures, where "function-like" types apply transformations and produce phrases.

To build up a linguistic type theory, I assume, then, a framework of types and type associations with a few underlying properties, such as these:

- Types have a spectrum of granularity, from the very broad (Parts of Speech) to the much narrower, including (at the fine end of the scale) where they incorporate lexical data (types can potentially include *tiger*, *house*, and so on). In between are constructions related to "Ontology", like sentient/nonsentient, pointwise/extended, artifact/institution, among many others.

- Types are neither strictly grammatic nor strictly semantic, but their gradations of precision cross between grammar and semantics.

- Returning to "Ontology": types have associated qualities like sentient/nonsentient; spatially (and/or temporally) extended, pointwise, or non-spatial (/non-temporal); caused, self-causing, self-determining, affected by other things, affecting other things; objects, events, processes, or institutions; abstracta or spatetime present things; observables or subjectives like emotions or sensations, which are temporally present for someone but not (directly) encountered by others. These are qualities pertaining to the manner of referents' appearing, causing, and extending in the world and in consciousness, and to a "classification" of kinds of entities (like a metaphysical Ontology, though the point is not to reproduce Medieval philosophy but, more modestly, to catalog word senses). I will refer to these qualities generically as "associations". They may be introduced via subtyping or more complex type operators.

- Some types are "function like": this means that they are *applied* to senses (i.e., word senses and phrase meanings) which have their own types. Here they exhibit one form of head/dependent relation, where a head word instances a function-like type and is applied to one or more "dependents". As I mentioned in the last section, the source-to-target direction of this relation can be inverted from Dependency relations in other context. To reiterate, the cognitive case for this direction (setting aside the purely formal function-type structure) is how, for example, nouns "depend on" verbs in the progression from general concepts to propositional judgment.

- Type information "distributes over" Link Grammar pairs. For any pair of words which have a meaningful inter-word relation, we can consider types which may be applicable to both words, and how these types affect and are affected by the significance of the particular kind of link. Some kinds mandate particular type interpretations of the paired elements: TS links,[12] to cite a narrow example, would only be formed

[12] http://www.link.cs.cmu.edu/link/dict/section-TS.html

between verb and $\mathcal{P}rop$ types (at least, this is a plausible interpretation of the relevant Link Grammar rules). Other type/link combinations are more open-ended.

- Type information similarly "distributes" over clusters of link-pairs, where the presence of one such link influences how a connected link is understood (or whether it is allowed). Type-related qualifications can propagate from one link-pair to connected link-pairs.[13]

- Type information also "distributes over" applicative structures. Given a function-like type we can consider how associations for the head and dependent elements propagate to associations on the resulting phrase — again, via subtyping or some other mechanism.

Such a "linguistic type theory" needs to model (at the least) these aforementioned associations, the "distribution" of type details over link and applicative structures, and the "propagation" of associations and other type details. While informal analyses in any single case may be clear, integrating many case-studies into a unified theory can be advanced by drawing ideas from rigorous, quasi-mathematical type theories — relevant research has adopted technical formations like "dot-types", higher-order types, Dependent Types, Monoidal Categories, Tensors, Continuations, "Linguistic Side Effects", Monads, Combinatory Logic, and (Mereo)Topology/Geometry.[14] Such techniques can marshal type-theoretic ideas without falling back on simplistic type notions that can end up collapsing a type-system into a one-dimensional "Ontological" classification, rather than exploring more advanced formulations like higher-order types and (what I am callling) "associations".

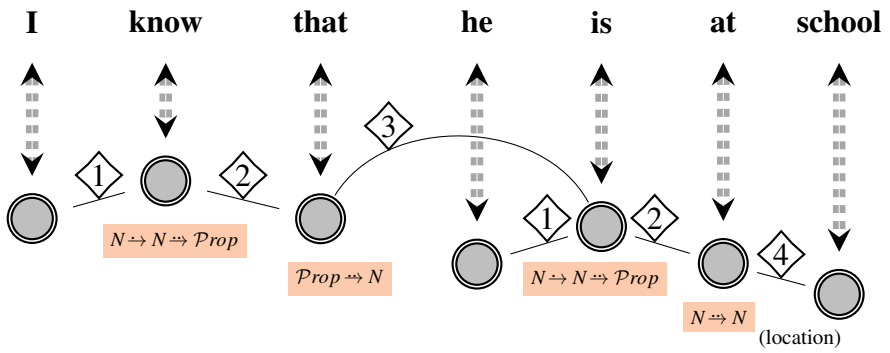
With respect to Type Theory related to Link Grammar, consider again the TS links (there are dozens of potential link-grammar pairs, of which TS are among the less common, but they provide a useful example). First, note that $\mathcal{P}rop$ provides a type attribution for sentences, but also for sentence parts: *he is at school*, for example, presents a complete idea, either as its own sentence or part of a larger one. In the latter case, a $\mathcal{P}rop$ phrase would typically be preceded with a word like *that*; in the case of Link Grammar, we can define words relative to their semantic and/or syntactic role, which often lies primarily in linking with other parts of a sentence or helping those parts link with each other. Type-theoretically, however, we may want to assign types to every word, even those which seem auxiliary and lacking much or any semantic content of their own. Arguably, *that* serves to "package" an assertion, encapsulating a proposition as a presumed fact designated as one idea, for the sake of making further comments, as if "making a noun" out of it: $\mathcal{P}rop \twoheadrightarrow N$. Perhaps our intuitions are more as if *that he is at school* is also a proposition, maybe a subtly different kind, by analogy to how questions and commands are also potentially $\mathcal{P}rop$ variants. Since THAT-phrases are "arguments" for verbs, the choice then becomes whether it is useful to expand our type picture of verbs so that they may act on propositions as well as nouns, or rather type "encapsulated" propositions as just nouns (maybe special kinds of nouns).

In either case, *I know that ...* clearly involves a verb with subject and direct object: so either $V :: N \twoheadrightarrow N \twoheadrightarrow \mathcal{P}rop$

[13] For example, we can say that the linkage structure in "Three times students asked an interesting question" alters the normal type-attribution of "students" as just a plural noun; relative to the connected structure linking "three times" through "students" to "a question", we can say that *three times* modifies "students" so that it may function, as subject of "asked", as if typed as singular, because *three times* acts as a "space builder" and creates a mental frame wherein the students are singular, even if the word is plural. Because of this frame phenomenon, the singular/plural status of students does not propagate to "a question"; collectively they presumably did not all ask just one question. Type annotation for "students" has to be defined, in this case, relative to multiple "cognitive frames".

[14] Monoids: [19]; Tensors: [43]; Continuations: [4]; Combinators: [76]; Dependent Types: [44]; Side Effects: [62]; Monads: [25], [61], [34]; Topology: [53], [13].

Figure 2: Dependency-style graph with type annotations



- 1 Verb's subject argument
- 2 Verb's direct object argument
- 3 Propositional "packaging" ("typed" as $\mathcal{P}rop \dashrightarrow N$)
- 4 Locative auxiliary link
  (may be typed as converting nouns to place-designations)

or $V :: N \dashrightarrow \mathcal{P}rop \dashrightarrow \mathcal{P}rop$. Consider the role of a TS-link here: specifically, TS connects the verb to the assertorial direct object (most directly, to *that*). The purely formal consideration is ensuring that types are consistent: either the TS target is $\mathcal{P}rop$, as I suggested above, with the verb type modified accordingly; or the TS target is a noun, though here it is fair to narrow scope. For this particular kind of link, the target must express a proposition: either typed directly as such or typed as, say, a noun "packaging" a proposition, which would then be a higher-order type relation (just as "redness" is a noun "packaging" an adjective, or "running" is an adjective packaging a verb). In other words, it is difficult to state the type restrictions on the link-pair without employing more complex or higher-order type formations.

On the other hand, this is another example of the fuzzy boundary between syntax and semantics: given a sentence which seems to link a verb calling for a belief or assertion (like "know", "think", "suggest", "to be glad") to something that is not proposition-like, is such a configuration ungrammatical, or just hard to understand? Clearly, the *semantic* norms around verbs like "know" is that their *subject* has some quality of sentience (or can be meaningfully attributed belief-states, even if speakers know not to take it literally: "The function doesn't know that this number will never be zero"); and their *object* should be somehow propositional. But applying type theory (or type theory in conjunction with Dependency Grammar) leaves open various analytic preferences: these requirements can be presented as rigid grammatic rules or as "post-parsing" semantic regulations. How to model the qualities of sentience (or at least of having propositional attitudes broadly conceived), for the noun, and of propositionality, for the direct object, are again at the discretion of the analysis (subtypes, quality-associations, or etc.). Figure 2 shows one potential unpacking of the sentence: from this structure details can be added perhaps as extra syntax constraints or perhaps more as cues to interpretation. If these requirements are seen as more syntactic, so qualities are incorporated into data like Part of Speech (say, a noun designating something with propositional attitudes being a subtype of a generic N type), then we are more likely to analyze violations as simply incorrect (recall "The tree wants to run away from the dog" — ungrammatical or just somehow "exotic"?). Some examples suggest less incorrectness as clever or poetic usage

— so a richer analysis may recognize expressions as type- and link-wise acceptable, but showing incongruities (which is not the same as impropriety) at a more fine-grained type level. That *to want* takes a subject *associated* with sentience does not force type annotations to inscribe this in grammatic or lexical laws; instead, these associations can be introduced as potential "side effects", *triggering* re-associations such as forcing hearers to ascribe sentience to something (like a tree) where such ascription is not instinctive. The type effect in this case lies more at the conceptual level, the language-user sifting conceptual backgrounds to find a configuration proper to the type requirements (in what sense can a tree "want" something?). In this "tree" case we probably appeal to concepts of "as if": if the tree *were* sentient, it would be nervous of the dog sniffing around — a humorous way of calling attention to the dog's actions (obliquely maybe alluding to people's background knowledge that dogs sometimes do things, like pee, in inconvenient places, from humans' perspectives).

In brief, it is certainly possible — though by no means mandatory — to model type requirements with greater flexibility at a provisional grammatical layer, and then narrow in on subtypes or extra accumulations of qualifications on type-instances in a transition from grammar to semantics. Regarding the most recent example, different types with varying levels of precison can be applied to the *tree*: just a noun (or singular noun); or our usual understanding of trees as living, inanimate, nonsentient things; or the tree exotically talked about as if sentient, for that one sentence. Each type attribution is reasonable at different levels of analysis, and the formal consequence of attributions varies accordingly. From the viewpoint of purely grammatic categories like noun and verb, the most important "type check" — which I will review in the next subsection — is ensuring that sentences "fold" properly into a proposition type inhabited by the sentence as a whole. At this level a paradigmatic sentence is like a tree, whose "leaves" are nouns and whose "root" is a proposition, and sentence-understanding involves a conceptual progression from nouns (as general concepts) to assertions (of specific states of affairs, or at least belief-states). Such a truth-theoretic take on signification is indeed oversimplified; but recall that extreme simplicity may be warranted for discerning just the basic type scaffolding of a language act. This is only the most provisional outline of a meaning still to be projected in, with type analysis accordingly eroded to a bare-boned "reduction to proposition" — the minimal semantic outline assumed at the outset, given "propositional cycle" accounts of language performance as I mused on in the first Section. On other levels the analyses can take on greater detail, building in what the "cycle" merely promises. From the finer viewpoint of lexical meaning, for instance, the type model can focus on disambiguating word-senses and showing how sense, morphology, and syntax constrain each other.

Perhaps, in this variance of levels, cognitive schema occupy an intermediary role: progressing from basic recognition of grammaticality — taking "reduction to proposition" as a starting point — reconstructing speaker's intent passes through cognitive schema, to conceptual framing, with type machinery capturing some of the thought-processes at each "step" (not that such "steps" are necessarily in a temporal sequence). The basic verb-subject-direct object articulation sets up an underlying cognitive attitude (represented by a basic type-framing of verb, noun, and proposition, like the $V :: N \nrightarrow N \nRightarrow \mathcal{P}rop$ signature). Cognitive ascriptions fill this out by adding detail to the broader-hewed typing, associating (for instance) sentience with the subject and propositionality with the object (sub- or higher-order typing modeling this stage). And how the actual lexical choices fit these cognitive expectations — I call them cognitive because they are intrinsically tied to structurational schema

in the type, morphology, and word-order givens in the encountered language — compels conversants to dip into background beliefs, finding concepts for the signified meanings that hew to the intermediary cognitive manipulations (finding ways to conceptualize the subject as sentient, for example). This also has a potential type model, perhaps as forcing a type conversion from a lexical element which does not ordinarily fit the required framing (such as giving unexpected subjects some fashion of sentience). Type theory can give a window onto unfolding intellection at these multiple stages, although we need not conclude that the mind subconsciously doing this thinking mimics a computer that churns through type transformations mechanically and exactly.

I envision the unfolding that I have just sketched out as something Phenomenological — it arises from a unified and subjective consciousness, one marked by embodied personal identity and social situation. If there are structural stases that can be found in this temporality of experience, these are not constitutive of conscious reality but a mesh of rationality that supports it, like the veins in a leaf. Stuctural configurations can be lifted from language insofar as it is a conscious, formally governed activity, and lifted from the ambient situations which lend language context and meaning intents. So any analytic emphasis on structural fixpoints threaded through the lived temporality of consciousness is an abstraction, but one that is deliberate and necessary if we want to make scientific or in any other manner disputatable claims about how language and congition works. In that spirit, then, I will try to condense the three "layers" of unfolding understanding, which as I have sketched them are posited in the metaphysical order of temporal experience — "unfolding" in likely overlapping, blending ways — I will "read into" them a more static and logically stacked meta-structure. Where I have sketched three layers or stages of unfolding language understanding, I will transition to proposing three "tiers" of language organization, in particular three levels where type-theoretic models can be applied.

2.2 Three tiers of linguistic type theory

By three "tiers" of linguistic organization, I am thinking of different levels of granularity, distinguished by relative scales of resolution, amongst the semantic implications of putative type representations for linguistic phenomena. Type-related observations can be grouped (not necessarily exclusively or exhaustively) into those I will call *functional* — relating mostly to Parts of Speech and the functional treatment of phrases as applicative structures; *Ontological* — engaged with existential/experiential qualities like sentient/nonsentient, rigid/nonrigid, and others I have discussed; and *Lexical* — related to lexemes and word-senses. The lexical level can include "microclassification", or gathering nouns and verbs by the auxiliary prepositions they allow and constructions they participate in (such as, different cases), and especially how through this they compel various spatial and force-dynamic readings; their morphosyntactic resources for describing states of affairs; and, within semantics, when we look toward even more fine-grained classifications of particular word-senses, to reason through contrasts in usage.[15] Microclasses can point out similarities in mental "pictures" that explain words' similar behaviors, or study why different senses of one word succeed or fail to be acceptable in particular phrases. There are *stains all over the tablecloth* and *paint splattered all over the tablecloth*, but not (or not as readily) *dishes all over the tablecloth*. While "stains" is count-plural and "paint" is mass-aggregate,

[15] So, conceiving microclasses similar in spirit to Steven Pinker in Chapter 2 of [54], though I'm not committing to using the term only in the way Pinker uses it. Cf. also [75], which combines a microclass theory I find reminiscent of *The Stuff of Thought* with formal strategies like Unification Grammar.

they work in similar phrase-structures because both imply extended but not rigid spatial presence; whereas "dishes" can work for this schema only by mentally adjusting to that perspective, spatial construal shifting from visual/perceptual to practical/operational (we might think of dishes "all over" the tablecloth if we have the chore of clearing them). Such observations support microclassification of nouns (and verbs, etc.) via Ontological and spatial/dynamic/configuration criteria. So, the *lexical* level (for the current samples) addresses the various senses of *over*, *dishes*, *paint*, *splattered*, and so forth; whereas the Ontological level addresses more abstract situational/perceptual formulations like *a mass concept extended in two dimensions over a background* — along with whatever reframings are needed to make the denoted situation conform to the prototype form, like reading "dishes" as mass-plural.

Type-theoretic semantics can also apply Ontological tropes to unpack the overlapping mesh of word-senses, like *material object* or *place* or *institution*. This mode of analysis is especially well illustrated when competing senses collide in the same sentence. Slightly modifying two examples:[16]

- The newspaper you are reading is being sued
- Liverpool, an important harbor, built new docks

Both have a mid-sentence shift between senses, which is analyzed in terms of "type coercions". The interesting detail of this treatment is how it correctly predicts that such coercions are not guaranteed to be accepted — *the newspaper fired the reporter and fell off the table*; *Liverpool beat Chelesea and built new docks* (again, slightly modifying the counter-examples). Type coercions are *possible* but not *inevitable*. Certain senses "block" certain coercions — that is, certain sense combinations, or juxtapositions, are disallowed. These preliminary, motivating analyses carry to more complex and higher-scale types, like plurals (the plural of a type-coercion works as a type-coercion of the plural, so to speak). As it becomes structurally established that type rules at the simpler levels have correspondents at more complex levels, the use of type notions *per se* (rather than just "word senses" or other classifications) becomes more well-motivated.

Clearly, for example, only certain kinds of agents may have beliefs or desires, so attributing mental states forces us to conceive of their referents in those terms (*Liverpool wants to sign a talented young striker*). This *can* be analyzed as "type coercions"; but the type-theoretic machinery should contribute more than just obliquely stating linguistic wisdom, such as maintaining consistent conceptual frames or joining only suitably related word senses. Liverpool "wants" forecloses most (at least non-"exotic") readings in terms of the geographical place. More narrowly, the sense of *sign* as in "employ to play on a sports team" can only be linked to a sense of Liverpool as the Football Club. Similarly, *fire* as in "relieve from duty" is only compatible with newspapers as institutions. These dicta can be expressed in multiple ways. But how classifications (like "inanimate objects" compared to "mental agents") disseminate through complex type structures lends credence to the notion that type-theoretic perspectives are more than just an expository tool; they provide an analytic framework which integrates grammar and semantics, and various scales of linguistic structuration. For instance, we are prepared to accept some examples of dual-framing or frame-switching, like thinking of a newspaper as a physical object and a city government (but we reject other cases, like "Liverpool voted in a new city government and signed

[16] [15, p. 40] (former) and [45, p. 4] (latter).

a new striker" — purporting to switch from the city to the Football Club). The rules for such juxtapositions appear to reveal a system of types and inter-type relations with some parallels to those in formal settings, like computer languages.

In short, "Ontological" types like *institution* or *place* serve in some examples to partition senses of one multi-faceted word. Here they reveal similar cognitive dynamics to reframing-examples like *to the press*, where Ontological criteria (like reading something as a place) are triggered by phrase-scale structure. But there are also interesting contrasts: the *newspaper* and *Liverpool* examples imply that some words have multiple framings which are well-conventionalized; newspaper-as-institution feels less idiomatic and metaphorical than press-as-place. So these examples suggest two "axes" of variation. First, whether the proper Ontological framing follows from other word-choices (like "fire" in *the newspaper fired the reporter*, which has its own semantic needs), or from morphosyntax (like the locative in *to the press*); and, second, whether triggered framings work by selecting from established word senses or by something more metaphorical. Metaphors like *to the press* do have an element of standardization; but apparently not so much so to be distinct senses: note how *the press* as metaphorical place does not work in general: ?*at the press*, ?*near the press* (but *at the newspaper*, *near the newspaper* — imagine two journalists meeeting outside the paper's offices — sound quite reasonable).

The "type coercion" analysis works for some mid-sentence frame-shifts; but other examples suggest a more gradual conceptual "blending". For example, the place/institution dynamic is particularly significant for *restaurant* (whose spatial location is, more so, an intrinsic part of its identity). Being a *place* implies both location and extension; most places are not single points but have an inside where particular kinds of things happen. I am not convinced that restaurant as place and as institution are separate word senses; perhaps, instead, conversations can emphasize one aspect or another, non-exclusively. As I have argued, we need not incorporate all framing effects via "subtypes" (restaurant as either subtype of hypothetical "types of all" places or institutions, respectively). But "placehood", the Ontological quality of being a place — or analogously being a social institution — identify associations that factor into cognitive frames; types can then be augmented with criteria of tolerating or requiring one association or another. So if "restaurant" is a type, one of its properties is an institutionality that *may* be associated with its instances. In conversation, a restaurant may be talked about as a business or community, foregrounding this dimension (*That restaurant moved*, or *opened a new branch*). Or (like in asking for directions, or *over there will be a new restaurant*), its spatial dimension may be topicalized instead. The availability of these foregroundings is a feature of a hypothetical restaurant type, whether or not this is modeled by subtyping or something more sophisticated. The "newspaper" examples suggest how Ontological considerations clearly partition distinct senses marked by properties like objecthood or institutionality (respectively). For "newspaper" the dimensions are less available for foregrounding from a blended construal, than "unblended" by conventional usage; that is why reframings evince a type *coercion* and not a gentler shift of emphasis. The example of *restaurant*, in contrast, shows that competing routes for cognitive framing need not solidify into competing senses, though they trace various paths which dialogs may follow. But both kinds of examples put into evidence an underlying cognitive-Ontological dynamic which has potential type-oriented theories.

At the most general level — what I called *functional* type modeling — a type system recognizes initially only the grammatical backbone of expressions, and then further type nuances can be seen as shadings and interpretations which add substance to the syntactic form. So in type-theoretic analysis at this more grammatic level, to which I now turn, we can still keep the more fine-grained theory in mind: the relation of syntax to semantics is like the relation of a spine to its flesh, which is a somewhat different paradigm than treating syntax as a logical or temporal stage of processing. Instead of a step-by-step algorithm where grammatical parsing is followed by semantic interpretation, the syntax/semantics interface can be seen as more analogous to stimulus-and-response: observation that a certain grammatic configuration appears to hold, in the present language artifact, triggers a marshaling of conceptual and cognitive resources so that the syntactic backbone can be filled in. Perhaps a useful metaphor is grammar as gravitation, or the structure of a gravitational field, and semantics is like the accretion of matter through the interplay of multiple gravitational centers and orbits. For this analogy, imagine typed lambda reductions like $\mathcal{P}rop \twoheadrightarrow N \succcurlyeq N$ taking the place of gravitational equations; and sentences' grammatic spine taking the place of curvature pulling mass into a planetary center.

Parts of speech have "type signatures" notionally similar to the signatures of function types in programming languages: a verb needing a direct object, for example, "transforms" two nouns (Subject and Object) to a proposition, which I have been notatating with something like $N \rightarrow N \twoheadrightarrow \mathcal{P}rop$. At the most basic level, the relation of Parts of Speech to "type signatures" seems little more than notational variants of conventional linguistic wisdom like a sentence requiring a noun and a verb (`S = NP + VP`). Even at this level, however, type-theoretic intuitions offer techniques for making sense of more complex, layered sentences, where integrating link and phrase structures can be complex. Even the most broadly scoped analysis of type signatures, dealing only with generic Parts of Speech like nouns and verbs, can lead to surprising complications. One example I have alluded to several times, and will return to shortly: the problem of applying Dependency Grammar where phrases do not seem to have an obviously "most significant" word for linkage with other phrases.

A tendency in both dependency and phrase-oriented perspectives is to define structures around the most "semantically significant" words — so that a phrase like "many students" becomes in some sense collapsible to its semantic core, "students". Some of my earlier examples, however, argued that phrases cannot just be studied as replacements for semantic units. Incorporating type theory, we can instead model phrases through the perspective of type signatures: given `POS` annotations for phrasal units and then for some of their parts, the signatures of other parts, like verbs or adjectives linked to nouns, or adverbs linked to verbs, tend to follow automatically. A successful analysis yields a formal tree, where if (in an act of semantic abstraction) words are replaced by their types, the "root" type is something like $\mathcal{P}rop$ and the rest of the tree is formally a reducible structure in Typed Lambda Calculus: $N \rightarrow N \twoheadrightarrow \mathcal{P}rop$ "collapses" to $\mathcal{P}rop$, $\mathcal{P}rop \twoheadrightarrow N$ collapses to N, and so forth, with the tree "folding inward" like a fan until only the root remains — though a more subtle analysis would replace the single $\mathcal{P}rop$ type with variants that recognize different forms of speech acts, like questions and commands. In Figure 2, this was diplayed via the type annotations: from right to left $N \twoheadrightarrow N$ yields the N as second argument for *is*, which in turn yields a $\mathcal{P}rop$ that is mapped (by *that*) to N, finally becoming the second argument to *know*. Such calculation only considers the most coarse-grained classification (noun, verb, proposition) — as I have emphasized, a purely formal reduction can introduce finer-grained grammatical or

lexico-semantic classes (like *at* needing an "argument" which is somehow an expression of place — or time, as in *at noon*). Just as useful, however, may be analyses which leave the formal type scaffolding at a very basic level and introduce finer type or type-instance qualifications at a separate stage.

In either case, Parts of Speech are modeled as (somehow analogous to) functions, but the important analogy is that they have *type signatures* which formally resemble functions'. Phrases are modeled via a "function-like" Part of Speech along with one or more additional words whose own types match its signature; the type calculations "collapsing" these phrases can mimic semantic simplifications like "many students" to "students", but here the theory is explicit that the simplification is grammatic and not semantic: the collapse is acknowledged at the level of *types*, not *meanings*. In addition, tree structures can be modeled purely in terms of inter-word relations (this is an example of embedding lambda calculii in process algebras), so a type-summary of a sentence's phrase structure can be notated and analyzed without leaving the Link Grammar paradigm.

As a concrete example, in the case of "many students", both "students" and the semantic role of the phrase are nouns (count-plural nouns, for where that's relevant). Accordingly, "many" has a signature $N \twoheadrightarrow N$ (or $N^{+} \twoheadrightarrow N^{+}$, dependending on how narrowly we want to notate the types in context). Once we assign types and signatures to all words in a sentence, we can also see a natural hierarchy resembling an expression in typed lambda calculus, where some words appear as "functions" and others as "arguments". Often the less semantically significant words appear as "higher" in the structure, because they serve to modify and lend detail to more significant words. The kind of structure or "Charpente" which falls out of a sentence — adopting a term from Tesnière (cf. [72, p. 181]) — is typically different from a link-grammar "linkage", although the two structures can be usefully combined.

To return to the example of "Student after student", where designating one word to "represent" the phrase seemed arbitrary, we can analyze the situation via type-signatures. I have teased a proposed solution repeatedly; here's what I had in mind. Insofar as *after* is the only non-noun, the natural conclusion is that "after" should be typed $N \twoheadrightarrow N \twoheadrightarrow N$ (which implies that "after" is analogous to the "functional" position, and in a lambda-calculus style reconstruction would be considered the "head" — recall Figure 1 as an example of how the sentence could be annotated, for sake of discussion). This particular idiom depends however on the two constituent nouns being the same word (a pattern I've also alluded to with idioms like *time after time*), which can be accommodated by invoking the (computationally rather complex and topical) concept of *dependent types* [7], [71] — in other words the parameters for *after* are a dependent type pair satisfied by an identity comparison between the two nouns. The signature for "after" has this added complication, but the nuances of this example can still be accommodated within the overall architecture of type theory. I would pair this argument with my earlier analysis of "many" variations which suggested how apparent complications can be accommodated largely within the extant theoretical resources of Link Grammar, and in combination suggest that the union of Link Grammar with Type-Theoretic Semantics seems poised to accommodate many complex real-world linguistic cases within a coherent abstract perspective.

Consider alternatives for "many students". The phrase as written suggests a type signature (with "many" as the "function-like" or derivative type) $N^{+} \twoheadrightarrow N^{+}$, yielding a syntactic interpretation of the phrase; this

interpretation also suggests a semantic progression, an accretion of intended detail. From *students* to *many students* is a conversion between two plural nouns (at the level of concepts and semantic roles); but it also implies relative size, so it implies some *other* plural, some still larger group of students from which "many" are selected. While rather abstract and formal, the $N^{+} \dashrightarrow N^{+}$ representation points toward a more cognitive grounding which considers this "function" as a form of thought-operation — a refinement of a situational model, descriptive resolution, and so forth. If we are prepared to accept a cognitive underpinning to semantic classification, we can make the intuition of POS signatures as "functions" more concrete: in response to what "many" (for example) is a function *of*, we can say a function of propositional attitude, cognitive schema, or attentional focus. The schema which usefully captures the sense and picture of *students* is distinct (but arguably a variation on) that for *many students*, and there is a "mental operation" triggered by the *many students* construction which "maps" the first to the second. Similarly, *student after student* triggers a "scheme evolution" which involves a more explicit temporal unfolding (in contrast to how *many students* instead involves a more explicit *many/all*, quantitive comparison). What these examples show is that associating Parts of Speech with type signatures is not just a formal fiat, which "works" representationally but does not necessarily capture deeper patterns of meaning. Instead, I would argue, type signatures and their resonance into linkage acceptability structures (like singular/plural and mass/count agreement) *point toward* the effects of cognitive schema on what we consider meaningful.

In *Student after student came out against the proposal*, to *come out*, for/against, lies in the semantic frame of attitude and expression (it requires a mental agent, for example), but its reception carries a trace of spatial form: to come out *to* a public place, to go on record with an opinion (a similar dynamic applies to the idiomatic "come out" to mean, for someone gay or lesbian, "come out of the closet" — in that idiom the spatial figure is explicit but metaphorical). Usually "come out [for/against]", in the context of a policy or idea, is similarly metaphorical. But the concrete spatial interpretation remains latent, as a kind of residue on even this abstract rendition, and there sustains a chance that this undercurrent will actually figure in conversants' mutual understanding — if there were not just columns being written and opinions voiced but demonstrations on the quad. The spatial undercurrent is poised to emerge as more literal, should the context warrant. However literally or metaphorically the "space" of the cognitive "coming out" is understood, however explicit or latent its cogitative figuration, is not something internal to the language; it is a potentiality which will present in different ways in different circumstances. This is not to say that it is something apart from linguistic meaning, but it shows how linguistic meaning lies neither in abstract structure alone, nor contextual pragmatics, but in their cross-reference.

2.3 Levels of formalization

Of the three type levels I have proposed, the "functional" level is the most quasi-mathematical; for other levels, formal type theory may provide interpretive tools and methodological guides, but formally representable framings and transformations may be only approximations of how people actually think, while they are understanding language. From this perspective, we are left with the metatheoretical question of clarifying how different kinds of analyses, which put different degrees of weight on formal or on interpretive argumentation, are to be joined in overarching theories. In particular, are the linguistic phenomena which seem to demand

more “interpretive” treatment actually beyond formalization, or is it just impractical (but possible in theory) to provide formal analysis of each individual case-study, each real-world language formation? Is Natural Language actually no less formal than (for example) computer programming languages, except that the former have a much larger set of semantic and syntactic rules such that any analysis can uncover them only partially? Or is any rule-based model of language, no matter how complete, necessarily partial relative to real language?

Computer languages are a good case-study in what I might call “semiotic computability”. This designates the question of whether the operations of sign-systems — how sign-users express intentions by forming or modifying structured networks of signs that explicitly exhibit or are understood to have been formed according to collectively recognized signifying rules — can be modeled, at least to some substantial degree, by computable algorithms. Our notion of computation can be based on modern computer code, not just academic topics like pure functions: the behavior of computing systems where many functions run concurrently, with possible side-effects, is often non-computable via static analysis; such systems can only be understood by actually running them. Nevertheless the capabilities of software programmed in modern languages certainly deserve to be characterized as “computable” behaviors. A single function, which embodies a computable calculation, may be part of a process space whose evolution through time is nondeterministic, and computing environments which employ functional side-effects are difficult or impossible to evaluate in the abstract. I use “computability” therefore in this wider sense: operationally implementable according to theories underlying mainstream programming languages, which is conceptually (if perhaps not mathematically) distinct from “computability” in subjects like algorithm analysis.

Natural Langauge Processing, working with human languages from a computing platform, is then a step further, continuing beyond logico-mathematic abstractions and toward empirical language-use. We can consider at what point formal and computational methods reach a limit, beyond which they fail to capture the richess and expressiveness of Natural Language, or whether this limit itself is an illusion — whether even fully human language competence is (perhaps in principle if not in practice) no less reducible to formalizable patterns. Using the wording I just proposed, we can speculate on whether all language is “semiotically computable” or whether language merely depends on faculties which in some neurological and/or presentational sense are “computable” in those terms — faculties that, measured against linguistic fluency, are necessary but not sufficient. Whatever one’s beliefs on this last question, a progression of subdisciplines — from formal-logical semantics through programming langauges and computational Natural Langauge Processing — is a reasonable scaffolding for a universe of formal methods that can build up, by progressive theoretical sophistication or assembly of distinct analyses which piece together jigsaw-like, to model real-world language understanding. Perhaps real language is an “emergent property” of many distinct algorithms that run and combine in the mind; or perhaps the relevant algorithms are a precondition, presenting cognition with essential signifying givens but fleshed out in other, more holistic ways, as we become conscious of language not just as a formal system but an interactive social reality.

I have sketched a similar theoretical progression, starting with a theory of grammar (Link Grammar), transitioning to a form of semantics (a Type-Theoretic semantics dealing with type hierarchies, higher-order

type classes and inter-type relations, and type signatures, defined over Categories of grammatic representation structures such as linkage graphs), and finally proposing a cognitive interpretation of the resulting semantics. I will refer to this *interpretation* as "Cognitive State Semantics", meaning that such a theory adopts its *formal* structures from Link Grammar and type-theory but also attempts to *motivate* these structures by appeal to cognitive considerations. Both Link Grammar (through its specific Category of labeled graphs modeling sentence linkage-structures) and Type-Theoretic Semantics work with rigorous, algebraically formal models satisfying criteria of (we can say) "programmable operationality": translation of language content into these formats and subsequent review or transformation of the target structures can be implemented in computer code, and reviewed in algorithms or algebras as a purely mechnical space of operations.

By itself, the superposition of type-theoretic semantics on link-grammar graphs does not cross a hypothetical "barrier" between the formal and the cognitive. But I intend here to suggest a cognitive *interpretation* for the formal structures: that they represent an outline of cognitive schema, or progressions, or represent linguistic "triggers" that a cognitive language ability (taking language as part of an environing world and produced by others, in rule-bound social situations, to communicate ideas and sentiments) responds to. This range of interpretations is deliberately open-ended: we can say that a formal infrastructure grounds the cognitive reception of language givens, without arguing specifically that formal structures identified in language therefore model cognitive operations directly; or that these are instead patterns identified in language that trigger a cognitive response; or any other paradigm for mapping cognition as process and activity to language structure as model and prototype. Leaving these options open, however, I will focus in the remainder of this paper on one interpretation, considering formal structures as "triggers" which get absorbed into language understanding via observatory propensities: as language users (on this proposal) we are disposed to identify certain formal structurations operating in language as we encounter it, and respond to these observations by building or refining mental models of the situations and signifying intentions we believe have been implied by the discourse, in evolving and intersubjective dialogic settings that involve joint practical activity as well as communication.

In this sense, I believe natural language reveals mutually-modifying juxtapositions of concepts whose full semantic effects are probably non-computable: I would work on the assumption that language *as a whole* and as human social phenomena is not "computable" in a semiotic sense, or any related practical sense (although I make no metaphysical claims about the "abstract" computability of mental processes merely by virtue of their neurophysical materiality). The aforementioned "linguistic side effects" can be *modeled* by tracing our reception of linguistic meaning through syntactic and semantic formations, like Link Grammar and Type Theory, but I argue for such models not as models *of* cognitive processes, but rather models of *observations* which trigger cognitive follow-up. Even if we believe in and practice a rigorous formalization of morphosyntactic structure, where the *pattern* of conceptual "side-effects" can be seen as unfolding in algorithmic ways, the cognitive *details* of these effects are too situational, and phenomenologically rich, for computability as ordinarily understood. But the formal structure is not wholly irrelevant: to call up nuanced cognitive schema — or so I submit for consideration — may not be possible without algorithmically reproducible lexicosemantic and morphosyntactic triggers, at least modulo some approximation. A (perhaps non-computable) space of cognitive schema may be projected onto a (perhaps computable) set of affiliated morphological patterns, using notations

like link-grammar pairs and type signatures to catalog them. For example, there may be a non-computable expanse of possible construals of pluralization; but any such construal, in context, is called into focus in conversants' minds by morphosyntactic invitations, by speakers' choices of, say, $N^{\odot} \dashrightarrow N^{+}$-pattern phrases. The important balance is to take formalization as far as is reasonable without being seduced into logico-symbolic reductionism — a methodological pas de deux I will explore further in the next, concluding section.

Any word or usage invites various facets to either emphasize or deemphasize, and these subsumed concepts or foci are latent in potential meanings, brought into linguistic space by the play of differentiation [17] : *baked*, not *made*; *flew*, not *traveled*; *spill*, not *pour*. These under-currents of subsidiary concepts and foci are selectively hooked onto by morphosyntactic selection, so in analyzing phrase structure we also have to consider how using syntax which constructs a given structure also brings to the forefront certain nested concepts and construals, which are latent in word-sense options; in the topos of lexicosemantic possibilia.

So, any talk about "side effects" of morphosyntactic functions — mapping verb-space to adjective-space, noun-space to proposition-space, singularity to plurality, and so forth — should consider a type-theoretic gloss like $N \dashrightarrow N$ as sketching just the motivating scaffold around an act of cognitive refocusing. The interesting semantics lies with *how* a sense crosses over, in conversants' minds, to some other sense or concept, wherein other aspects are foregrounded — for example, within temporal event plurality: multiplicity as frequency, or episodic distribution relative to some time span; or suggesting something that is typical or predominant; or relative count against some other totality — each such refocusing triggered by a phrasal construction of the form $N \dashrightarrow N^{+}$ or $N^{+} \dashrightarrow N^{+}$. Or we can map singulars, or count plurals, to mass nouns, and vice-versa (*shrubs* become *foliage*; *water* becomes *a glass of water*). The plural and the singular are a coarse-grained semantic that has not yet arrived as *meaning*. Conceptual spaces guide attention to classes and properties, defining a path of ascending precision as speakers add descriptive detail; cognitive construals negotiate relations between different kinds of aggregates/individuals; individuality, aggregation and multiplicity as phenomena and disposition. These construals are practical and embodied, *and* phenomenological — they direct attention (*qua* transcendental universal of mentality, if we like), to and fro, but in the course of intersubjective and goal-driven practical action (and in that sense particular, world-bound, historicized).

Given these considerations, I propose a "Cognitive State Semantics" — understanding phrase structure in terms of (or analogous to) functional effects (like [62]), but cognitive: word and syntax choice effectually steering cognitive appraisals of jointly experienced situations in specific directions. Cognitive State Semantics also has formal implications: the inner structuration of data "spaces", including unknown and undefined values, and including (side-effects-bearing) function types, can be understood as dynamic *states of knowledge* and their changes, grounding datatype semantics in human use/interactions. Linguistically, the "effects" of language "functions" are mutations/modifications in cognitive state, respondant to concrete or abstract scenarios which are topics of dialog. Sometimes, effects may tolerate mathematical analysis; but such analytical thematics tend to peter out into the ambient, chaotic worldliness of human consciousness.

[17] Alluding, in part, to Sausurrean "system of differences" [51, p. 15] — to choose a reference which introduces Sausurre in a rather unexpected context.

3 Conclusion

Without reducing linguistic *performance* to language qua field of propositional expression, and without collapsing linguistic meaning to a computable/propositional fragment, we can still allow interpretive-Phenomenological and formal/mathematical perspectives to co-exist. In the theory I have sketched, Cognitive Schema summarize lived, situated judgments and intentions that (in concrete form) are not "computable" (again with the caveat that our mostly science-driven worldview may imply that all reality is "computable" in some infinitely-powerful computation; I understand "computability" to terminologically exclude such a purely speculative level of capacity). However, our propensity to call up certain construals rather than others is triggered by linguistic formations, and in broad outline the catalog of these triggers, and their compositional structure, can be formalized (and even used to improve formal systems, like programming languages). The challenge is to advocate for this co-existence without implying that formal systems, and mathematically provable system-properties, are the only kind of research tools which have scientific merit.

Subjective assessments are intrinsic to most linguists' argumentation — warranting claims not with empirical data or logico-mathematical proof but by appealing to speakers' intuitions, so that reading linguistic texts is also collaborating on an ongoing research project (partly because language evolves, so word-meanings change, and formations which are ungrammatical for one generation may be experienced differently by others). Nevertheless, linguistics, like economics, seems broadly accepted as a human *science*, not just an interpretive discipline. The claim that an economist's equation or a linguist's meta-grammar are accurate explanations, useful explanatory frameworks, seems generally evaluated in terms of whether their framework captures emergent higher-order structure, and offers an explanatory potential that does not merely reiterate lower-scale paradigms. A theory expressed in the language of linguistics (not, say, neural networks), if it meets general criteria of testability and refutability (not necessarily empiricist/quantitative), arguably carries even more weight than lower-level neurophysical explanation — precisely because the higher-scale "theory language" carries the burden of explaining emergent properties, which as *emergent* bear some descriptive/behavioral (if not causal) autonomy. Likewise, a subjectively plausible and theoretically motivated equation which fits economic data probably carries more weight than a mere statistical analysis. An explanatory focus on the higher-scale in terms of its own distinct (emergent) structures and theorized entities (like words and morphemes, in the case of linguistics, or markets and commodities, in the case of economics), reflects the linguist's or economist's charge to connect human phenomena with mental (and therefore, ultimately physical) law. Nonetheless, even with liberal use of subjective judgments, economics and linguistics (and some other human sciences as well, potentially) are attached to the overall sphere of natural science, by virtue of causal links in principle even if not in practice. Scientific rigor in this humanistic setting is neither reducible to the techniques of natural science, nor dualistically separate from them. Natural science and humanities are certainly not mutually irrelevant, but nor is the proper vehicle for scientific literacy to find a forum in the humanities merely to emulate numeric methods, as with statistics in sociology, or a retreat to narrow and behavioristic reductionism, in place of localized interpretation and situational particularism.

Subjective impressions (conscious experiences, emotions, intuitions, qualia, qualitative universals and

particulars — the qualitative characteristic in itself, and the hyletic-spatial trace, the site in experiential space as the quale becomes a moment of consciousness) — these are not scientifically tractable and do not have obvious physical location or measurability, which makes them controversial as objects of scientific method. Yet, even so, we do have conscious experiences, we do subconsciously (and when needed consciously, or with deliberate conscious attention) make judgments about classifications, or how parts aggregate into wholes, or are individuated apart from a larger whole in context; we can reflect on patterns in these judgments, not *introspectively* examining thoughts as they occur, but marshalling an overall familiarity with mental processes. Consciousness is not only a kind of mentality, shared by humans and some animals; it is also a metacognitive tool, something we deploy to focus attention on a certain object or topic. We "practice" how to *be* conscious, how best to distribute attention, in each setting (like an athlete maintaining a meditative state of ambient awareness, poised to latch conscious attention onto playing technique which is optimally instinctive, but "feels" different when degraded by fatigue or distraction). Our faculty for these modulations, switching among sub- and passive consciousness, attentive consciousness, "ambient" awareness, and back again, reveals that consciousness is not only an aspect of mind but a tool; it has a meta-cognitive and epistemic dimension, an awareness of what is known or not-yet-known and a technique of directing attention to the latter.

A case-study: in a motel I unexpectedly find a newspaper outside the door. Next morning I look outside curious whether a paper is there; after several days I come to expect the paper. So I open the door not preoccupied with confirming this, but with (maybe rather distractedly) fetching it. Initially I do not expect the paper, but, generally poised to notice both expected and unexpected circumstances, I make a mental adjustment and interpret the situation quickly; by the third day the paper has become expected, like other things I anticipate finding in a motel hallway, and the thrust of my attention, during the brief episode of my picking it up, is kinaesthetic and motor-intentional more than visual and inquisitive. Only on the second morning is the question of a paper's presence intended in an epistemic mode; but, while it is so thematized, I direct attention to optimize my ability to resolve the question. How we engage attention is a deliberate choice, reflecting and responding to our metacognitive attitudes, what we think we know and do not know.

Because consciousness is in some ways a mental tool, we have an intimate familiarity with it, a familiarity which extends beyond our own minds: we can make reasonable guesses about what others do or do not know and perceive. Our ability to anticipate others' epistemic states is an intrinsic feature of social interaction, of intersubjectivity; we therefore understand consciousness not only via our own use and possession/experience of it, but as a general feature of the human mind. We can accordingly make structured claims about conscious processes, not in the sense of introspective reports but of retrospective suggestions — by analogy, a pianist on reflection may have alot to say about playing technique, but she does not acquire this wisdom from introspective study of her own playing while it happens; rather with accrued wisdom and reflection. In terms of phenomenological method, our study of thought and consciousness is analogous: it is reflective examination of what it means to be consciously intelligent beings, not introspective psychology, or meditative meta-experience.

The methodological implications of this retrospection (as opposed to *intro*spection), how phenomenological

writing seeks reflective consensus on claims about consciousness — this fashion of constructing a research community, a discursive-methodological field, does not conform to empirical scientific method, but is arguably a quite valid and defensible means of meeting the criteriological goals — the discourse ethics, the democratization of scientific participation — which physical science achieves via empiricist Ontology. For all its limitations, Positivism has the one virtue of disputational inclusiveness, demanding potential observability (not some special revelation or insight) for theoretic ur-entities. The civic norms of Phenomenology are more complex, because both "transcendental" analysis of consciousness — as a kind of philosophical ground zero, a neo-Cartesian fortress against skepticism and empiricism — and also a more pluralistic, enculturated, embodied, social Phenomenology, are well-represented (and interpenetrate in complex ways) in the continuing post-Husserl tradition. That being said, even in its most neo-Idealist, reifying consciousness as a primordial frame on any cognitive-scientific reasoning, as human sciences' condition of possibility, Phenomenology cannot help but textually acknowledge pluralism, and philosophical collaboration — precisely because its claims are not descriptive of empirically locatable/observable objects.

Interestingly, the phenomenological tradition reveals substantial interest in both the socio-political and the formal-mathematical: this is not so noteworthy in itself, because Analytic philosophy also connects (say) language with (say) logic, but Phenomenology is distinct in that it joins the humanistic and the formal/mathematical without the same tendency to hone in on a overlapping, logico-semantic core. In writings where Analytic philosophers appear to address both social and mathematical concerns, usually their underlying motivation, or so it seems to me, is to find some logical underpinnings to linguistic or cognitive structure (say, *implicatures*) — logic, subject to formal treatment, also manifesting itself in the organization of thoughts and expressions. Amongst phenomenologists, however, for example Husserl, Merleau-Ponty (in his science-oriented writings; [46]), and Anglo-American writers in the "Naturalizing Phenomenology" tradition, there is evident interest in mathematics *apart from* logic: topology, differential geometry, mereotopology, multi-granularity.[18] Phenomenology therefore uncovers an arguably deeper and truer bridge between human and "eidetic" sciences, in Petitot's phrase, one which is not pre-loaded with logico-reductive presuppositions. If this is accurate, Phenomenology can provide a deeper methodology for the humanities in their interactions with natural science. Even insofar as we stay committed to the idea that social/cultural/mental phenomena emerge from (neuro-)physical ones, we need to curate methods for these "emergent" sciences which have the requisite theoretical autonomy to actually extend the explanatory reach of the natural sciences on which they causally rest. Cognitive Linguistics, I would argue, is a good example of this notion of autonomy, and its methodology, I would also argue, bears an important resemblance to phenomenological research.

Another brief case-study (revisiting footnote 1): our environing world mostly discloses itself through

[18]Not that logic is wholly unrelated to these subjects: consider topological and type/Category-theoretic embeddings of logical systems within certain categories, or technical domains, like toposes, sheaves, granules; but logic in this sense, mathematically founded within spaces otherwise discussed at least as metaphoric guides within Phenomenology, does not appear to be the dominant understanding of logic in the Analytic philosophical tradition. To be fair, style may dictate that argumentation should be trimmed to its essential elements, and mathematical deductions are rarely if ever essential for defending phenomenological claims. In Jean Petitot, for example, mathematics is sometimes intrinsic to empirical backing for phenomenological ideas, but other times (say, sheaf mereology), the formal theories, while useful analogies, do not clearly pair up with logico-deductive justifications. But, I would reply, there is so much unexplained about consciousness, and cognition as it occurs in conscious minds — the controversial "Explanatory Gap" between mind and matter — that much of the important argumentation does not yet have deductive signposts; we need an effective methodology which is not so linear. As we approach beyond a simplifying, logico-functionalist vantage, which we eventually must transcend, both functionalization and empiricism fall by the wayside as reasonable methods for "Naturalizing" consciousness. We have to accept when the formal/mathematical stands as more intuitive than rhetorical, on pain of "Naturalization" being quarantined from a humanistic core entirely.

objects' visible exterior: as much as we have on occasion a palpable sense of volume as well (as when looking through a fog) — and as much as what we see is inextricable from our embodied interactions with objects, adding tactile and kinaesthetic dimensions, a canonical sense of perception is still the vision of distant objects, usually through their surface geometry. A canonical example of perceptual cognition is therefore reconstructing geometry from visual appearances, especially color gradations — mathematically, converting "color" vector fields to curvature vector fields (it's worth noting that color is an almost primordial example of a Conceptual Space Theory as developed by Gärdenfors and others [69]). This kind of transformation, described (say) via differential geometry, is *qua* theoretical device an example of semiotic morphism, a mapping between representation disciplines [27], [26]. The point is not, however, that there are precise correlates in the brain which "implement" this procedure; that the semiotic morphism takes a domain and codomain that quantify over empirically locatable, neurophysical entities. We can study how software reconstructs geometry from color data as an approximation to a *process*, a model-building whose semiotics of approximation is coarse-grained and holisitc.[19] Formal devices like vectors or vector fields need not mold symbolic systems by mapping individual symbols to spacetime objects, or processes, but rather afford representation-mappings that capture cognition indirectly and patternwise.

I make this point using visual consciousness as an example, but it applies also to cognitive grammar, where the color -to- curvature-vector morphism has an analogue in the mapping of word-sequences to tree- or graph-algebras. I do not intend to claim that there are specific, individuated neurophysical analogues to theoretical posits in the symbolic regime I sketched earlier, in terms of POS and lexical annotations, inter-word and inter-phrase connections, applicative structures, and the rest. There are not, necessarily, for example, little brain regions whose role is to represent different types of phrase structures (e.g., different flavors of pluralization). Our explanatory ambitions, instead, should be cognitive-linguistic models of a global process-structure, agnostic about one-to-one correspondence between the posits of the theory and the empirical stuff whose behaviors it wants to explain. Cognitive triggers bridge formal/empirical sciences with the phenomenological/humanistic: their causal engenderings are physical and structural phenomena, but their manifestation in the world is not fully tractable without an interpersonal deliberation accounting for both the privateness of consciousness and the sociality of mind, and, so, something akin to Phenomenology.

It may appear that I am describing a weak-functional theory (or metatheory) which uses functional description in lieu of precise micro-physical explanation — in other words, that in lieu of explaining precisely how the brain achieves vision or language, we describe functional capabilities that are prerequisite for these competences, and refactor the goal of scientific explanation as to describe the system of intermediate functionality as correctly as possible, rather than describe how this functionality is physically realized. In a strong form, this re-orientation yields functionalism in theories/philosophies of Mind, that try to refrain from Ontological commitments to mental states or properties *apart from* descriptions of their functional roles. In other words, according to the

[19]The experiential verisimilitude of computer graphics is a phenomenological data point, but so is their obvious unreality — the mathematics reveals something about, but is not an all-encompassing model for, shape and color *qua* material phenomenon, still less the neuroscience of color experience. Morphism between structures may model *processes* more correctly than the structures themselves approximate their substrata — but this is no longer a semiotics of causal/physical reductionism, a use of mathematics (like differential geometry) to iconify empirical givens, the way that (say) the Navier-Stokes equations are understood to refer explicitly to (even while idealizing and abstracting from) fluid-mechanical dynamics. Our theory-semiotics has to locate the site of designation at a more oblique scale, a different Ontological register, of processes and transformations — seeing in phenomena the image of a theoretical model because of its global structure, as a sign in its own right, rather than a collage of symbols and numbers to which are reduced spatializations and trajectories of causation and physical influence.

parameters of the field of study and its institutions, even if not deep metaphysical beliefs, mental states are reducible to functional states, and cognitive systems are scientifically equivalent if they reveal similar functional organization, whether they belong to human or animal minds or computers or extra-terrestrials. A more modest functionalism would reject the implied reductionistic (maybe eliminative) Ontological stance, and maintain that mental things are not wholly, metaphysically subsumed by their functional organization, while still practicing a kind of theory whereby this functional organization is the proper object of study; the specific aspect of the mental realm which is scientifically tractable.

I do not believe I am making even such weak-functionalist claims: either branch of functionalism can misattribute the methodological association between theoretical structures and explanatory goals. We may be led toward the stronger or weaker functionalist viewpoints if we understand that a cognitive theory should task itself with making symbolic icons for scientifically grounded referents, grounded in an abstract space of functional organization if not in empirical space-time. Of course, most scientific explanation does construct a specialized, technical semiotics whose signs refer into either formal spaces or accounts of empirical space-bound things, however abstracted or idealized. But, conversely, insofar as I propose to focus on functional structures, and particularly cross-representation-framework transformations, my intent is to "functionalize" the discursive norms of the theory, not the phenomena it investigates. In order to negotiate between the competing demands of scientific rigor and formalization — on the one hand — with the immediacy and etheriality and subjectivity of consciousness, on the other, we need to "attach" theoretical structures to mental phenomena without getting bogged down in questions of the scientific or Ontological status of mental things, how they are "scientific" individually and collectively (collectively as in the Ontology of "Mind" overall).

This suggests adopting functional attitudes not in the theory but the metatheory: to use functionalism as an organizing principle on the theoretical *discourse*, on the attitudes of the scientists and scholars who want to straddle the divide between natural and mathematical sciences and humanism and consciousness. The "semiotic morphism" of color-to-curvature vector fields, or word-sequences to typed semantic graphs, are recommendations for guidelines on how researchers should write and communicate about cognitive processes in their global structure. I have tried to outline a metadiscourse more than a metalanguage — not a template for building theory-languages whose signs refer into a realm of posited empirical or abstract entities, but a template for using certain formal-mathematical constructions (in domains like typed lambda calculus, type theory, or differential geometry) as a textual prelude, a way to position the norms of writing to be receptive to both scientific-mathematical and phenomenological concerns. If semiotic morphisms like color-to-curvature or word-sequence-to-semantic-graph have explanatory merit as ways to picture cognitive processes, this merit is intended to be judged according to how it affects discursive norms on this scientific borderlands between mathematics and humanities, rather than how it reduces empirical phenomena to mathematizable abstractions. If there is *something* in cognition analogous to these morphisms, even if "analogous" means merely that holding the morphisms as formally defined in our minds while thinking about cognition can show us philosophical ways forward, then we should be interested in refining these formalizations as part of the overall Cognitive-Phenomenological project.

References

1 Benjamin Adams and Martin Raubal, *A Metric Conceptual Space Algebra*.
http://raubal.cartography.ch/Publications/RefConferences/COSIT_2009_Adams_Raubal_CameraFinal.pdf

2 Alan Akbik and Jürgen Broß, *Wanderlust: Extracting Semantic Relations from Natural Language Text Using Dependency Grammar Patterns* http://ceur-ws.org/Vol-491/semse2009_7.pdf

3 Diana Allam, Rémi Douence, Hervé Grall, Jean-Claude Royer, and Mario Südholt, *Well-Typed Services Cannot Go Wrong*. [Research Report] RR-7899, 2012. hal-00700570v1. https://hal.inria.fr/hal-00700570v1/document

4 Chris Barker and Chung-Chieh Shan, *Continuations and Natural Language*.
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.454.8690&rep=rep1&type=pdf

5 Radim Bělohlávek and Vladimír Sklenář, *Formal Concept Analysis Constrained by Attribute-Dependency Formulas* B. Ganter and R. Godin, eds.,: ICFCA 2005, LNCS 3403, pp. 176-191, Berlin, Springer-Verlag, 2005.
http://belohlavek.inf.upol.cz/publications/BeSk_Fcacadf.pdf

6 Benjamin K. Bergen and Nancy Chang, *Embodied Construction Grammar in Simulation-Based Language Understanding*.
http://www1.icsi.berkeley.edu/~nchang/pubs/ecg.pdf

7 Jean-Philippe Bernardy, et. al., *Parametricity and Dependent Types*. http://www.staff.city.ac.uk/~ross/papers/pts.pdf

8 Thomas Bittner, Barry Smith, and Maureen Donnelly, *The logic of systems of granular partitions.*
http://ontology.buffalo.edu/smith/articles/BittnerSmithDonnelly.pdf

9 Hans C. Boas and Ivan A. Sag, eds. *Sign-Based Construction Grammar*. http://lingo.stanford.edu/sag/papers/theo-syno.pdf

10 Mathieu Bouchard, *A Type Theory for the Documentation of PureData* http://artengine.ca/~catalogue-pd/43-Bouchard.pdf

11 Line Brandt, *The Communicative Mind.* Newcastle-upon-Tyne: Cambridge Scholars Publishing, 2013

12 Per Aage Brandt,
Spaces, Domains, and Meaning: Essays in Cognitive Semiotics. Newcastle-upon-Tyne: Cambridge Scholars Publishing, 2013
http://semiotics.au.dk/fileadmin/Semiotics/pdf/per-aage-brandt/Per_Aage_Brandt__Spaces__Domains__and_Meaning._Essays_in_Co.pdf

13 Roberto Casati and Achille C. Varzi, *Parts and Places: The Structures of Spatial Representation* MIT Press, 1999

14 *Speech Lost from Speech: The Cognitive Linguistics of Alienation, Objectification, and Reclaiming*. Doctoral Dissertation, Berkeley. http://escholarship.org/uc/item/7rv3j4nf

15 Stergios Chatzikyriakidis and Zhaohui Luo, *Individuation Criteria, Dot-types and Copredication: A View from Modern Type Theories. Association for Computational Linguistics, Proceedings of the 14th Meeting on the Mathematics of Language (MoL 14)*, pp. 3950, 2015. http://www.aclweb.org/anthology/W15-2304

16 Mary Dalrymple, *Lexical Functional Grammar*. http://web.stanford.edu/group/nasslli/courses/as-cr-da/apbook-nasslli.pdf

17 Ralph Debusmann, *Extensible Dependency Grammar: A Modular Grammar Formalism Based On Multigraph Description.* Universität des Saarlandes, dissertation 2006.

18 Ralph Debusmann, Denys Duchier and Andreas Rossberg, *Modular Grammar Design with Typed Parametric Principles*. James Rogers, ed., *Formal Grammar/Mathematics of Language 2005*, CSLI Publications, 2009.
http://web.stanford.edu/group/cslipublications/cslipublications/FG/2005/debusmann.pdf.

19 Antonin Delpeuch and Anne Preller, *From Natural Language to RDF Graphs with Pregroups*. *Proceedings of the EACL 2014 Workshop on Type Theory and Natural Language Semantics (TTNLS)*, pp. 5562, Gothenburg, Sweden, April 26-30 2014.
https://www.aclweb.org/anthology/W/W14/W14-1407.pdf

20 Jean-Pierre Desclés, *Reasoning in Natural Language in Using Combinatory Logic and Topology: An Example with Aspect and Temporal Relations.* http://www.aaai.org/ocs/index.php/FLAIRS/2010/paper/viewFile/1350/1736

21 Martín Escardó, *Synthetic topology of data types and classical spaces*. *Electronic Notes in Theoretical Computer Science* 87, 2004. http://www.cs.bham.ac.uk/~mhe/papers/barbados.pdf

22 Gilled Fauconnier, *Mental Spaces: Aspects of Meaning Construction in Natural Language*. Cambridge, 1994

23 Kit Fine, *Part-whole*, in Barry Smith and David Woodruff Smith, *The Cambridge Companion to Husserl*, Cambridge University Press, New York, 1995.

24 Peter Gärdenfors and Frank Zenker, *Theory Change as Dimensional Change: Conceptual Spaces Applied to the Dynamics of Empirical Theories*. *Synthese 190(6)*, pp. 1039-1058, 2013.
http://www.vielbein.it/pdf/Traduzioni/2010-Gaerdenfors-Theory%20Change%20as%20Dimensional%20Change.pdf

25 Gianluca Giorgolo and Ash Asudeh, *Monads as a Solution for Generalized Opacity*. Proceedings of the EACL 2014 Workshop on Type Theory and Natural Language Semantics (TTNLS), pages 1927, Gothenburg, Sweden, April 26-30 2014.
http://www.aclweb.org/anthology/W14-1403

26 Joseph Goguen, *What is a Concept?* https://cseweb.ucsd.edu/~goguen/pps/iccs05.pdf

27 ———*Semiotic Morphisms, Representations, and Blending for Interface Design*
https://cseweb.ucsd.edu/~goguen/pps/uid.pdf

28 Kees Hengeveld, *Prototypical and Non-Prototypical Noun-Phrases in FDG*. In Daniel García Velasco and Jan Rijkhoff, *The Noun Phrase in Functional Discourse Grammar*, New York, de Gruyter, 2008, pp. 43-62.
http://home.hum.uva.nl/oz/hengeveldp/publications/2008_hengeveld.pdf

29 Juneki Hong and Jason Eisner, *Deriving Multi-Headed Planar Dependency Parses from Link Grammar Parses*
https://www.cs.jhu.edu/~jason/papers/hong+eisner.tlt14.paper.pdf

30 The Univalent Foundations Program, *Homotopy Type Theory: Univalent Foundations of Mathematics* Princeton 2013
https://hott.github.io/book/nightly/hott-online-1075-g3c53219.pdf

31 Mark Johnson, *The Body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason*. University of Chicago Press, 1990

32 Sean Dorrance Kelley, *Seeing Things in Merleau-Ponty*.
http://www.nyu.edu/gsas/dept/philo/courses/representation/papers/Kelly.pdf

33 Stephan Kepser and Uwe Mönnich, (Un-)Decidability Results for Head-Driven Phrase Structure Grammar. Algebraic Methods in Language Processing AMiLP-3, Anton Nijholt and Giuseppe Scollo, eds., 2003.
http://www.tcl-sfs.uni-tuebingen.de/kepser/papers/amilp3-hpsg.pdf

34 Oleg Kiselyov, *Applicative Abstract Categorial Grammars*. http://okmij.org/ftp/gengo/applicative-symantics/AACG.pdf

35 Arne Köhn and Wolfgang Menzel, *Incremental Predictive Parsing with TurboParser*.
http://edoc.sub.uni-hamburg.de/informatik/volltexte/2014/203/pdf/koehn_incremental_predictive_parsing_with_turboparser_korrigiert.p

36 Lingpeng Kong, Alexander M. Rush, and Noah A. Smith, *Transforming Dependencies into Phrase Structures*.
http://www.aclweb.org/anthology/H01-1014

37 Alexander V. Kravchenko, *Grammar as semiosis and cognitive dynamics*.
http://www.univie.ac.at/constructivism/archive/fulltexts/480.pdf

38 George Lakoff and Mark Johnson, *Philosophy in the Flesh: the Embodied Mind and its Challenge to Western Thought*. New York: Basic Books, 1999.

39 Ronald Langacker, *Nouns and Verbs* *Language*, Vol. 63, No. 1 (March 1987) pp. 53-94.

40 Ronald Langacker, *Foundations of Cognitive Grammar, vol. 1*. Stanford University Press, 1991

41 Robert D. Levine and W. Detmar Meurers, *Head-Driven Phrase Structure Grammar: Linguistic Approach, Formal Foundations, and Computational Realization* http://lingo.stanford.edu/sag/papers/meur-lev-hpsg.pdf

42 Zhaohui Luo, *Type-Theoretical Semantics with Coercive Subtyping*.
https://www.cs.rhul.ac.uk/home/zhaohui/ESSLLI11notes.pdf

43 Jean Maillard, Stephen Clark, and Edward Grefenstette, *A Type-Driven Tensor-Based Semantics for CCG*.
http://www.cl.cam.ac.uk/~sc609/pubs/eacl14types.pdf

44 Scott Martin and Carl Pollard, *A Dynamic Categorial Grammar*. http://www.ling.ohio-state.edu/~murat/dycg.pdf

45 Bruno Mery, Richard Moot, and Christian Retoré, *Plurals: individuals and sets in a richly typed semantics*.
http://arxiv.org/pdf/1401.0660.pdf 3 Jan 2014

46 David Morris, *The Sense of Space*. State University of New York, 2004

47 Stefan Müller, *Unifying everything: Some remarks on simpler syntax, construction grammar, minimalism, and HPSG*
http://www.linguisticsociety.org/sites/default/files/Lg_89_4_Muller.pdf

48 Stefan Müller, *Grammatical theory: From transformational grammar to constraint-based approaches*. Berlin: Language Science Press, 2016

49 Joakim Nivre, *Dependency Grammar and Dependency Parsing*. http://stp.lingfil.uu.se/~nivre/docs/05133.pdf

50 Esther Pascual, *Fictive Interaction: The conversation frame in thought, language, and discourse*. Philadelphia, John Benjamins, 2014.

51 Efe Peker, *Following 9/11: George W. Bush's Discursive Re-Articulation of American Social Identity* Master's Dissertation, Linköping University, Sweden http://www.diva-portal.org/smash/get/diva2:21407/FULLTEXT01.pdf

52 Jean Petitot, et. al., eds., *Naturalizing Phenomenology: Issues in Contemporary Phenomenology and Cognitive Science*. Stanford University Press, 1999.

53 Jean Petitot, *Syntax Topologique et Grammaire Cognitive*. *Langages 25.103*, pp. 97-128, 1991.

54 Steven Pinker, *The Stuff of Thought: Language As a Window Into Human Nature*. Penguin, 2007.

55 Griselda Pollock, *Modernity and the Spaces of Femininity*. https://msu.edu/course/ha/446/griseldapollock.pdf

56 Carl Pollard, *Covert Movement in Logical Grammar*. http://www.ling.ohio-state.edu/~pollard/cvg/covert.pdf

57 Frank Richter, *A Mathematical Formalism for Linguistic Theories with an Application in Head-Driven Phrase Structure Grammar*. Ph.D. dissertation, University of Tübingen, 2000.
http://www.sfs.uni-tuebingen.de/hpsg/archive/bibliography/papers/richter_dissertation.pdf

58 Giuseppe Riva and Fabrizia Mantovani, *Being There: Understanding the Feeling of Presence in a Synthetic Environment and Its Potential for Clinical Change*. http://cdn.intechopen.com/pdfs-wm/39042.pdf

59 Aurélie Rossi, *Applicative and Combinatory Categorial Grammar: Analysis of the French Interrogative Sentences*. *FLAIRS Conference, Association for the Advancement of Artificial Intelligence*, 2008.
http://www.aaai.org/Papers/FLAIRS/2008/FLAIRS08-118.pdf

60 Anthony J. Roy and John Stell, *Convexivity in Discrete Space*. http://www.comp.leeds.ac.uk/jgs/RoyStellCOSIT03.pdf

61 Chung-Chieh Shan, *Monads for natural language semantics*. http://arxiv.org/pdf/cs/0205026.pdf 17 May 2002

62 ———*Linguistic side effects.* Harvard University, dissertation 2005.

63 Gerold Schneider, *A Linguistic Comparison of Constituency, Dependency and Link Grammar*. Zurich University, diploma, 2008. https://files.ifi.uzh.ch/cl/gschneid/papers/FINALSgeroldschneider-latl.pdf

64 Barry Smith, *Mereotopology: A Theory of Parts and Boundaries*.
http://nemo.nic.uoregon.edu/wiki/images/3/38/Smith1996_Mereotopology.pdf.

65 David Woodruff Smith, *Mind World*. Cambridge University Press, 2004.

66 ———*Mind and body*, *The Cambridge Companion to Husserl*, New York 1995.

67 David Woodruff Smith and Ronald McIntyre, *Husserl and Intentionality: A Study of Mind, Meaning, and Language*. Dordrecht and Boston: D. Reidel, 1982.

68 Michael Anthony Smith and Jeremy Gibbons, *Unifying Theories of Objects*
http://www.cs.ox.ac.uk/jeremy.gibbons/publications/uto.pdf

69 Gregor Strle, *Semantics Within: The Representation of Meaning Through Conceptual Spaces*. Univ. of Novi Gorici, dissertation, 2012.

70 Leonard Talmy, *Force Dynamics in Language and Cognition*. From *Toward a Cognitive Semantics*, Vol. 1, MIT Press 2000.
http://linguistics.buffalo.edu/people/faculty/talmy/talmyweb/Volume1/chap7.pdf

71 Ribeka Tanaka, et. al., *Factivity and Presupposition in Dependent Type Semantics*
http://www.lirmm.fr/tytles/Articles/Tanaka.pdf

72 Elke Teich, *Systemic Functional Grammar & Natural Language Generation* New York: Cassell, 1999.

73 Bernardo Toninho, et. al., *Functions as Session-Typed Processes*. http://www.cs.cmu.edu/~btoninho/fossacs12.pdf

74 *Representing Content: Semantics, Ontology, and their Interplay* Dissertation, Université Paul Sabatier, Toulouse
https://www.irit.fr/publis/LILAC/LV-HDR09.pdf

75 Anne Vilnat, *Dialogue et analyse de phrases* Habilitation Mémoire, Université Paris-Sud
http://perso.limsi.fr/anne/HDR/MemoireHDR.pdf

76 Jørgen Villadsen, *Multi-dimensional Type Theory: Rules, Categories, and Combinators for Syntax and Semantics.*
http://arxiv.org/pdf/cs/0408037.pdf 15 August 2004

77 Yves-Marie Visetti and Pierre Cadiot, *Instability and theory of semantic forms*. S. Feigenbaum and D. Kurzon, eds., *Prepositions in their Syntactic, Semantic and Pragmatic Context*, Amsterdam, John Benjamins, 2002, pp. 9-39.
http://formes-symboliques.org/IMG/pdf/doc-14.pdf

78 Olav K. Wiegand, *A Formalism Supplementing Cognitive Semantics Based on a New Approach to Mereology*. Ingvar Johansson, Bertin Klein and Thomas Roth-Berghofer, eds., *Contributions to the Third International Workshop on Philosophy and Informatics*, 2006.

79 ———*On referring to Gestalts*. Mirja Hartimo, ed., *Phenomenology and Mathematics*, pp. 183-211. Springer, 2010.

80 Rudolf Wille, *Conceptual Graphs and Formal Concept Analysis*. *Conceptual Structures: Fulfilling Peirce's Dream Fifth International Conference on Conceptual Structures*, 1997.

81 Fei Xia and Martha Palmer, *Converting Dependency Structures to Phrase Structures*.
http://www.aclweb.org/anthology/H01-1014

82 Yiyu Yao, *A Comparative Study of Formal Concept Analysis and Rough Set Theory in Data Analysis*.
http://www2.cs.uregina.ca/~yyao/PAPERS/Rough_concept.pdf

83 Jordan Zlatev, *The Dependence of Language on Consciousness*.
http://www.mrtc.mdh.se/~gdc01/work/ARTICLES/2014/4-IACAP%202014/IACAP14-GDC/pdf/Language-Consciousness-Zlatev.pdf