Cognitive State Semantics and Cognitive Transform Grammar: Bridging Formalization and Phenomenology in Linguistic Representations

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Abstract

> 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, [**?**, p. 1]

> 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, [**?**, p. 11]

The question of whether computers can be programmed to understand language may be philosophical, but it overlaps with broad methodological bifurcations: after all, linguists *are* programming computers to "understand" language, at least to some approximation. Given that computational linguistics is now a well-established practice, we can consider how this program for investigating the nature of language orients into linguistics as a whole: to what degree are the computers really "understanding" their linguistic input? How much does *behavior* consistent with language-understanding suggest actual understanding? Is linguistic competence mostly a behavioral phenomenon, or something more holistic and (inter-) subjective? Are the imperfections of automated Natural Language Processing inevitable, and if so, does that foreclose the possibility of NLP engines being considered truly linguistic? That is, should we treat flawed and oversimplistic (but practically useful) NLP software — or "personas" driven by this software, like "digital assistants" — as bonafide (if rather primitive) participants in the world of human language? Or are they merely machines that simulate linguistic behavior without manifesting real linguistic behavior, as a computer simulation of a celestial galaxy is not a real galaxy?

These are methodological as well as thematic questions. There is a wide swath of formal and computational linguistics, for instance, for which the measure of a theory is its chance of being operationalized on NLP terms and within NLP tools, yielding automated systems whose accuracy and/or computational efficiency competes favorably with other systems. Faithfulness to how *humans* process language is at most a secondary concern. Conversely, there is a broad literature in Cognitive Linguistics and the Philosophy of Language for which uncovering the cognitive and interpretive registers through which *we* understand, produce, and are affected by language is the main goal. For scholars chasing that telos, failure to encode theoretical models in mathematical or software

systems is not *prima facie* an explanatory limitation — conversely, we might take this as evidence that cognitive models are addressing the deep, subtle realities of language that are opaque to computer simulation.

Then there is hybrid work, like attempts to formalize Cognitive Grammar (Matt Selway [**?**], Kenneth Holmqvist [**?**]), or other branches of Cognitive Linguistics (cf. Terry Regier's influential [**?**]), or Conceptual Space Theory as initiated by Peter Gärdenfors (which has seen several attempts at mathematical-computational formalization, such as Frank Zenker, Martin Raubal, and Benjamin Adams's metascientific perspectives, and more recent Category-Theoretic structures linked to mathematicians such as Bob Cocke and David Spivak [**?**]). To this list we could add research that extends beyond language alone to broader cognitive-perceptual and conceptual themes, like formal descriptions rooted in Husserlian analyses by phenomenologists whose methods encompass some computer-scientific techniques, like Barry Smith (as in [**?**]) and Jean Petitot (see [**?**]); we can see these accounts as generalizing cognitive-linguistic theories by noting the phenomenological basis of linguistic phenomena, as articulated by (say) Olav K. Wiegand ([**?**]) and Jordan Zlatev ([**?**]). In each of the works just cited (prior anyhow to the last two) we can find formal/computational models whose rationale is, in large part, to shed light on human cognitive processes (albeit not necessarily translating to practical NLP components in any straightforward way).

This kind of "intermediate" research is perhaps underappreciated, because it neither accepts the dismissive attitude that formal models are a distraction from the analysis of "real" language, nor the reductionistic faith that language is *intrinsically* computational, so that progress toward ideal NLP avatars is just a matter of time. To be sure, layering formal systems on a cognitive/phenomenological foundation adds a complexity of theoretical structure, which could prompt questions about the efficacy of the theoretical dilation: is extra complexity desirable as an end in itself, if the new formalizations have only limited explanatory or practical pay-offs? If there is a human kernel in language that is intrinsically non-computable and non-formalizable, does analysis of language truly benefit from complex but only partly applicable structural overlays? On the other hand, if language *is* computationally tractable, shouldn't NLP implementation be a factor in assessing which formal models are worthy of attention?

Perhaps for these kinds of considerations, linguistics seems to bifurcate between a camp that essentially ignores computational methodology and resources and a camp that centers its whole attention on building better automated NLP tools. Left out of this division is research that invokes formal models as explanatory vehicles while not enmeshing them in an ecosystem oriented toward automation — the difference between deploying formal repesentations to model (some aspects) of language processing, syntax, and semantics, and trying to program software to *automate* the construction, translation, and pipeling between and among formal models. When situating research relative to computational linguistics, we should bear in mind the metatheoretical point that *incorporating* formal schema into linguictis models does not *necessarily* mean committing ourselves to a task of programming computers to discover the target representations automatically, given raw linguistic input.

But this perspective is not only metatheoretical: I believe that the nature of language is *intrinsically* "hybrid" in a manner that warrants neither blind faith in automation nor *a priori* disengagement with formalizing projects. This is first of all because language is neither wholly isolated from other cognitive phenomena nor without some structural autonomy: it's reasonable to suppose that there are distinct intellectual faculties internal to our understanding of language, while other reasonings intrinsic to parsing the form and intentions of a linguistic unit are drawn from the wider inventory of situational, conceptual, social, and practical/enactive cognition. Sentences can vary in terms of their context-sensitivity and the degree to which extralinguistic rationality is implicit in grasping intended meanings. So neither a theory which ignores extralinguistic cognition, nor one which treats *all* linguistic processing as inseperable from the totality of our cognitive processes from moment to moment, are complete; the larger account needs to place sentence on a spectrum where extralinguistic and (I'll say) "intra-linguistic" theoretical machinery is available to analyze different sentences as their form and context demands.

Extending this point, I believe a comparable spectrum matches the duality of language seen as intrinsically formalizable and computable or as too subtle, social/cultural, embodied, and context-dependent to be

tractable to any computer or any idealized logicomathematical abstraction. Some sentence are more logically straightforward; others are more elusive, requiring holistic and context-sensitive interpretation on conversants' parts to be understood. Combined with my claims last paragraph, I argue accordingly that we can (at least as a suggestive picture) view linguistic artifacts (canonically, sentences) along a two-axis spectrum defined both by extralinguistic integration (or lack thereof) and by formal tractability (or lack thereof), like so: (this is intended as an intuitive sketch, not a formal model).

Logicomorphic	− − −	Extra-Linguistic
‖		‖
Intra-Linguistic	− − −	Interpretive

I will elucidate the terms on that picture later. Summarily, though, I claim that *some* sentences evince logically straightforward compositional pattern that can be analyzed *either* at the language-specific (syntactic or semantic) level *or* within cognitive registers outside of language proper (e.g., situational shemata); conversely, some sentences have nuances that call for interpretive judgments which appear to transcend formal simulacra outside the full range of human intelligence, emotion, and embodiment, *either* in terms of parsing complex syntactic or semantic structures *or* in grounding linguistic phenomena in ambient contexts. My overall point is then that sentences take a spectrum of models spanned by these axes; no one paradigm is self-contained as a metalinguistic commitment.

In effect, the choice between paradigms wherein language is or is not formally/computationally tractable, and between paradigms wherein language is or is not intellectually autonomous vis-à-vis our total cognitive faculties, should not be seen as a metaphysical alternative anterior to language as a totality. Instead, these spectra are threaded into language internally, competing polarities which rise or fall from sentence to sentence. Language is not *intrinsically* either formal or non-formal; autonomous or non-autonomous.

But at the same time, sentences are clearly phenomena of the same ilk; the distinctions I have made are not so sharp as to disrupt the ontological similitude among sentences, so that two sentences (however much they differ on the spectra of my diagram) are still manifestations of the same ontological place; they are still roughly the same *sort* of existents. Accordingly, we should conclude philosophically that there are certain aspects of sentences that lie beneath the formal/interpretive and intralinguistic/extealinguistic dualities. There are, in short, paleostructures in language that manifest *either* with formal specificity or with contextual nuance; *either* internal to syntax or semantics or external to intrinsically linguistic cognition; varying from sentence to sentence. This paper will present a theory of one such paleostructure, drawing inspiration both from formal theories (Dependency Grammar, Type-Theoretic Semantics, Generative Lexicon) and from more philosophical approaches (Cognitive Grammar, Semiotics, Phenomenology).

The central element in my analysis is the *conceptual modification* implied or effected by one word in the presence of another word. More precisely, some words' linguistic roles can be analyzed as adding cognitive detail (conceptual and/or perceptual and/or pragmatic) to the ideas or referents signified via other words. The underlying scheme, at this level where the model is undeveloped and thus fairly simple, is close to Dependency Grammar: in lieu of a head/dependent relation we can treat one word (or similar lexical unit) as a *modifier* and the second as a "ground". I believe this two-pronged picture is not complete vacuous, but is general and underspecified enough to spread over both syntax and semantics, and over competing paradigms. I will call the modifier's effect on its ground a *transform*, and the two words together (taking "word" as a convenient designation for lexemes in general) as a *transform pair*.

I will argue that the underlying transform-pair concept is amenable to both more formal and more philophical/interpretive development. One the one hand, transform-pairs can sometimes be mapped explicitly to dependency or link-grammar pairs, so the theory can be treated as a philosphical preliminary or motivation for Dependecy or Link Grammar. Relatedly, transforms themselves can be integrated into type systems (e.g., the kinds of transforms associated with adjectives depend on their ground being typed as a noun), so a theory of transform-pairs can motivate elaboration in a Type-Theoretic context. On the other hand, we can focus on the interpretive and situational nuanced often evident in cognitive transformations to find evidence for linguistic phenomena which do not fit neatly into Dependecy Grammar or Type-Theoretic (or any other) formalization. These various continuations, which I will present further over the next several sections, try not to foreclose

either formal or philosophical/interpretive paradigms. The goal is to trace both formal models of language and alterntive models — for which excessive formalization is reductionistic and depends on ad-hoc avoidance of many real-world significations — to a common structural kernel from which both perspectives can be deployed on a case-by-case (e.g., sentence-by-sentence) basis.

In keeping with the perspective that formal models have *some* merit, I have tried to orient the presentation around certain computational-linguistic techniques. Some of my examples are drawn from popular annotated corpora, and I provide models of other examples as processed by representative NLP technologies (e.g., Malt Parser trained against the most recent Universal Dependency training data at the time of writing). I have packaged the examples and supporting code into an open-source data set for purposes of demonstration. I do not dwell on the accuracy of the NLP components, in part because I am motivated in this paper to examine how computational methods can be employed as explanatory tools separate and apart from their feasibility in automated pipelines. That is, the computational resources I present here are designed more as technological supplements to philosophical, interpretive, and speculative examinations of interesting linguistic examples, rather than as algorithms ultimately targeted at fully automated NLP frameworks. I incorporate code and data as a supplement to my argumentation in the hope that this can serve as an example of computational linguistics adopted outside the priorities of NLP automation and Artificial Intelligence in its more reductive, science-fictional sense. I am not aspiring to develop code or theoretical claims that could advance the hypothetical project of implementing artificial agents that can mimic and understand human language and behavior in all its subjectivity and complexity. However, I *do* want to leverage certain computational techniques as offering their own explanatory perspectives on structures in human language.

The remainder of this paper will draw and expand on the outline of terms and structures sketched thus far, specifically the contrast of intra/extra-linguistic and "logicomorphic"/interpretive aspects from my "diagram" of sentences' paradigmatic spectrum, and the basic modifier/ground transform-pair account. I use the phrase Cognitive Transform Grammar for the core notion of "transform-pairs" as, at core, cognitive phenomena, which nonetheless allow for further exposition via different methods. I will explain some of this variation in the first section.

1 Cognitive Transform Grammar and Transform-Pairs

The idea that inter-word pairs are a foundational linguistic unit — from which larger aggregates can be built up recursively — is an central tenet of Dependency Grammar. Here I will generalize this perspective outside (but not excluding) grammar, to overall semantic, pragmatic, and even extralinguistic relations indicated via interword relations.

In some cases word-relations can still be theorized mostly via syntax. Consider hypothetical, example sentences like

- (1) His having lied in the past damages his credibilty in the present.
- (2) Voters question whether he is truthful this time around.

In (1), *having* is necessary to syntactically transform its ground *lied* from a verb-form to a noun (something which can be inserted into a possessive clause). Analogously, in () *whether* modifies *is* (since this is the head of a subordinate clause), wrapping a propositional clause into a noun so that it furnishes a direct object to the verb *question*. The essential transformation in these cases is motivated by grammatic considerations, particularly part-of-speech: a verb and a subordinate, propositionally complete clause (in and , respectively) need (for syntactic propriety) to be modified so as to play a role in a site where a noun is expected (in effect, they need to be bundled into a noun-phrase).

The relevant transforms here — signified by *having* and *whether* — have a semantic dimension also, and we can speculate that the syntactic rules (requiring a verb or propositional-clause to be transformed into a noun) are actually driven by semantic considerations. Conceptually, for example, *his having lied* packages a verb into a possessive context because the sentence is not foregrounding a specific lying-event but rather the fact of the existence of such occasions. We cannot perhaps "possess" an event, but we possess (as part of our nature or history) the fact of past occurances, viz., events in

the form of things we have done. In this sense *his having lied* marks a conceptual transformation, from events qua occurants to events (as factical givens) qua states or possessions, and the grammatical norm — how we cannot just say "his lied" — is epiphenomenal to the conceptual logic here; the erroneous "his lied" sounds flawed because it does not match a coherent conceptual pattern in how events and states fit together. But, still, the syntactic requirement — the expectation that a noun or noun-phrase serve as the ground of a possessive adjective, or the direct object of a verb — manifests these underlying conceptual patterns in the order of everyday language. Syntactic patterns become entrenched *because* they are comfortable translations of conceptual schema, but *as* entrenched we hear these patterns as grammatically correct, not just as conceptually well-formed. Likewise, we hear errata like "his lied" as *ungrammatical*, not as conceptually incongruous.

I contend, therefore, that many conceptually-motivated word-pairing patterns become syntactically entrenched and thus engender a class of transform-pairs where the crucial, surface-level tranformation is syntactic, often in the form of translations between parts of speech, or between morphological classes (singular/plural, object/location, etc.). Consider locative constructions like

- (3) Let's go to Grandma.
- (4) Let's go to the lawyers.
- (5) Let's go to the press.

Here nouns like *Grandma*, *the lawyers*, and 'the press are used at sites in the surrounding sentence-forms that call for a designation of place — this compels us to read the nouns as describing a place, even while they are not intrinsically spatial or geographical (e.g., Grandma is associated with the place where she lives). 'p'

In (5) and perhaps (4), this locative figuring may be metaphorical: going *to the press* does not necessarily mean going to the newspaper's offices. Indeed, each of these usages are to some degree conventionalized: going *to Grandma* is subtler than going *to Grandmas house*, because the former construction implies that you are going to a *place* ("Grandma" is proxy for her house, say), but also Grandma is actually there, and that seeing her is the purpose of your visit. In other words, the specific *go to Grandma* formation carries a supply of situational expectations. There are analogous implications in (4) and (5) — going *to the press* means trying to get some news story or information published. But the underlying manipulation of concepts, which structures the canonical situations implicated in (3)-(5), is organized around the locative grammatical form as binding noun-concepts to a locative interpretation. However metaphorical or imbued with additional situational implications, a person-to-location or institution-to-location mapping is the kernel conceptual operation around which the further expectations are organized. Accordingly, the locative case qua grammatic phenomenon signals the operation of these situational conventions, and the syntactic norms in turn are manifest via word-pairings, such as *to Grandma*.

In short, a transform-pair like *to Grandma* can be analyzed in several registers; we can see it as the straightforward syntactic rendering of a locative construction (via inter-word morphology, insofar as English has no locative case-markers) or explore further situational implications. In these examples, though, there is an obvious grammatic account of pairs' transformations, notwithstanding that there are also more semantic and conceptual accounts. Part-of-speech transforms (like *having lied*) and case transforms (like *to Grandma*) are mandated by syntactic norms and therefore can be absorbed into conventional grammatic models, such as Dependency Grammar: the head/dependent pairings in *having lied* and *to Grandma* are each covered by specific relations within the theory's inventory of possible inter-word connections. So a subset of transform-pairs overlaps with (or can be associated with) corresponding Dependency Grammar pairings.

Another potential embedding of transform-pairs into formal models can be motivated by Type Theory. This analysis can proceed on several levels, but in general terms we can assume that parts of speech form a functional type system (as elucidated, say, in Combinatory Categorial Grammar). For instance, we can recognize nouns and propositions (sentences or sentence-parts forming logically complete clauses) as primitive types, and treat other parts of speech as akin to "functions" between other types. For instance, a verb combines with a noun to form a proposition, or complete idea: *go* acts on *We* to yield the proposition *We go*. Schematically, then, verbs are akin to functions that map nouns to propositions. Similarly, adjectives map nouns to nouns, and adverbs map verbs to other verbs (here I use "noun" or "verb" to mean a linguistic unit which is functionally a noun, or verb; in this sense a noun-phrase is a kind of noun — i.e.,

a linguistic unit whose *type* is nominal). This provides a type-theoretic architecture through which transform-pairs can be analyzed. For instance, an adverb modifies a verb; so an adverb in a transform pair must have a verb as a ground. Moreover, the "product" of that transform is also a verb, in the sence that the abverb-verb pair, parsed as a phrase, can only be situated in grammatic contexts where a verb is expected.

In effect, we can apply type-theoretic models to both parts of a transform-pair and to the pair as a whole, producing structural requirements on how words link up into transform-pairs. We can then see an entire sentence as built up from a chain of such pairs, with the rules of this construction expressed type-theoretically. Given, say, *his having lied flagrantly* we can identify a chain of pairs *flagrantly-lied*, *having-flagrantly*, and *his-having*, where the "outcome" of one transform becomes subject to a subsequent transform. So *flagrantly* modifies *lied* by expressing measure and emphasis, adding conceptual detail; grammatically the outcome is still a verb. Then *having*, as I argued earlier, applies a tranform that maps this verb-outcome to a noun, which is then tranformed by the possessive *his*. Each step in the chain is governed by type-related requirements: the output of one transform must be type-compatible with the modifier for the next transform. This induces a notion of *type-checking* transform-chains, which is analogous to how type-checking works in formal settings like computer programming languages, Typed Lambda Calculus, and Dimensional Analysis.

Type-Theoretic Semantics holds out the hope that many syntactic and semantic rules can "fall out" as a direct consequence of type-checking requirements. A correct sentence is one built up from a chain of transforms where the outcome of one transform is type-compatible with the modifier of the next one, with the eventual or "root" transform, which completes the sentence, yielding a proposition. This expresses, in linguistic terms like "outcome" and "modifier", the same type-checking requirements as in Lambda Calculus, which would use more mathematical vocabulary: the output of one function must be type-compatible with the input parameter of the next function, insofar as this output is to be substituted for a lambda-abstracted symbol in the outer function's formula.

This gloss actually understates the explanatory power of type-theoretic models for linguistics, since I have mentioned only very coarse-grained type classifications (noun, proposition, verb, adjective, adverb); more complex type-theoretic constructions come into play when this framework is refined to consider plural/singular, classes of nouns, and so forth, establishing a basis for more sophisticated structures adapted to language from formal type theory, like type-coersions and dependent types (I will revisit these theories in a later section). Here, though, I will just point out that Dependecy Grammar and Type-Theoretic Semantics can often overlap in their analysis of word-pairs (inter-word relations is not centralized in type-oriented methodology as much as in Dependecy Grammar, but type concepts can certainly be marshaled toward word-pair analysis).

Even though Dependency and Type-Theoretic analyses will often reinforce one another, they can offer distinct perspectives on how pairs aggregate to form complete phrases and sentences. In the transform-pair *having lied*, *lied* is clearly the more significant word semantically. This is reflected in *having* being annotated (at least according to the Universal Dependency framework) as auxiliary, and the dependent element of the pair, while *lied* is the head. Then *lied* is also connected to *his*, establishing a verb-subject relation. So *lied* becomes the nexus around which other, supporting sentence elements are connected. This is a typical pattern in Dependecy Grammar parses, where the most semantically significant sentence elements also tend to be the most densely connected (if we treat the parse-diagram as a graph, these nodes tend to have the highest "degree", a measure of nodes' importance to the degree as this is reflected in how many other nodes connect to it). Indeed, by counting word connections we can get a rough estimation of semantic importance, distinguishing "central" and "peripheral" elements. These are not standard terms, but they suggest a norm in Dependecy Grammar that the structure of parse-graphs generally reflects semantic priority: the central "spine" of a graph, so to speak, captures the primary signifying intentions of the original sentence, while the more peripheral areas capture finer details or syntactic auxiliaries whose role is for grammatical propriety more than meaningful content.

Conversely, a type-theoretic analysis might incline us to quetion this sense of semantic core versus periphery: in the case of *his having lied*, the transform *having* supplies the outcome which is content for the possessive *has*.

If we see the sentence as a cognitive unfolding, a series of mental adjustments toward an ever-more-precise reading of speaker intent, then each step in the tranformation contributes consequential details to the final understanding. Moreover, *lied* is only present in the transformation signified by *his* insofar as it has in turn been transformed by *having*: each the modifier in a transform-pair has a degree of temporal priority because *its* effects are directly preesent in the context of the following transformation. This motivates a flavor of Dependency Grammar where the head/dependent ordering is inverted: a seemingly auxiliary component (like the function-word to a content-word) can be notated as the head because its output serves as "input" to a subsequent transform. In the analogy to Lambda Calculus, *his having lied* would be graphed with *having* being the head for *lied*, and *his* the head for *having*, reflecting the relation of functions to their arguments. In lisp-like code, this could be written functionally as (his (having lied)), showing *having* as one function, and *his* as a second one, the former's output being the latter's input.

Implicitly, then, Type-Theoretic Semantics and Dependency Grammar can connote different perspectives on semantic inportance and the unfolding of linguistic understanding. I will explore this distinction further below, with explicit juxtaposition of parse graphs using the two methods. I contend, however, that the distinction reflects a manifest duality in linguistic meaning: we can treat a linguistic artifact as an unfolding process or as a static signification with more central and more minute parts. Both of these aspects coexist: on the one hand, we understading sentences via an unfolding cognitive process; on the other hand, this cognition includes forming a mental review of the essential points of the sentence, a collation of key ideas such as (for 1) *his*, *lied*, *damages*, and *credibiliy*. Given this two-toned cognitive status — part dynamic process, part static outline — it is perhaps understandable that different methodologies for deconstructing a sentence into word-pair aggregates would converge on different structural norms for how the pairs are interrelated, internally and to one another.

This analysis, which I will extend later, has considered transform-pairs from a syntactic angle — in the sense that I have highlighted pairs which obviously come to the fore via grammatic principles. As I indicated, I believe the notion of transform-pairs cuts across both syntax and semantics, so I will pivot to some analyses which attend more to the semantic dimension.

1.1 *Semantic Analyses of Transform-Pairs*

In the simplest cases, a transform-pair represents a modifier adding conceptual detail to a ground, like *black dogs* from *dogs*. But the nature of this added detail — and its evident relation to surface language — can be very varied. Compare between examples like:

- (6) I saw my neighbor's two black dogs.
- (7) I saw my neighbor's two rescued dogs.
- (8) I saw my neighbor's two latest dogs.

Whereas (6) presents a fairly straightforward conceptual tranformation, the detailing in (7) is a lot subtler; mentioning *rescued* dogs makes no reference to perceptual qualities, but rather implies intricate situational background. The term *rescued dogs* strongly suggests that the dogs were adopted by their current owner, probably after an animal-welfare organization found them abandoned, or removed them from a prior abusive owner. This kind of backstory is packaged up, as a kind of situational prototype, in the conventionalized phrase *rescued dogs*, implying a level of specificity more precise than the ajective *rescued* alone implies. Correspondingly, the verb *to rescue* when applied to dogs suggest more information than in more generic contexts.

The phrase *latest dogs* carries implications in its own right; we assume the neighbor had owned other dogs before. Of course "latest" implies some temporal order, but the understood time-scale depends on context. If we hear talk about a *vet*s two latest dogs, we would presumably interpret this in terms of patients the vet has seen over the course of a day:

- (9) We're going after the vet's two latest dogs.
- (10) I'm concerned about the rescue organization's two latest dogs.

Understanding the relevant time-frame depends on understading the relation between the dogs and the possessive antcedent. In (8) the neighbor (in a typical case) actually owns the dogs, so the situational context grounding the modifier *latest* would be understood against the normal time-scale for dog ownership (at least several

years). In (9), the vet only "possesses" the dogs in the sense of endeavoring to examine them, a process of minutes or hours. In (10), the implication of the *organization's* possessive vis-à-vis rescued dogs is that the group endeavors to rehabilate and find permanent homes for the rescuees. So in each case *latest* implies a succession of dogs, leading over time to two most recent ones, but the implied time-frame for our conceptualizing this sequence can be minutes-to-hours, or days-to-months, or years.

We should also observe that the implied time-frames and backstories in (7-10) are not directly signified via morphosyntax or lexical resources alone. The word *rescued* only carries the *rescued dog* backstory when used in a context involving the dogs' eventual owners; in some context the more generic meaning of *rescue* could supercede:

- (11) Boatmen rescued dogs from the flooded streets.
- (12) Firemen rescued dogs from the burning building.

Neither (11) nor (12) imply that the dogs were abandoned, or will have new owners, or be sent to a shelter, or that their rescuers are members of an animal-welfare organization — in short, no element of the conventionalized backstory usually invoked by *rescued dogs* is present. Analogously, there is no lexical subdivision for *latest* which regulates the variance in time-frames among (8-10). It is only by inferring a likely situational background that conversants will make time-scale assumptions based on one situation involving dog ownership, another involving veterinary exams, and a third involving animal-welfare rehabilitation.

That is to say, the time-scale inference I have analyzed is essentially *extralinguistic*: there is no specific *linguistic* knowledge (lexical or grammatical, or even pragmatic inferences in the sense of deictic or anaphora resolution) which warrants the situational classification of (8-10) into different time scales. Instead, the inference is driven by (to some degree socially or culturally specific) background-knowlege about phenomena like veterinary clinics or animal rescue groups. Whether or not the nuances in *rescued dogs* are similarly extra-linguistic is an interesting question — we can argue that the phrase is now entrenched as a *de facto* lexical entrant in its own right, so the role of *rescued* is not only to lend adjectival detail but to construct a recurring phrase with a distinct meaning, like *red card* (in football) or *stolen base* (in baseball). Lexical entrenchment is, I would argue, an intra-linguistic phenomenon, in the sense that understanding entrenched phrases is akin to familiarity with specific word-senses, which is a properly linguistic kind of knowledge. But even in that case, entrenchment is only possible because the phrase has a signifying precision more rigorous than its purely linguistic composition would imply. There are, in short, extralinguistic considerations governing *when* phrases are candidates for entrenchment, and a language-user's ability to learn the conventionalized meaning (which I believe is an intra-linguistic cognitive development) depends on their having the relevant (extra-linguistic) background knowledge.

If we consider then the contrast between transform-pairs like *black dogs*, *rescued dogs*, and *latest dogs*, the similar grammatic constructions — indeed similar semantic constructions, in that each pair has an adjective modifying a straightforward plural noun (*dogs* designates a similar concept in each case; this is not a case of surface grammar hiding semantic diversity, like *strong wine* vs. *strong opinion* or *long afternoon* vs. *long snake*) — package transforms whose cognitive resolution spans a range of linguistic and extralinguistic considerations. Straightforward adjectival modification in *black dogs* gives way to lexical entrenchment in *rescued dogs* which, as I argued, carries significant extra-linguistic background knowledge even though possession of this knowledge is packaged into basic linguistic familiarity with *rescued dogs* as a signifying unit; and in the case of *latest dogs* the morphosyntactic evocation of temporal presedence and two different multiplicities (the latest dogs and earlier ones) is fleshed out by extra-linguistic estimations of time scale. The same surface-level linguistic structures, in short, can (or so such examples argue for) lead conversants on a cognitive trajectory in which linguistic and extra-linguistic factors interoperate in many different ways.

This diversity should call into question the ability of conventional syntactic and semantic analysis to elucidate sentence-meanings with any precision or granularity. Lexical and morphosyntactic observations may certainly reflect details which *contribute* to sentence-meanings, but the overall understading of each sentence in context depends on holistic, interpretive acts by competent language users in light of extra-linguistic, socially mediated background knowledge and situational understanding. Contextuality applies here not only in the pragmatic

sense that pronoun resolution, say, depends on discursive context (who is *her* in *her dogs*); more broadly, transcending even pragmatics, context describes presumptive familiarity with conceptual structures like veterinary clinics, animal shelters, and any other real-world domain which provides an overall system wherein particular lexical significations can be standardized. Without the requisite conceptual background it is hard to analyze how speakers can make sense even of well-established variations in word-sense, like *treat* as in a veterinarian treating a dog, a doctor treating a wound, a carpenter treating a piece of wood, or how an actor treats a part. These senses have lexical specificity only in the domain-specific contexts of medicine, carpentry, theater, and so forth.

The problem of holistic cognitive interpretation (as requisite for sentence-meanings) can be seen even more baldly in examples where semantic readings bifurcate in ways wholly dependent on extra-linguitic conceptualization. Consider for instance:

- (13) All New Yorkers live in one of five boroughs.
- (14) All New Yorkers complain about how long it takes to commute to New York City.

In (13), *New Yorkers* refers specifically to everyone who lives in the City of New York, since the five boroughs collectively span the whole of city. In (14), by contrast, we should understand *New Yorkers* as referring to residents of the metropolitan area *outside* the city itself (who commute *to* the city); and moreover *All* should be read less then literally: we do not here the speaker in (14) committing to the proposition that *every single* New Yorker complains. So both *All* and *New Yorkers* have noticeably different meanings in the two sentences. However, I cannot find any purely linguistic mechanism (lexical, semantic, syntactic, morphological) which would account for these difference as linguistic signifieds *per se*: the actual differences depend on conversants knowing some details about New York geography, and also general cultural background. It does not make too much sense to commute to a place where you already live, so our conventional picture of the word *commute* constrains our interpretation of (14) — but this depends on *commute* having a specific meaning, of traveling in to a city, usually from a suburban home, on a regular basis; a meaning in turn indebted to the norms of the modern urban lifestyle (it would be hard derive an analogous word-sense in the language spoken by a nomadic tribe, or a pre-industrial agrarian community). Likewise, reading *All* in (13) as *literally* "all" depends on knowing that the five boroughs are in fact the whole of the city's territory.

Given that in everyday speech quantifiers like *all* or *every* are often only approximate — and that designations like *New Yorker* are often used imprecisely, with not-identical alternative meanings intended on a case-by-case basis — these kind of examples point to signifying ambiguities that can easily arise as a consequence. Often extra-linguistic considerations resolve the ambiguity by rejecting one or another (otherwise linguistically plausible) reading as non-sensical. Consider:

- (15) The Leafs failed to beat the Habs for the first time this year.
- (16) The Leafs failed to win two consecutive games for the first time this year.
- (17) The Leafs failed to score a goal for the first time this year.

Sentence (15) has two competing readings: either the Toronto Maple Leafs won *all* or *none* of their previous games, in the relevant year, against the Montreal Canadiens. The differense is whether *for the first time this year* attaches to *beat* or to *fail*. In (16), on the other hand, the only sensible interpretation is that the Leafs had not yet won two games: while it is logically accurate to describe a team on a long winning streak as repeatedly winning two consecutive games, it would be very unexpected for (16) to be used in a case where the Leafs lost their first game of the season, after a three-plus-game winning streak. And in (17) any hockey fan would understand that the Leafs, for the first time, failed to score a goal; even though there is no linguistic rule foreclosing the reading such that the Leafs have not scored a goal at all — i.e., that for yet another game they failed to score a goal.

These variations — the degree to which superficial ambiguity is actually perceived by competent language-users as presenting competing plausible meanings — depend on background factors; the contingencies of hockey fix how potential ambiguities resolve out because one or another alternative is extralinguistically incoherent. But these cases point to how linguistic criteria alone, no matter how broadly understood, cannot necessarily predict in what sense linguistic structurations have empirically

plausible meanings — or whether they have sensible meanings at all.

Notice however that the examples have alternate versions which are less subtle or ambiguous, which shows that the complications are not localized in the communicated ideas themselves, but in their typical linguistic encoding:

- (18) All residents of the city of New York live in one of five boroughs.
- (19) Many residents of the New York metropolitan area complain about how long it takes to commute to New York City.
- (20) For the first time this year, the Leafs failed to beat the Habs.

These versions are more logically transparent, in that their propositional content is more directly modeled by the structure of the sentences. Indeed, hearers unfamiliar with New York or with hockey might find these versions easier to understand; more context-neutral and journalistic. But perhaps for this reason the "journalistic" versions actually sound stilted or non-idiomatic for everyday discource.

In short, even if sentences have a basically transparent logical content, *how* sentences holistically signify this content does not always emerge straightforwardly from semantic or syntactic structures on their own. I think this weakens the case for semantic paradigms which concentrate on logically-structured content which appears to be signified through sentences — even if we grant that this propositional ground of meaning is real, it does not follow that propositional contents are designated by purely linguistic means, rather than by a cohort of cognitive processes many of which are extra-linguistic. This is the basis of my proposing "logicomorphic" qualities as one axis for evaluating sentences, which I will now discuss further.

1.2 *Logical Structure versus Sentence Structure*

Let us grant in general that particular sentences can be mapped to distinct, relatively transparent propositional contents. In some cases sentences expresses propositional attitudes to such content (requests, commands, questioning) rather than unadorned locutionary assertions. To properly respond to speech-acts, however (even ones with illocutionary force) conversants need to derive the content which is logically conjured via the discource, either as the speaker's primary intent or as a condition for that intent. In effect, a proposition like *the window is closed* furnishes logical content to accertions like *The window is closed now* but also statements of belief (*I think the window is closed*) or requests or opinions (*The window should be closed*; *Pleace close the window*).

Philosophical treatments of language often imply that such propositional contents are the *essential* meanings within language; that analyzing semantic forms via logical structure is the core of a rigorous theory of semantics. It is certainly true that many elements of language can be translated, or deemed as conventionalized encodings for, structures in predicate logic — invocations of multiplicity and quantification; logical connectives between propositions; negations, modalities, and possibilia. This provides an analytic matrix wherein *some* sentences' structures may be analyzed. I will argue, however, that in typical cases logical forms are invoked only indirectly — which calls into quection the applicability of logical analysis as explanatory vehicles for *linguistic* analysis in itself (as opposed to more general cognitive/extralinguistic processing).

There are several cognitive operations requisite for grasping sentence-meanings as a logical gestalt: figuring individuals or multiplicities as conceptual fosi (verb subjects or objects); establishing relationships between individuals and multiplicities or amond multiplicities (member/part of, larger/smaller, overlap/disjoint); predicating properties to individuals or multiplicities; quantification; logical conjunction or disjunction, between predicates (also negation). In some cases we can find these operations fairly directly encoded in explicit language form — sentences which are precise in figuring multiplicities numerically, or through unambiguous use of determiners like *all* and *every*; which are structured to avoid scope ambiuities; which use transparent semantic resources to describe verb subjects and objects; and so forth. In the most recent Universal Dependencies Shared Task corpus we can find examples like:

- (21) It is the most common tumour found in babies, occurring in one of every 35,000 births.
- (22) Dengue fever is a leading cause of illness and death

in the tropics and subtropics, with as many as 100 million people infected each year.

- (23) Many Taliban living in Afghanistan voted for President Karzai.
- (24) Most of the girls I was meeting had grown up in Mujahedeen schools in Ashraf, where they lived separated from their parents.
- (25) Most experts believe China intends to develop a small space station of its own over the next several years.
- (26) Check out their wine tastings every Friday night!
- (27) For each start tag , there is a corresponding end tag.
- (28) Each collection donated by the Andy Warhol Photographic Legacy Program holds Polaroids of well-known celebrities.

These sentences have straightforward logical structure, in terms of how they establish topical foci (*one of every 35,000 births*, *as many as 100 million people*, *Many Taliban*, *every Friday night*, *For each start tag*), and how predicates or references are bound together to create more precise significations (*the tropics and subtropics*, *in Mujahedeen schools in Ashraf*, *a corresponding end tag*). Properties ascribed to subject foci are neatly drawn, both in conveying the property intended and its bearer, accoriding to the sentence's terms: *the most common tumour found in babies*, *a leading cause of illness and death*, *China intends to develop a small space station*, *holds Polaroids of well-known celebrities*. With aggregate foci and/or quantification, there is an unambiguous framing of predication and quantifier scope — Each collection has its set of Polaroids; the set of Karzai voters, Dengue infections, birth tumours, etc., are crisply figured.

For many philosophers of language, identiying similar logical structuration is an intrinsic aspect of coming to terms with human language in general. This paradigm also reinforces the goal of AI Natural Language Processing, because computers can certainly engage in the kind of symbolic-logical reasoning outlining signified meanings in cases where language reciprocates propositional morphology very clearly. The problem is that language artifacts very often cloak their logical core, such that examples like (21-28) are not representarive of language as a whole. Logical patterns may certainly be present, but they are not necessarily structurally reproduced in surface-level formations; rather a sentences' propositional content may depend on a subtle interpretive trajectory. I will present examples throughout this paper, but a few further corpus items are reasonable case-studies:

- (29) A furry black band of ants led up a cupboard door to some scrap that had flicked from a plate.
- (30) The current waiting period is eight weeks.
- (31) I think that's why they immersed themselves in pattern and colour.
- (32) With her appearance finalized, Jasmine became Disney's first non-white princess as opposed to being of European heritage.

It requires a certain cognitive flexibility to understand a band of ants as "flurry", or to parse the disjoint time-frames in *current waiting period*. In (31), the presumed sense of "immerse" transcends any immediate, perceptual immersion, instead involving scholarship or engagement with artistic form; and (32) depends on us understanding the meaning of temporality in Jasmine's appearance being *finalized*, and also her *becoming* non-white. As a fictional character, discourse about Jasmine can be evaluated in the time-frame of her artistic creation, distinct from the fictional time of her narrated world.

I think the intended propositional content in (29-32) is no less evident than in (21-28); however, interpreting the topical foci and predicate attributions constituting such propositional content requires a holistic reading whose compositional structure is not recapitulated in the sentence-forms themselves. In the latter examples, then, merely notating propositional content in logical fashion does not yield a very informative *linguistic* analysis, since it does not address the key question of *how* the sentences signify those propositions.

I propose to use the term "logicomorphic" for sentence in the former vein; in such cases, pointing out propositional content is linguistically useful because we can treat that content as a prototype for sentence organization. That is, propositional content is not only *holistically* signified but, in its logical structure, sheds light on pattern in the language. The purpose of phraseology like *most common tumour*, *Many Taliban living in Afghanistan*, *Most of the girls I was meeting*, etc., is to circumscribe a focus or a property suitable for predication, and we can logically model the tools used to do so: logical superlative (*most common*), assertions of magnitude (*Many*, *Most of*), refining an multiplicity with some further criteria (*the girls I was meeting*, *Taliban living in Afghanistan*), and so forth. These are "logicomorphic" constructions in

that we can read the logical structure of signified propositional content as a direct cause of the given phrasal morpholgy.

On the other hand, I call examples like (29-32) "interpretive" because the sentences' propositional content, with its logical structure, does not explain the compositional rationale for the explicit linguistic form: we cannot read any pattern in the logic as a direct motivation for how the sentence is pieced together. The spectrum between *logicomorphic* and *interpretive* represents different strategies by which language is composed in anticipation of its cognitive reception, with the eventual goal of establishing a signified propositional content, but in different ways. On the logicomorphic side, logical form informs language directly; on the interpretive side, the actual rationale for compositional structures transcends exact predicative structure — a more perceptual or indirect figuring of topical focus, for instance, or a more elliptical construal of predicate attributes, leaving the hearer to piece together the final propositional via some pragmatic or extralinguistic calculation.

Accordingly, the *logicomorphic*–*interpretive* distinction — along with the overall contrast between linguistic and extralinguistic aspects of meaning — are contrasts between sentences that become manifest in the compositional maxims evident at subsentence (phrasal and inter-word) scales. We can apply all four criteria to estimate the cognitive as well as syntactic and semantic paradigms in effect for given inter-word pairs and phrasal structure; identifying sentences as logicomorphic or interpretive propagates down to how phrasal and interword patterns should be analyzed. With this in mind, having presented certain claims as to the holistic nature of sentences vis-à-vis propositional content, I will now switch attention to the composition of sentences from the interword level upward.

2 Functional Type Theory and Dependency Grammar

My discussion toward the end of the last section focused on characterizing sentences' holistic meaning. On the face of it, such holistic analysis is more semantic than syntactic. However, syntactic paradigms can be grounded in theories of how language elements aggregate *toward* holistic meaning.

Here I propose the language of "cognitive transforms" — that holistic meanings emerge from a series of interpretive and situational modeling modifications which progressively refine our understanding of a speaker's construal of our environing context and her propositional attitudes. While elucidation of these transforms as cognitive phenomena may be semantics, syntactic structure dictates the *sequence* of transforms. Many transforms are expressed by individual word-pairs. Taking the temporal or logical order of transforms into consideration, we can derive a syntactic model of sentences by introducing an order among word-pairs — a methodology akin to using Dependency Grammar parse-graphs as an intermediate stage, then ordering the graph-edges around an estimation of cognitive aggregation. One transform is a successor to a predecessor if the modifications induced by the predecessor are consequential for the cognitive reorientation pertinent to the successor, and/or to the morphosyntactic features which trigger it.

In this spirit I talk of Cognitive Transform *Grammar*, because while in the general case transforms are semantic and interpretive — not the purview of grammar per se — we can theorize grammar as governing the *order of precedence* among transforms. More precisely, there is a particular order of precedence germane to sentence meaning; sentences have their precise syntax in order to compel recipients' reception of the linguistic performance according to that same ordering.

From this perspective, an essential aspect of grammar theory is that whatever units are understood as syntactic constituents — like phrase structure or word-pairs — an order of precedence should "fall out" of grammatic reconstructions. We should be able to supplement parse-representations with a listing of salient syntactic features in order, retracing the *cognitive* steps by which localized alterations in sense synthesize into holistic meaning. The details of this precedence-establishment will vary across grammatic paradigms, so one way to assess grammar theories is to consider how the engender corresponding cognitive-transform models.

Models based on Functional Type Theory are useful in this context because in their case order of precedence falls out automatically. In linguistics, a functional type theory can be seen as a theory where a small set of primitive Part of Speech types — e.g., nouns and propo-

sitions — generates a collection of further "functional" types. For any two (not necessarily distinct) types, the functional transformations which take inputs of one type and produce outcomes of a second type reprecent a third type, which can be notated something like TyOneTo-TyTwo. Assuming all lexemes are assigned a Part of Speech drawn from such a type system, the definition of functional types directly yields a precedence order: instances of functional types are functionally dependent on their inputs, which are therefore precedent to them. On this basis, any well-typed functional expression has a unique precedence ordering on its terminal elements (i.e., its "leaves" when the expression is viewed as a tree, or its nodes when viewed as a graph), which can be uncovered via a straightforward algorithm (one implementation is part of this paper's data set; see the "parse_sxpr" method in file xxx.cpp).

In practice, many functional parts of speech can be formally modeled with one "argument"; they have a single input and output type. These cases conveniently lend themselves to cognitive transforms defined through word pairs — an adjective modifies a noun to another noun, an adverb maps a verb to a verb, an auxiliary like *that* or *having* can map verbs or propositions to nouns, and so forth. The only main complication to this picture is that verbs, which typically have subjects as well as objects, can take two or three "inputs" instead of just one. Instead of a transform *pair* we can then consider a three- or four-part transform structure (verb, subject, direct object, indirect object). We can still assign a precedence ordering to verb-headed phrases, however, perhaps by stipulating that the subject takes presedence before the direct object, and the direct object before the indirect. This ordering seems cognitively motivated: our construal of the significance of a direct object appears to intellectually depend on the verb's subject; likewise the indirect object depends on the direct object to the degree that it is rationally consequential.

A secondary complication involves copulae like *and*, which can connect more than two words or clauses. Here, though, a natural ordering seems to derive from linear position in the sentence: given *x, y, and z* we can treat *x* as precedent to *y*, and *y* to *z*, respectively.

In total, sentences as a whole can thus be seen as structurally akin to nested expressions in lambda calculii (and notated via "S-Expressions", like code in the Lisp programming language). S-Expressions are occasionally recommended as representations for some level of linguistic analysis (cf. [**?**], [**?**], [**?**]), and this form by itself adds little extra data, it does offer a succinct way to capture the functional sequencing attributed to a sentence during analysis. Given, say,

▾ (33) The city's ambience is colonial and the climate is tropical.

the gloss *(and (is ((The ('s city)) ambience) colonial) (is (the climate) tropical))* summarizes analytic commitments with regard to the root structure of the sentence (in my treatment the copula is the overall root word) and to precedence between words (which words are seen as modifiers and which are their ground, for instance). So even without extra annotations (without, say, the kind of tagging data included by treebanks using S-Expression serializations), rewriting sentences as nested expressions captures primitive but significant syntactic details.

Nested-expression models also give rise directly to two other representations: a precedence ordering among lexemes automatically follows by taking function inputs as precedent to function (words) themselves[1]; moreover, S-Expression formats can be rewritten as sets of word-pairs, borrowing the representational paradigms (if not identical structures) of Dependency Graphs. This allows Dependency Graphs and S-Expressions to be juxtaposed, which I will discuss in the remainder of this section.

2.1 *Double de Bruijn Indices*

Assume then that all non-trivial sentences are nested expressions, and that all lexemes other than nouns are notionally *functions*, which take typed "inputs" and produce typed "outcomes". Expression "nesting" means that function inputs are often outcomes from other functions (which establishes a precedence order among functions). Since there is an obvious notion of "parent" — instances of functional types are parents of the words or phrase-heads which are their inputs — nestable expressions are formally trees. Via tree-to-graph embedding, they can also be treated as graphs, with edges linking parents to children; since parse-graphs are canonical in some grammar theories (like Link and Dependency grammar),

[1] But note that using "function-words" as terminology here generalizes this term beyond its conventional meaning in grammar.

it is useful to consider the graph-style representation as the intrinsic structure of linguistic glosses based on S-Expressions. That is, we want to define a Category of labeled graphs each of whose objects is isomorphic to an S-Expression (using this terminology in the sense of mathematical Category Theory); equivalently, a bijective encoding of S-Expressions within labeled graphs given a suitable class of edge-labels.

Indeed, labels comprised of two numbers suffice, generalizing the lambda-calculus "de Bruijn Indices". The de Bruijn notation is an alternative presentation of lambda terms using numeric indices in lieu of lambda-abstracted symbol. The *double* indices accommodate the fact that, in the general case, the functional component of an expression may be itself a nested expression, meaning that "evaluation" has to proceed in several stages: a function (potentially with one or more inputs) is evaluated, yielding another function, which is then applied to inputs, perhaps again yielding a function applied to still more inputs, and so forth. I use the term "evaluate" which is proper to the computer-science context, but in linguistics we can take this as a suggestive metaphor. More correctly, we can say that a funtion/input structure represents a cognitive transform which produces a new function (i.e., a phrace with a function-like part of speech), that is then the modifier to a new transform, and so forth. In general, the result of a transform can either be the *ground* of a subsequent transform, which is akin to passing a function-result to another function; or it can be the *modifier* of a subsequent transform, which is akin to evaluating a nested expression to produce a new function, then applied to other inputs in turn.

For a concrete example, consider

▼ (34) The most popular lodging is actually camping on the beaches.

with gloss *((actually is) ((The (most popular)) lodging) ((on (the beaches)) camping))*. Here the adverb *actually* is taken as a modifier to *is*, so we imagine that interpreting the sentence involves first refining *is* into *is actually*, yielding a new verb (or "verb-idea") that then participates in verb-subject-object pattern. Hence, the parse opens with the evaluation *(actually is)* in the head-position of the sentences top-level expression. Similarly, I read *on the beaches* as functionally a kind of adverb, like *camping outside*. In the generic pattern, a verb can be paired with a designation of location to construct the idea of the verb happening at such location; the designation-of-location is then a modifier to the verb's ground. When this designation is a locative construction, the whole expression becomes a modifier, while it also has its own internal structure. In *on the beaches*, *on* serves as a modifier which maps or reinterprets *the beaches* to a designation of place. So here is the unfolding of the phrase: in *the beaches* the determinant (*the*) is a modifier to the ground *beaches*, signifying that *beaches* are to be circumscribed as an aggregate focus. Then *on* modifies the outcome of that first transform, re-inscribing the focus as a place-designation. Then *that* transform's output becomes a modifier for *camping*, wherein the locative construction becomes a de-facto adverb, adding detail to the verb *camping* (camping on the beach as a kind of camping, in effect).[2]

Notice in this review that *the* as modifier in *the beaches* yield a pair whose outcome is the *ground* for *on*. If we take the modifier as representative for a modifer-ground pair, *the* is the *modifier* in its own transform pair but then the *ground* in the subsequent pair; the pattern is modifier-then-ground. However, *on* is the modifer vis-à-vis *the* and then *also* modifier vis-à-vis *camping*; the pattern is modifier-then-modifier. This latter case is the scenario where a lexeme will be a modifier on two or more different "levels", giving rise to the "doubling" of de Bruijn indices. The first index, that is, represents the "level" tieing a modifier to a ground, while the second index is the *normal* notation of lambda-position. In *camping on the beaches*, the indices for the pair *onthe* would be "1,1" (meaning *the* is the first argument to *on* on the first transform level); the indices for *oncamping* would be "2,1" (*camping* is the first argument to *on* on the *second* transform level).

By combining an index for "transform levels" — capturing cases where a modifier produces an outcome which is a modifier again, not a ground — with an index for lambda position (e.g. the direct object has index 2 relative to the verb, and the indirect object has index 3), we can transform any expression-tree into a labeled graph.

[2] If it seems better to read camping as a *noun* — the act or phenomenon of camping (qua verb) — then we could treat the locative as an *adjective*, with the stipulation that the operation converting verbs to nouns (from X to the phenomenon, act, or state of X-ing) propagates to any modifiers on the verb: modifying constructions that refine X as verb are implicitly mapped to be adjectives likewise modifying X in the nominal sense of "the phenomenon of X-ing".

Parse graphs can then be annotated with these double-indices via the same presentations employed for Link or Dependency Grammar labels. Sentence (34) could be visualized as in Figure **??**. Alternatively, the double-indices can be juxtaposed with conventional Dependency labels — one option is to graph the indices below the sentence, and relation labels above it. The examples (**??**) and (34) are annotated in the Universal Dependency corpus, so the two annotation styles can be juxtaposed (figures **??** and **??**).

As a natural corollary to this notation, parts of speech can 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 could be notatated with something like $N \dashrightarrow N \dashrightarrow \mathcal{P}rop$. The notation is consistent so long as each constituent of a verb phrase has a fixed index number: the subject at position one, for instance, direct object at position two, and indirect object at position three. Type "signatures" like $N \dashrightarrow N \dashrightarrow \mathcal{P}rop$ may seem little more than notational variants of conventional linguistic wisdom, such as sentences' 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 Dependency Graphs and phrase structures can be complex. One complication is 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*. In real-world examples, however, lexemes tend to be neither wholly subsumed by their surrounding phrase nor wholly autonomous:

- (35) Many students and their parents came to complain about the tuition hikes.
- (36) Many students came by my office to complain about their grades.
- (37) Student after student complained about the tuition hikes.
- (38) Student after student came with their parents to complain about the tuition hikes.

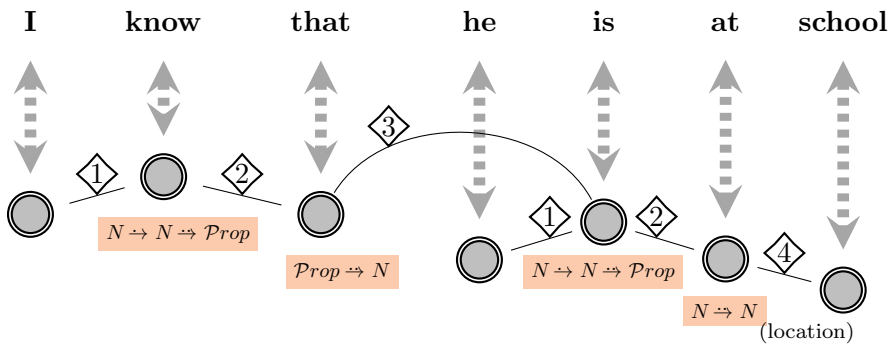
In (**??**) and (**??**), we read *Many students* as topicalizing a multitude, but we recognize that each student has their own parents, grade, and we assume they came to the office at different times (rather than all at once). So *students* links conceptually with other sentence elements, in a way that pulls it partly outside the *Many students* phrase; the phrase itself is a space-builder which leaves open the possibility of multiple derived spaces. This kind of space-building duality is reflected in how the singular/plural alternative is underdetermined in a multi-space context; consider Langacker's example:

- (39) Three times, students asked an interesting question.
- (40) Three times, a student asked an interesting question.

Meanwhile, in (**??**) and (**??**) the phrase *Student after student* invokes a multiplicity akin to *Many students*, but the former phrase has disting syntactic properties; in particular we can replace *their parents* (which is ambiguous between a plural and a gender-neutral singular reading) with, say, *his parents* (at a boy's school), a valid substitution in (**??**)-(**??**) but not (**??**)-(**??**).

As these sorts of examples illustrate, phrases cannot just be studied as full-scale replacements for semantic units. Incorporating type theory, we can instead model phrases through the perspective of type signatures: given Part of Speech 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 a tree is formally a reducible structure in Typed Lambda Calculus: $N \dashrightarrow N \dashrightarrow \mathcal{P}rop$ "collapses" to $\mathcal{P}rop$, $\mathcal{P}rop \dashrightarrow N$ 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 **??**, this can be seen via the type annotations: from right to left $N \dashrightarrow N$ 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*. This 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"

Figure 1: 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)

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" Parts 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 — as I have proposed here with double-indices — so a type-summary of a sentence's phrase structure can be notated and analyzed without leaving the Link or Dependency Grammar paradigm.

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. 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 singu-

lar/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?

In effect, type-related observations can be grouped (not necessarily exclusively or exhaustively) into those I will call *macrotypes* — relating mostly to Parts of Speech and the functional treatment of phrases as applicative structures; *mesotypes* — engaged with existential/experiential qualities and "Ontological" classifications like sentient/nonsentient, rigid/nonrigid, and others I have discussed; and *microtypes* — related to lexemes and word-senses. This 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.[3] 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, 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.

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:[4]

- (41) The newspaper you are reading is being sued.
- (42) 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:

- (43) The newspaper fired the reporter and fell off the table (?).
- (44) Liverpool beat Tottenham and built new docks (?).

(again, slightly modifying the counter-examples). Type coercions are *possible* but not *inevitable*. Some word-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:

- (45) Liverpool wants to sign a left-footed striker.
- (46) That newspaper plans to fire its editorial staff.

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. 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; or *fire* as in "relieve from duty" is only compatible with newspapers as institutions. These dicta can be expressed in multiple ways. But the propagation of classifications (like "inanimate objects" compared to "mental agents") through complex

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

[4] [?, p. 40] (former) and [?, p. 4] (latter).

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 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 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 meeting outside the paper's offices — sound quite reasonable).

The "type coercion" analysis works for 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. Or (like in asking for directions) its spatial dimension may be foregrounded. The availability of these foregroundings is a feature of a hypothetical restaurant type, whether or not these phenomena are 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 models.

At the most general level — what I called *macrotype* 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-theoretical analysis at this more grammatic level, 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 langauge 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 $\mathcal{P}rop \nrightarrow N \nRightarrow N$ taking the place of gravitational equations; and sentences' grammatic spine taking the place of curvature pulling mass into a planetary center.