From Naturalizing Phenomenology to Formalizing Cognitive Linguistics (II): Externalism and the Interface Theory of Meaning

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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, [67, 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, [84, p. 11]

A sign demands an individuation — a criteriology, for anyone addressed and solicited by each sign, to recognize and isolate it as such. Signs, and their referents, need an isolating, from the world around (and one another), or they are not signs. In extreme cases a sign may stand alone, like the smoke fire telling a hiker's location; but by norm, embedded in discourse and performance, signs require (and carry with them, internally) understood inter-boundaries. Both the recognition and the interpretation of signs therefore implicates cognition-logics of part/whole (mereology), and (dis/)continuity, each sign/referent disconnected in some ways, and continuous in others, with larger wholes inside which they are semi-autonomous parts.

Ad-hoc signs can blur the boundaries between conventionalized languages (verbal or not) and more impromptu social interactions — the smoke fire is in part a conventional distress signal and in part a tool, an engineered natural phenomenon designed with intended effect, like causing rescuers to see it. The distress fire is also in a sense its own referent: its function as a sign is to call attention to itself, and so its location. Or, choosing to write on one's own body — like Hamas commander Mahmoud Ishtiwi, betrayed and killed by his own movement, carving into his leg the word "zulum" ("wronged") — is expression spreading beyond the conventions of words; the signs are made to signify the conditions of their execution. These rather dramatic examples are more the provenance of semiotics than linguistics. But people in ordinary verbal communication equally rely on a mixture of linguistic and other signs — we point, make gestures, use "body language" and tone of voice. When conversation turns to some topic, like "that building over there", such cues help speakers synchronize their attentions. Tone and gestures clarify sentiment (honest, joking, sarcastic, anger) that may be ambiguous in spoken words alone, taken "out of context". The weight of linguistic meaning is borne by semantics and pragmatics in fusion. Semantics has both formal and informal dimensions — linking first to cognitive schema, or (as I will argue) prototypes of how schema are triggered; and second to pragmatics and contexts. Conventionalized in semantic norms, schema, part abstract and part cognitive, help prime language users to manipulate formal structures in language, relative to the situational aether. (Dis/)continuity in the plane of reference brings consciousness to a mereo-logic [30], [82] that language-cognition can then reshape into syntax and semantics [13]. 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 formal/abstract and the concrete/phenomenological.

For signs, the largest whole is a "plane" of articulation; for referents, it is an overall phenomenological surround; or, for more abstract signifieds, a space of concepts. 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. Attunement to structured organization therefore warrants the perceptual and mental isolation of particular foci of attention [102], [103].

As this plays out on planes of articulation alongside general situational 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. Grammar does not iconify interrelationships among referents — unlike diagrams, maps, scientific simulations, or scale models — but it ensures communicators may create structures among words that suggest, in each others' minds, concordant patterns in the environing world/situation. Even where there is direct sensory and perceptual evidence for objects' individuation and intercontinuity, visually and experientially present (which of course is only one kind of talk and reference), our preparedness to focus attention here or there depends on mental models of situations which are more abstract and schematic, and receptive to functional and interpersonal details. The objects around us are not just blobs of matter, but usually have a constructed purpose, socially sanctioned meaning, nostalgic weight, and other significance that cannot be grasped by perception alone.

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 [69], [91]. The difference between *pour water* and *spill water*, for example, 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 rationale as well. These are differences 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 as an example: one (very general) manner of spatial gestalt, subject to either intuitive, reflective analysis or to formalization ([11], [99]). "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,[1] but by the more abstract effects of intentions signaled, via both 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 pregiven: not as a perfected or homogenous theory, but as a working hypothesis on the origins of linguistic structuration as such. The scope of this paper is then to analyze its ramifications for our understanding of grammar and formal semantics.

[1] 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.

This essay adresses topics in linguistics and the philosophy of language, though (by conventional measures of expertise) I am more of a Phenomenologist and a Computer Programmer than a linguist. I confess this not as biography, but to introduce my metatheoretical anchor points, from which derive intuitions that others might find unconventional. I am, in particular, sensitive to the experiential nuances of human cognition and skeptical that mechanical systems can emulate human minds except for narrowly defined tasks. At the same time, I think computational systems have interesting aspects that can enrich our understanding of cognition, even if we do not philosophically buy a "cognition is computation" metaphor.

To be precise, I am skeptical about "AI"; and I am also skeptical about a kind of logical reductionism that I believe exerts a definitive influence on several interrelated filds, including philosophy, linguistics, and computer science. As the paradigm seemingly goes, if we accept some form of "mind as computer" analogy, then we intrinsically accept *first* the idea that "mind" encompasses as some important part a logically articulated subsystem, which can be scientifically studied via formal logic; and *second* that as a consequence of this scientifically tractable logicality, AI is a good model or proxy for the study of mind. The unconscious deduction here seems to be that *mind as computer* has as a consequence that mind is (to some salient degree) a logical system, following a premise that computers are logical systms. But this premise is more false than it is true; so for me the whole paradigm is on shaky grounds. I will explain later why computers are not as logical as non-programmers seemingly believe. For now I'll just say this: there are rigorous accounts of computation that, I contend, are not grounded on formal logic in any techical or reductive sense. As a result, someone's non-logical-reductive views on language and consciousness do not *a priori* preclude computational models having some intuitive, explanatory, or structural-analogy place in their analyses of cognition.

Meanwhile, on the Phenomenological menu I am a committed "realist". What I mean is that, in a nutshell, we should renew our commitment not to read Husserl too psychologically; for instance, not to read *intentionality* as a psychological phenomenon. If I see a red sofa, we should go ahead and accept that what I see is a red sofa

— that very object. I do not see a mental image of a red sofa or a phenomenal appearance of a red sofa or a token of red-sofa-appearance-ness. We should not be led astray by the sofa being a few feet away from me, so it is not "in my brain". Yes, my brain is over here, not over there — If I am suddenly distracted by something, look away, and forget about the sofa, my sofa-impression (but not the sofa) goes away, which seems to suggest that there my sofa-impression is not the same kind of thing as a sofa — which in turn invites us to qustion whther what I am really seeing is that sofa-impression, not that sofa.

But, without disputing that in *some* sense the impression is not ontologically identical to the thing itself, I still maintain that the best gloss on the situation still starts from the givenness that I do see the sofa (and not the sofa-impression or any other psychologistic posit). I will have more about to say about this realism, also. For now I'll say this: the case for "impressions" over "things themselves" seems stronger when talking about vision (which works at a distance) rather than touch — if I actually sit down on the sofa and physically contact it, we may feel more comfortable saying that my experience is directly encountering that physical object (though someone could still say that tactile sense-impressions are still not identical to objects; for one thing, the contact point between my hands/torso and the sofa — the locus of those haptic nerve cells — is not in my brain either, ergo a spatial gap still exists between brain and the sensed object). If we accept that our nervous system is in some sense a functionally organized complex, then an encounter between some external body and *part* of that system, with suitably holistic functional response, can plausibly be treated as "my brain" (or nervous system or mind) contacting the sofa — we don't need to rule out this gloss because my *central* nervous system remains physically isolated, any more than we would dispute that a knife has punctured a sealed carton when in fact only the knife-tip did so. In short, sense-causing physical contact as part of my embodied propensity to register tactile contact experientially, through the medium of functionally-organized processing that eventually includes the brain, is — I would say — a sensate manifestation of my contact with the sofa (not with a tactile-sense-impression or haptic-phenomenon of the sofa).

And if we accept this line of reasoning for touch, we should do so for vision also — partly because an intrinsic feature of *seing* something is that we *could* with proper movement touch it, and apprehension of visual form includes anticipation of how surfaces will respond when we kinaesthetically interact with them (we might presume, for instance, that we can run our hand over the wall to the right but not to the left, if there's another wall there: this visual disclosure is also in a sense proto-kinetic).

So, before making claims about language, I have hereby asserted two main intuitive feints guiding my subsequent discussion: computer programs as useful but not logically reductive analogs for cognitive processes; and the virtues of a "realist" Phenomenology which accepts arguments to the effect that we experience "things themselves": that touching and seeing (etc.) are experiential encounters with real, external, non-psychological entities. This does not have to be a blunt realism — I don't dispute that we experience appearances in some sense — but we need to articulate the thing/apearance distinction in a way that does not disallow common-sense intuitions like "seeing the sofa" meaning that I do see some real, external sofa-thing. That would make for an analysis in pure Phenomenology if I just framed my arguments with reference to, say, Husserl's own treatment of the noemata/phenomena distinction. Here, howevere, I am going in a different direction and package a loose theory of "realism" about intended "external" objects within a treatment of "externalism" (and *internalism*) in the philosophy of language.

I am not ignoring that "external" in the sense of "wide scope" mind-world relations as a Semantics hypothesis is only tangentially related to "external" in a phenomenological sense of experienced external objects (as opposed to experienced internal, e.g. somatic, states). But I *will* present a theory that connects these two senses of "external" (and likewise two senses of "internal").

All told, my goal here is to sketch a theory of cognitive linguistics which can resonate soundly with Phenomenology (while not being especially phenomenological on its own). This theory will be incomplete — deliberately, strategically incomplete. Indeed, every theory should be incomplete: an essential quality of modern science is our recognition that scientific explanation covers a vast breadth of scales and kinds of phenomena, and "science" as a singular human institution only exists insofar as there are many sciences, each with some measure of theoretical autonomy but also areas of overlap, so scientific explanations can bridge across scales. Biologists take it for granted that the basic intellectual structures of their disciplines can be justified by appeal to chemistry (as a causative or emergent base of bioloigical phenomena); and the presence of *parts* of biology where this connection is explicit (like organic chemistry) is important for our overall sense of biology as something grounded in a general scientific method. But these "reductive" links are not typically operationalized in biology as a whole — a biologist is not "doing" chemistry, biological properties are not necessarily chemical properties, biological laws are not necessarily chemical laws, and biological terms are not semantically (or even arguably referentially) reducible to chemical terms.

We can consider whether biological concepts are "in some sense" reducible to (or extensionally equivalent to or "the same stuff as") chemical concepts, but framing this discussion as a nuanced debate implies that biology is not *trivially* reducible to chemistry, and we may accept such a reduction as a plausible option only insofar as some of us may hold philosophical commitments, which "we" collectively do not want to dismiss out of hand, that higher-scale sciences are necssarily reducible to lower-scale ones that are their causal or physical-constitutive base. But even if there is a sense of "reduction" and of "biology" and "chemistry" that makes biology reducible to chemistry, this dos not make biological *science* reducible to chemical *science* — that is, a well-constructed and discursively evaluable biological theory should not be expected to consider in any detail its own reductive interpretations, or express its concepts in chemical (rather than biological) terms, or attempt to *explain* rather than just *presuppose* chemical laws (preservation of quantities in chemical reactions, acid/base qualities, solvents and solubility, molecular interactions, etc.). Ditto for chemistry in relation to molecular physics, molecular physics in relation to quantum physics, neurology in relation to biology, and so forth. In short, whatever our philosophical intuitions about emergent phenomena and the ontological duality (or monism) between emergent and base scales, these philosophical points are only tangentially related to the equally important philosophical question about what makes a good theory in a science.

This bears reiterating: when considering a science (I'll include social sciences and humanities here) philosophically, there are two different sorts of questions that can arise. On the one hand, what is the ontological status of the entities, laws, and quantitative models postulated by the science and its currently influential theories? Should we understand terms to be proposed natural kinds (like "protons"), structural features that don't necessarily align with straightforward patterns of reference (like "dark matter"), referring expressions into complex systems whose parts have somehow fuzzy or underdetermined boundaries or criteria of individuation (like "storms" in the context of climate science), or quasi-references which have the form of concrete designations but are really just shorthand for elaborate paradigms (like "natural selection")? These are various options in the semantics of scientific jargon, which are clues to the proper ontological status of sciences' theoretical posits (this much applies to linguistics also, with its theoretical vocabulary of concepts, lexemes, syntax rules, generative semantic rules, and so forth — are these mental subsystms? Innate cognitive faculties? Clusters of nerve cells? Neural pathways reinforced during language acquisition?). But, on the other hand, there is a different order of question philosophers can ask with regard to a particular science: what qualifies as a well-constructed theory for that science? What sorts of formal models hold explanatory merit as, seemingly, capturing the casuative factors determining the behavior of the systems that science investigates: continuum-based numerical models? Models in discrete mathematics? Systems of logic? State machines? And interconnected with that question is the proper scope of the science: a well-constructed theory needs to honor bounaries between and autonomy of different sciences. Having a clear picture of what beliefs in *other* sciences to take as explanatory primitives in *this* science is an essential criteria of theoretical soundness — no less than the urge to pursue explanatory closure within the proper bounds of each science.

One of my objections to "logical reductive" paradigms in linguistics (and computer science) is their failure to distinguish these two aspects of a philosophy of science, by my lights. When discussing chemistry or biology, we can make a clear distinction between metaphysical commitments according to which higher-scale systems reduce (via physical composition and the propagation of causality across levels of organization) to lower ones — biology to chemistry to physics — as a genre of reduction obviously diffrent from reducing sciences as collective intellectual exercises. We do not reduce the community of biologists to the community of chemists, or the kinds of expertise and fluency in certain mental gymanastics, or the criteria of what makes good biological theories, to the concordant community, conceptualizations, gymnastics, and theory-criteria of chemists. This is for me part of what makes biology a successful science — *it is incomplete in an ontologically necessary, intellectual fertile way.* But if this is a reasonable criterion, what can we say about linguistics as a science? Is it incomplete in an ontologically necessary and intellectually fertile way? In fact, I intend to argue here that some popular linguistic theories are *not incomplete enough.* They are (or would be, if successful) too complete — while also, I will claim, incomplete in the wrong ways, leaving too many *relevant* phenomena, issues that *are* in its scientific wheelhouse, incompletely explained.

I will make these arguments as a prelude to describing the (incomplete) linguistic theory I *am* prepared to defend. Specifically, the first two sections here will weigh in on Conceptual Role Semantics and Truth-Theoretic Semantics and explain why I believe some popular paradigms in the philosophy of language are problemmatic. While the details will vary, the main thurst of my points will be that philosophers of language fail to appreciate the importance of sciences' internalizing a map of the division of labor between sciences — a science is constituted in part by how it touches but remains autonomouus from other (both higher- and lower-scale) sciences. So biology is constituted in part by its status as a potential reductive base for (e.g.) neuroscience, medicine, genetics, and paleontology, while having its own reductive base in chemistry and physics. Part of what it means to be biology is to be the explanatory bridge between, say, medicine and physics.

Analogously, I believe, part of what it means to be linguistics is to be the explanatory bridge between, say, sociology, anthropology, and ethnolinguistics, with cognitive science (or Cognitive Phenomenology). Language can be intrinsically characterized as the cognitive bridge between our everyday world — of social situations and kinaesthetic/pragmatic enaction and anticipation, planning and memory — with the neurophysical substratum (whatver it is) of our mental faculties. Language, that is, is an important tool for our negotiating the duality of our higher-scale social/situational world with our lower-scale neurophysical existence. Analogously, a phenomenon in language — say, a sentence — should be analyzed as a kind of transition-system between a social/situational layer of reality and a cognitive/neurological layer. Linguistics is accordingly suspended between these layers — or, better, I claim that linguistics should be the *theory of being suspended* between social/situational and cognitive/neurological strata. A linguistic analysis starts with entities shooting in from the first stratum (sentences we hear uttered, canonicaly), and it ends with some restructured representation or consummation of that sentence (parsed, lexified, etc.) understood as inputs to some neurophysical process belonging (ontologically, and as a matter of scientific jurisdiction) to the second stratum. Such an analysis is *correctly* incomplete because it recognizes that a basic criterion of well-formdness for linguistic theories is that they *refrain from* direct analysis of either societal/interpersonal or cognitive/neurophysical processes. Linguistic analysis is incomplete because a theortical machinery fine-tuned for analyzing processes of linguistic understanding at the intermediate level between social/situational and neurological strata cannot be the same as a theoretical machinery for analyzing either (in one explanatory direction) sociological or (in the other) neurophysical laws in turn — by analogy, the experimental (and theoretical) machinery for detecting Earthlike exoplanets cannot be the machinery for detecting Higgs bosons (and vice-versa).

Here I find an analogy to computer software useful: programs don't run themselves, so application developers realize that they do not control, or have access to much information about, when applications are launched (or when users will perform actions that require response from the software, like clicking a mouse button or pressing a key). Nor do programmers control input/output commands like emitting colors to the screen: they only influence electronic devices (like displays and networking capabilities) indirectly, via preimplemented system calls. In other words, the essential structure of a computer application is to be poised to react to various events (a mouse click, a key click, plus of course program startup initially) by eventually requesting certain operations (like changing the state of the screen) whose exact functioning remains outside the programmer's theoretical arsenal. Application developers have only a vague idea of how values and types in code are marshalled to an from electrical signals physically affecting (or reporting state from) devices like monitors, mouses, and keyboards. This is by design: if you are too closely attuned to low-level cyberphysical details, like how source code function calls map to digital signals, you're no longer doing computer programming (maybe you're doing chip design). To the degree that programming has a theory, it's a theory of how to *bridge* users' desired interactions with the software you are building *to* the digital structures encoded at the level of microprocessors and machine language. It is not a theory of microprocessors themselves. Theory well-formedness in the realm of programming — the field sonetimes called Software Language Enginering — reflects the transforms bridging "Human Computer Interaction" with machine language; it is not a theory of HCI or of machine languages themselves. Indeed, HCI methodology is subjective and statistical; and the methods of physically realizing machine language in microprocessors depend on physical and nanochemical properties. Well-formed Software Language Enginering theories *have* to leave both HCI and microprocessors out of the frame, since software programming languages are not statistical or subjective, nor physical or nanochemical.

The hierarchical nature of computer architecture complicates any "mind as computer" metaphor: computers have many subsystems, with significantly different structures and properties. Using computers as case-studies of artifacts that are in some sense "intelligent" can take us in different directions for different answers as to what scale of computers' organization we propose to inform, say, cognitive-linguistic research: microprocessors? Machine Language? Programming languages? Software systems? The internet? Many instances of "mind as computer" analogic reasoning are not explicit research paradigms being proposed forth but are more like reports of intuitions: a community of linguists feeling that there's something going on in how computers work that usefully models or resembles how human rasoning or language-processing works. But cashing these intuitions into systematic models can prove challenging: even insofar as a computer may exhibit intelligent behavior, it does so only in an emergent manner, the whole "intelligence" being possible only through specific kinds of interaction between subsystems, in particular a tightly determined transition between high-level systems (like applocation source code) and low-level systems (like machine code).

Of course, many researchers probably believe that this emergent dimension is precisely why computers are a plausible cognitive analogy: they suggest that intelligence can be realized in structural systems whose lowest-level operations are not particularly complex. No-one would argue that in and of itslf a simple Van Neumann machine is particularly "intelligent"; but software evincing intlligent bhavior can be implemented as emergent phenomena for which Van Neumann machines are their reductive base. This may seem like a useful analogy to consciousness, realized in neurons and synapses even though neurons and synapses are not themselves conscious. That's an acceptable intuition, but it also leads to a kind of philosophical bait-and-switch: what starts as a "mind as computer" intuition ends up as a different kind of analogy, something more like comparing minds to functional systems *implemented* on a computer. There is a difference between being a system realized on a computer and actually being a computer.

In the case of language comprehension, someone may find a useful analogy in database-like constraint-solving applications, like Prolog: language users maintain an internal store of beliefs — about both language and the world — and a record of prior steps in the current conversation. This "database" gets updated as we hear new sentences, and we are equipped to make or reject inferences based on inference rules and constraints, respectively: from "John is my younger step-brother" we can conclude both that the speaker's parents are divorced and that John is not female. Of course, real-world complications sometimes intrude on the kinds of tidy frames linguists build around words: a brother can actually be a transgender woman, and divorcés can remarry each other. We can debate whether these are semantic or pragmatic issues (I think they're the former, but let's say they are the latter for sake of argument). So let's say language has enough logical order that conversations can be modeled rather like Prolog programs. This leads to a maybe-interesting mind-as-Prolog analogy, but — here's the crux — mind-as-Prolog analogies are *not* mind-as-computer analogies. Computers *run* Prolog programs; it's not that they *are* Prolog sessions.

Indeed, I think many "mind-as-computer" analogies are actually more like "mind-as-Prolog" analogies, or substitute some other technology for Prolog. For instance, mind-as-artifical-neural-network analogies are not mind-as-computer analogies, because computers are not ANNs (though they may implement them). Indeed, ANNs are designed to make computers more humanlike: to transcend the mechanistic limitations of Van Neumann architecture by realizing, at some virtual level, a more connectionist manifestation of computation. A mind-as-ANN analogy is therefore really mind figured as a computer programmed to operate like a mind (so, the analogy is basically circular). Mind-as-symbol-processing analogies have similar issues: computers are not symbol-processors, though they can implement symbol processing systems. As I'll defend below, I think computers are basically stack machines, and stack machines do not "process" symbols — what they do is process stacks, and jump around to different subroutines. When people think about "computers" in mind-as-computer analogies — or write in ways suggestive of such an analogy — I often get the impression that what people are really thinking about is not "computers" but some sort of mathematically formalizable, functionally specified system that can be *realized* on a computer.

These other analogies are not *a priori* bad — it's reassuring if we have accounts of intelligence that traffic through functional organizations that can be realistically embodied in mundane physical artifacts, rather than needing some magical mind-gunk. But if our "mind-as-computer" analogies are nothing more than a desire to find logico-functional systems that can credibly undergird cognitive behavior, computers are basically irrelevant: the computational realizability of such logico-functional systems is a nice reminder that we're not asking non-philosophers to believe in magic, but the structure of these systems are sufficiently remote from how computers internally operate that computer realizability should have no *theoretical* role. In other words, mind-as-computer analogies are usually basically mind-as-logico-functional-system analogies.

We're entitled to find these latter analogies intuitive. My problem is only with mind-as-logico-functional-system analogies that get defended *by appeal to* mind-as-computer analogies. There seems to be a kind of metatheoretical pattern that goes something like this: mind is metaphorically a logico-functional system *because* mind is metaphorically a computer, and logico-functional systems (when not just abstract mathematical territories) are realized via implementation in computer architecture. But mind-as-computer is not logically related to mind-as-logico-functional-system — any apparent link between these analogies is a biproduct of intellectually backgrounding the distinction between *being* and *implementing*. We may or may not like a mind-as-computer analogy, but even if we *do* accept such a perspective, even if provisionally, this does not then legitimize or entail that we are accepting a mind-as-logico-functional-system analogy. Of course, we can judge the latter analogy on its own merits, but the former analogy in no way retroactively justifies the latter.

So, my strategy for the remaining sections of this paper is as follows: I will review some language-philosophy controveries and argue that disentangling mind-as-logico-functional-system from mind-as-computer analogies should change our estimation of theoretical claims apparently motivated by mind-as-logico-functional-system paradigms. I will then present a different basic account of language processing which, I believe, does not work in any logico-functional-system orientation, though I will recognize some fashion of functional orientation. I will in places appeal to computer architecture, though the framework I propose will only absorb "mind as computer" analogies to a limited, targeted extent. A central theme will be that *logic* is not terribly relevant for either language or computers: functionally-organized systems do not have to be *logico-functional* systems. The ambient philosophy guiding these arguments is that "logic" in any formal, symbolic sense is not the proper vehicle for understanding the structured transitions and causative propagation endemic to multiscale, emergent systems.

Biology, for example, is not a *logical* intermediary between medicine and physics. We can consider how best to describe its "intermediariness": as a theory-construction maxim (in the sense that intermediariness is expressed in which laws/obervables are thematized and which are deferred to other sciences), as a causal network grounded in cross-scale physical constitutions and mereologies (e.g., tissues are both physically composed of cells and are wholes where cells are parts), as an emeregnt system which both *is* (vis-à-vis other sciences) and *has* a reductive base. Sciences are like computer programs in that they have *inputs* (observables from other sciences) and "outputs" (laws from other sciences). I use thse terms because they track analytic trajectories: medical *observables* (e.g. that many people who are exposed to a toxin develop neurological damage) are linked *via biological analysis* to causal/material explanations (how the toxin chemically damages nerve cells). Biology neither statistically models the medical observations nor physically explains the causative mechanism, but it provides a theoretical machinery for rigorously modeling and analyzing the transition between them. It writes the second act of the explanatory play, so to speak. Pictured computationally, the analysis is like a computer program whose inputs are higher-scale observables (say, medical data) and whose "outputs" are numerical models whose formulae or justifications are solved by other sciences — by analogy to programmers calling system-kernel functions. In this analogy, medicine is like the end-user, biology is the application developer, and physics is the system kernel.

These are analogies informed by computers, of course, but I am trying to focus in on the "intermediariness" they evoke. How computer software bridges users and bare-metal is a useful metaphor for how scientific theories bridge observations and causal/mathematical microphysical models. And, correlatively, how sciences bridge between other sciences — higher sciences yielding observations that are "inputs" to intermediary explanations, lower sciences defining formats for "outputs". Biology, for example, can defer to chemical or physical explanation if it can provide data in structures adequate to chemical or physical formulae: the reference frames, quantitative measures, dimensional systems. Biology does not need to solve such equations, just marshal data into their form. So a good biological analysis will take observation data (e.g. from medicine) and transform it to equational data in some sense, wherein chemistry and physics take over. By analogy, correct computer software takes observations (data in computer files and user actions) and translates these observations to the proper system-kernal calls, whrein the Operating System takes over.

Sometimes logical constraints come to bear on these transitions, but the importance of logic per se is overshadowed by the overarching phenomenon of "intermediariness": how the technical and ontological status of computer applications is defined by their intermediary position between input data/user actions and low-level system calls. Analogously, sciences are characterized by their posits' ontological status as — and their theories' structural criteria regulated by — intermediariness between observational data from one peer science and causal/mathematical formula from another. As a philosophical gestalt, such "intermediariness", I believe, should take the place of "logic" in our intuitions.

In the specific contexts of Conceptual-Role and Truth-Thoretic Semantics, I will now show what for me this means in practice.

Part I

In this first half of the paper, I will consider several semantic paradigms: Conceptual Role Semantics, Conceptual Space Theory, Truth-Theoretic Semantics, and ultimately Interface Theory of Maning (a term due to Orlin Vakarelov). I approach this material as, hopefully, a mediator: I'd like to negotiate the differences and aggregate the best parts of these analyses, while avoiding reductionism and remaining true to phenomenology. I will eventually tie the peices together into a "Cognitive State" Semantics — but in this case semantic analysis overlaps with theories of syntax, so I will develop this aggregative perspective more in Part II, that addresses syntax more head-on.

1 Conceptual Role Semantics and Externalism

Conceptual Role Semantics is often discussed together with a particular internalism/externalism debate which it tends to engender. Here I want to defend a kind of Conceptual Role Semantics (hereafter CRS) but I will first outline an account of compromise between externalism and internalism. I will suggest a compromise different, I believe, than Ned Block's "two factor" model that seems considered the leading example of an externalist/internalist hybrid.

The basic CRS picture is that linguistic meanings should be associatd with conceptual roles in our understanding situations more than in terms of their reference to external objects. Given sentences like

- (1) He opened the wine bottle with an ornate corkscrew.
- (2) He opened the beer bottle with a butterfly corkscrew.
- (3) He collects antique corkscrews and just bid on one online.
- (4) I thought this was a screw-top but it turns out I need a corkscrew.
- (5) This X3D file shows a very realistic corkscrew created with NURBS surfaces.
- (6) Could you send me the corkscrew (the X3D file you just mentioned)?

we should interpret "corkscrew", first, as a concept in a kind of functional organization. In some of these sentences there is also a specific corkscrew (qua phsyical object) on hand as a referent, but its actual physical properties — or even identity — is not decisive for the meaning of the sentence. After all, in (4) the speaker is not thinking of any corkscrew in particular (probably — more on that later) and in (5) and (6) the corkscrew is not real (at least not real qua corkscrew). But the conceptualization associated with "corkscrew" does not seem markedly different in (1) or (2) versus (4), at least (more on the other three later).

Not only physical details but even lexical identity seems tangential to the important conceptual meanings. Suppose I am hosting two guests, one has a magnum of ale and one a bottle of Malbec. They ask, respectively:

- (7) Do you have a bottle opener?
- (8) Could you get me a corkscrew?

and I give the first guest a butterfly corkscrew and the second a folding multi-knife. What I gave them is different from their request, but they should think nothing of it insofar as the winged corkscrew has a gap on its handle suitable for beer bottles and the multi-knife has a fold-out corkscrew helix. I have not violated any conversational maxims, because I reasonably assume that the instruments I gave them are suitable for the desired goals, of opening their bottles. Semantically "corkscrew" really means "something that can be used to open a wine bottle", and in that sense the lexeme gets it principle content from this operational role, not some list of attributes (like spirally and graspable) or prototypes.

Granted, a suitably designed winged corscrew can be construed as a kind of bottle opener, and a multi-knife a kind of corkscrew respectively. We are prepared to accept these tools as examples of the respctive concepts if they are functionally designed to support those tasks, even if they are not the primary function. But our inclination allowing concepts to dilate modulo functional criteria suggest that our grasp of concepts is first and foremost functional-pragmatic: we tend to internalize concepts in reference to (extralinguistic) functional roles and expand concepts to accommodate variegated implementers of those roles.

We can indeed accept sentences like:

- (9) He opened the bottle of beer with a hammer.
- (10) He pounded the nail with a lever corkscrew.

Of course here we are inserting objects into a conceptual nexus where they are not usually found. Winged corkscrews are often *designed* to double as bottle-openers, but lever corkscrews are not designed to double as hammers. Nevertheless we have no trouble imagining the scenarios being described, where someone uses the thick part of a corkscrew to pound a nail, or a hammer's handle/claw gap to pry off a bottle cap. We have schemata for "a tool to open a capped bottle" and "a tool to pound a nail", and the concepts of bottle-opener and hammer occupy that conceptual niche insofar as they are artifacts designed for those purposes. But the conceptual "slot" for, say, "a tool to open a capped bottle" is more general than the specific tools designed for those purposes.

We nonetheless *would* be presumably violating conversational maxims if we handed our friend who wanted to open a beer bottle a hammer. Even if there's a way to make the hammer work for that purpose, it's further outside the norm than, referring back to (2), proposing to use a winged corkscrew. So the implicature in (2) is satisfied, let's say, by bringing my guest a winged corkscrew, but not a hammer. But we can entertain the *thought* of using a hammer as a bottle-opener, and even this possibility presents problems for simplistic thories of language acquistion as essentially learning a static set of word correspondances, like "a hammer is used to pound nails" or "a corkscrew is used to open wine" — after all, you cannot conclude from

- A hammer is somthing used to pound nails, *and*
- A lever corkscrew is something used to open wine, *and*
- A lever corkscrew can be used to pound nails

that a hammer is a kind of lever corkscrew and can therefore open wine. What we *do* have are conceptual slots available encapsulating ideas like "that which can open bottles" or "that which can pound nails", and we "fill" these conceptual slots with different lexical content in different situations. The "that which can open capped bottles" slot can be filled descriptively — i.e., in declarative speech, like in (9) — by a hammer, but not in other kinds of speech acts (we cannot read the concept "bottle opener" as satisfied by "hammer" in the context of a request for a bottle opner). Note that the scope of conceptual roles can change merely by switching between locutionary modalities.

The takeaway from this discussion in the internalism/externalism setting is that conceptual roles have a linguistic priority over and against both lexical and physical realizers, and the scope for things inside and outside of language to play (or not play) such roles varies with context. I have introduced these issues via tool artifacts (like corkscrews) but would be closer to the spirit of the CRS internalism/externalism debate by discussing natural-kind concepts. Suppose I am building a sand castle on a beach and ask someone one of:

(11) Can you bring me a bucket of water?

(12) Can you bring me a glass of water?

For (11), a reasonable reaction would be a bucket filled with ocean water; but for (12) my addressee would probably infer that I was thirsty, and — since salt water is non-potable — was requesting water I could drink. But "*glass of* water" probably figures here just to establish my intention to drink it: you are entitled to bring me bottle of water instead. In other words, my request has implied content which in some aspects loosens and in some aspects restricts the conceptual scope of semantic entries in my utterance. Thus oceans are composed of water, and near a beach I can say:

(13) The ocean is over there.

(14) The water is over there.

(15) You can see the ocean from here.

(16) You can see the water from here.

Each pair is almost identical. But ocean-water ceases to fall under the conceptual role of "water" when we are in the context of drinking things instead of the context of geography. This suggests that water does not "mean" H_2O or other saline or non-saline water: the meaning is not fixed to any particular chemical composition but adapts to the situational context, including what the water is used for — e.g. as a drink or as a binder for a sand castle.

The most-discussed "water" analysis in the literature is less earthly than this: Putnam's "twin earth" argument about a planet whose substance (with chemical makeup) XYZ functionally indisinguishable from our (H_2O) water. Externalists and internalists use this thought-experiment to express their differences as disagreements over whether twin-earthers' XYZ concept is the same as our H_2O concept. For the latter, as the basic account goes, XYZ plays the same conceptual role in their lifeworld as H_2O plays in ours, so it is the same concept; for the former, the concepts designate different material substances (even if twin-earthers don't know this) so they can't mean the same thing, even if there is some sort of analogy or resemblance between them (concepts can be analogous or similar while still being different concepts).

Before making a case for one alternative here over the other, let me note the following: it is unfortunate that the case-study is formulated in terms of XYZ vs. H_2O, because at the level of molecular composition it is hard for us to conceive that XYZ is *really* indistinguishable from water. After all, our conceptual understanding of water includes things like electrolysis — if XYZ does not emit hydrogn and oxygen when electricallly charged under certain controlled conditions, it is not behaving like water and can not be (even internalistically) construed as conforming to our concept of water. Of course, we are free to expand our water-concept, just as we contract it when switching from geology/geography to drinking. But here we expand it with full recognition that finer-grained conceptual distinctions are possible, just that there are many contexts where they are unnecessary.

We do not need to contemplate far-fetched twin-earth scenarios to see this in practice: here on earth we have deuterium water which is chemically different from normal water (but both have the H_2O signature, although heavy water is also described as D_2O). We are free to let "X" mean normal hydrogen, "Y" mean deuterium ions, and "Z" mean oxygn, so XYZ becomes what chemists call HDO — semi-heavy water. Most people would probably say that HDO is just a kind of water, and so can be subsumed under the concept "water", but this is not conclusive. In reality, I don't think the English community has needed to establish whether "water" should mean ordinary H_2O or should include variations containing different hydrogen isotopes — whether heavy and semi-heavy and other variants of water should be considered "water" or some other concepts.

In practice, a fraction of ocean water has deuterium, which might argue for "water" subsuming heavy water — we don't point to the ocean and say

(17) The water and the Deuterium Dioxide is over there.

But this can alternatively be explained by the principle that referring to an impure sample of a substance is still a valid use of the concept:

- (18) Here's a glass of water (even though tap water is mixed with flouride).
- (19) Bing cherries are dark red (even though the stem is brown).

In the second case, we can validly call something red even if something less than its whole surface shows a red color. Applying a similar rule, we can call a solution "water" if there are only "sufficiently small" amounts of solutes. Clearly we use "water" to designate many substances other than pure H_2O. I can think of two options for explaining that semantically: (1) Salt water, tap water, distilled water, (semi) heavy water, etc., are all different kinds of water, but our coarser "water" concept subsumes them all (in most contexts). (2) There is only one water concept, pure H_2O, but impure samples of liquid that are mostly water can be called "water" by the same principle that a mostly red-colored object can be called just "red".

The second option has a common-sensical appeal because it fits a succinct "concepts as natural kinds" paradigm but does not venture too far from normal language use — that "red" actually means "mostly red" is a pattern common with many nouns and adjectives (someone can be *bald* with a bit of hair; I can point to a turkey burger made with bread crumbs and spices and say "that's turkey"; I can tell someone listening to Keny Arkana's song "Indignados" "that's French", although some of the lyrics are Spanish). However, the "mostly water" reading has a couple of problems: first, what about cases like a "glass of water" where "mostly water" is not "mostly" enough to drink? And, second, why can't we refer to plasma, say — which is 92% water — as water? This is not just a matter of numbers: the dead sea water is much less pure than plasma in the hospital (in terms of percentage H_2O in solution) yet we are authorized to call the former "water" but not the latter. This certainly seems to be a matter of conceptual roles — plasma occupies a certain place in our conceptual systems about blood and medicine (largely because it plays a specific role in biology and medicine) which does not fit the profike of "water", while the stuff in lakes *does* fit that profile, even if the lakes are hypersaline. Blood fits a conceptual ecosystem where we are not tempted to subsume it under the concept *water*, whereas our conceptualization of lakes pulls in the opposite direction — even though by purity the water in Gaet'ale Pond in Ethiopia is apparently not much more watery than blood. Our disposition to either contract or dilate the sense "water" seems to be determined by context — by the conceptual role water plays in different context — rather than by actual hydrological properties.

What about the hypothetical twin-earth XYZ that Putnam imagines is indistinguishable from our H_2O? Well, for this hypoyhsis to even make sense we have to assume that XYZ is scientifically indistinguishable from water, which is a matter not just of pure H_2O but of all solutions and deuterium- or triterium-related variants of water, and so forth. As a thought experiment, where we are free to conceive almost anything, this is not impossible. Let's imagine that there is an undiscovered subatomic particle that on some planets clings to atomic nuclei without affecting them in almost any way. We can call nuclei harboring these particles "twin nuclei", so hydrogen becomes "twin hydrogen", oxygen becomes "twin oxygn", and presumably water becomes "twin water". This twin water would essentilly retrace the the compositional structure of water — since it would have to form (and unform, under electrolysis) just like "our" water. If we plug this "twin water" into Putnam's scnario, I can't see why we don't just call this a variant kind of water, water with some extra (but observationally negligible) particles, just like heavy water is water with extra neutrons.

This does not do perfect justice to "twin earth" discussions, because I am describing "twin" water as something whose composition is almost identical to "our" water. In the original story, "twater" is XYZ, which as written suggests something whose physical constituents are much different than water, even if all propensities that influence our "water" conceptualizations are exactly the same as our water. But something compositionally different than water *can't* be functionally identical to water, at least if any of the actions we can take that reveal water's composition come out different. In short, whatever XYZ are, they must have a capability to *become* hydrogen and oxygen, because XYZ's emulating water means it emits hydrogen and oxygen under electrolysis. Meanwhile there is no action that could "release" the "X" (or whatever) because that would also behaviorally differ from water. So XYZ would differ from water only insofar as in its "unobserved" states it can float around as something without hydrogen or oxygen but, whenever subject to actions that cause water proper to emit these gasses, it would somehow conjure them up in exactly the same patterns as water (which actually *is* composed of hydrogen and oxygen) does.

By dictum, then, XYZ is not actually composed of hydrogen and oxygen, but whatever it *is* composed of can act as *as if* it *does* contain these gasses so as to emit them. In that case I'd question the argumentative force of claiming that XYZ does not contain hydrogen and oxygen to begin with. We are asked to believe that XYZ is made up of some ethereal non-hydrogen and non-oxygen that can nevertheless become hydrogen and oxygen whenever it is in the physical states wherein water that *is* made of hydrogen and oxygen will release them. I am inclined to say that this is just another way of being made of hydrogen and oxygen. After all, atoms are not little ping-pong balls: what we picture as a water molecule is actually apparently much more ethereal, suspended in quantum indeterminacy. I take it there is some Shrödinger equation for a water molecule, and only when the "wave function" collapses — say, by our observing the water subject to electrolysis — do we actually get hydrogen or oxygen atoms. So "our" water isn't really "composed" of hydrogen or oxygen in its pure quantum state. Maybe XYZ "collapses" to hydrogen or oxygen in different ways than earthly water (but with no way to measure the difference), but this is still not divergent enough that for me to feel compelled to call XYZ anything other than some variant form of water.

Of course, I am assuming that twin earthers have *the same* water-concept that we do, *in all respects*. Maybe a more faithful review would consider that twin earthers might have a related but more primitive water-concept than ours — maybe some subset of our concept in terms of the scientific knowledge embedded in our concept. Before we earthers knew about hydrogen, oxygen, or electrolysis, the behavior of water under electrolysis was not a factor in our concept of water. So imagine if twin earthers' level of scientific knowledge was akin to that on earth centuries ago — their XYZ is measurably different from our water, but they have no experimental or scientific apparatus to notice the difference. But this is *contingent*: the twin earthers *could* some day discover hydrogen and oxygen. Then, if XYZ really is not composed of hydrogen and oxygen (or acts as if composed of them when not in a nonobservable ethereal state) their scientific theory of water, and accordingly their conceptualization, would diverge from ours.

We can imagine a non-water XYZ that is water-like enough to play an identical rooe to (our) water, but this story can go in two directions: either XYZ is *absolutely* identical to water, its differences from water so obscure as to be observationally and causally maningless; or it has legitimate differences from water that *could* be conceptually significant but in some context are not (at least not yet). These are two different thought experiments. If some substance is in all respects and under any conceivable science identical to water, yet somehow compositionally different from it, I think the plausible response among normal language communities would be to extend the concept of water — subsuming XYZ under the concept, analogous to heavy water when it was discovered. We are generally prepared to expand the reach of concepts when there is no compelling reason not to do so. Whether a potential expansion takes hold probably varies by context. We are — a point that generally fits on the externalist side of the ledger — more willing to accept expansion when the revised conceptualization would not deviate too far from a basic alignment of natural kind concepts to scientifically reasonable classifications. We can readily extend "water" to D_2O because the two substances are compositionally very similar. We are less likely to accept conceptual mergers when they seem to violate our natural-kind pictures, even if they are functionally plausible: we do not accept "agave" as a subconcept of "honey", even though the two are physically rather similar and functionally very similar. Nor does physical form alone drive conceptual boundaries: we know full well that water vapor and ice are the same stuff as liquid water, but we recognize a conceptual distinction between them.

But these are not hard and fast rules: we may be inclined in many contexts to treat frozen-concentrate juice as conceptually subsumed under "juice" (as in "juice on sale"), and we will often accept almond milk or cashew milk as "milk", despite physical differences which we certainly acknowledge. In short, conceptual boundaries tend to be drawn to honor, albeit without excess granularity, both physical and functional factors — neither physical/compositional similitude alone, in the absent of functionalv resemblance (see water/ice) tends to earn concept dilation, nor vice-versa, but a mixture of functional and physical similarity even with *some* differences in both aspects tend to be likelier drivers of concept-expansion (see water vs. chlorinated water, or red wine vs. white wine). By these rules, expanding "water" to include XYZ — if XYZ is functionaly identical to *but* compositionally different from water — would be abnormal, like expanding "milk" to — without any qualification — include almond milk. But these rules are approximate, and on the idiosyncratic case where XYZ is *completely* functionally like water but (stipulated to be) physically different (though by functional identity we could not detect as much), I think the normal "conceptual dilation" rules would side with the functional identity and ignore the physical differences.

On the other hand, if XYZ has real discoverable differences from water, then the potential exists for twin earthers' concept of water to diverge from our own, even if at any point in time the concepts are identical. The time "points" don't need to be simultaneous: we can compare one country's concept of water in the year 1800 with a different county's in the 16th century. It is plausible that different people at different times have effectively the same conceptual attitudes toward concepts that, with the benefit of hindsight and more science, we know have potential for differentiation. I think the mere potential for differentiation warrants our identifying conceptual differences even if the parties involved are not aware of this potential. I am prepared, for example, to accept that a child's water-concept in our time can be different from a medieval child's water-concept merely by virtue of the modern child potentially learning about deuterium, hypersalinity, and other scientific nuances that complicate the modern conception of water relative to our forebearers.

1.1 *"Divorse or Dilate"? On Widening or Narrowing Concepts*

We certainly accept that people may have different understandings of a concept and, on that basis, may judge that what two people are entertaining are two different concepts — though we may also feel that they entertain two variations of *the same* concepts. There's room for most concepts to "diversify", subsuming subconcepts and variations; hence there's room for a concept to expand (see water to heavy water) without fragmenting. But sometims we *do* insist on splitting concepts — or, eqivalently, refuse to accept a concept-enlargement — and *the reasons for this refusal may be external to some peoples' use of the concepts.* Current political discourse in the United States, for example, is driven by turns of phrase that are rather haphazardly defined: *Border Wall*, *Green New Deal*, *Free Tuition*, etc. Suppose a health policy expert observes that Bernie Sanders's use of the term "Medicare for All" is different from Kamala Harris's. She may conclude that Sanders's concept "Medicare for All" is different from Harris's concept — and the rationale for this conclusion need not take into account whether the two candidates are aware of the differences. Suppose, as an expert, she has to mentally track the differences — she has a well-informed judgment that each of the "Medicare for All" plans have different ramifications due to policy differences; as a result when discussing "Medicare for All" she needs to note in her own mind which version of that idea is under discussion at any moment in a discourse. That is to say, she needs to subsume them under different concepts. Moreover, we endorse that she *should* do so, even if she thereby makes a distinction that the politicans or their supporters themselves do not realize. In this kind of case we may defer to expert opinion when adjudicating a potential conceptual divorce, even if there is only minimal differences in the role of the concepts vis-à-vis the conceptual systems of many relevant parties.

The possibility that "Medicare for All" may play the same *role* in a Sanders supporter's and a Harris supporter's conceptualizations does not preclude our judging that they are nonetheless different concepts — if by virtue of more information and more access to expert counsel we can understand that there are potential differences in their conceptualizations that *could* drive the conceptual roles to diverge. I think this is analogous to a "twin earth XYZ" scenario in that the thought experiment is set up as if we have access to expert confirmation that twin earth's XYZ is not physically the same substance as water. Projecting from earthly practice, we accordingly accept that "externalist" considerations may need to come to bear, and "XYZ" may need to be classifid as a different concept that water *notwithstanding* the lack of any conceptual role difference between XYZ for twin earthers as compared to water for us. This is consistent with our tolerance for including factors beyond just conceptual roles in more mundane circumstances: we accept that sufficiently divergent notions of "Medicare for All" *could* be most appropriately classified as two different concepts. Such is not mandated — we could certainly describe the Sanders and Harris platform as "two different Medicare for All plans", subsuming them under one concept but acknowldging their differences — as token differences, like the conceptual difference between this apple and that apple, rather than concept-differences like apple vs. cherry. Analogously, we *could* subsume XYZ under the concept *water* — XYZ being a kind of water insofar as samples of XYZ (tokens of the XYZ-concept) bear some physical differences to tokens of ordinary water (like heavy-water samples do), but we can handle this variation on a token-token level (analogous to comparing two apples). But we can *also* split rather than expand the conceps — *divorce* rather than *dilate* — making XYZ a different concept than water, just as we can make Sanders supporters' Medicare for All a different concept that Harris supporters'. The key point is that our choice of "divorce or dilate" may be driven by factors wholly external to some concept-bearers' internal concept-uses. Two different concepts — recognized by us as different — may play identical conceptual roles for some people.

This stance is at least minimally Externalist in that I don't insist on internal conceptual-role similitude being an immovable criteria selecting "dilate" over "divorce". We as a language community can and sometimes should override the tendency for concepts to expand under role considerations. As I pointed out earlier, a corkscrew and even a hammer can sometimes satisfy the role "bottle opener" in specific contexts. Usually we distinguish context-specific conceptual role-playing from general concept dilation — I think this is the gist of Zhaohui Luo's analysis of "situations" and "Manifest entries". We can adopt a temporary frame of reference wherein, say, hammers are bottle openers — or in Luo's example (in a single zoo exhibit) all animals are snakes — without mutating the concepts so wildly that "hammers" become expanded to including anything that may open a capped bottle, or "snakes" become all animals. Yet such situational dilations can recur and eventually spill beyond their situational guard rails. In a vegan cafe I can imagine the staff converging on a usage that soy, almond, and cashew milks are collectively called just "milk". If veganism becomes entrenched in some English-speaking community I can similarly imagine that in their dialect "milk" will mean anything that can be used like milk in a culinary context. The warrants for such expansions seem to be driven by conceptual roles — situations present "slots", like *that which opens this bottle* or *that which I pour on cereal*, and existing concepts tend to expand to fit these slots.

These considerations follow the *internalist* line: we take attitudes based on conceptual role more than external natural-kinds when adjudicating conceptual boundaries. Thus situationally we may present almond milk and agave to satisfy a request for milk and honey. But superimposed on such "centrifugal" tendency for concepts to expand into "under-lexified" conceptual niches we have a counter tendency to question conceptual uses where functional resemblance strays *too far* from common sense. Someone may accept agave in lieu of honey, or a hammer as a bottle opener, in the context of how one situation plays out; but they are less likly to accept these uses becoming entrenched, compared to, say, refiguring "milk" to include almond and cashew milk. And our hesitation to accept concept-expansion in these latter kinds of cases seems to implicitly look beyond conceptual roles — we may insist on limiting concept dilations even if there are many people for whom there will never be situations where the differences between concept referents, over and above functional resemblance, would be important. In short, even if a community could do just fine with some dialect idiosyncracy that ignores a conceptual distinction we would ordinarily make, we don't tend to take this as evidence that our multiple concepts can be merged into one more diverse concept.

Of course we *can* merge concepts, and the fact that many people can live their lives without a conceptual coarsening may render such merger likelier, but it seems we evaluate potential mergers more by reference to entire speech-communities, not isolated parts. Note that I am specifically talking here about merging or splitting concepts, not word-senses or lexemes or any purely linguistic artifacts. Certainly we have variegated "water" concepts — salt, tap, distilled, heavy — but we have an overarching water concept that includes these as subconcepts. We can make a conscious decision to modify concept/subconcept relations — which is different from changing how concepts are mappped to lexemes. So I take it that Conceptual Role Semantics prioritizes role factors in drawing concept/subconcept relations and boundaries, and the consequence is a mostly Internalist intuitive model: we should accept concept maps where concepts are mostly drawn together when there is a functional resemblance between their roles: our concept/subconcept renderings should witness and help us exploit functional analogies.

At the same time, however, I think we instinctively project notions of conceptual role outward from individual perople or subcommunities to the social totality. Even if technically distinct Medicare for All plans play similar conceptual roles in different voters' conceptions, we understand that such similarity may break down as we expand the community outward. Sanders and Haris supporters don't live on thier own islands. There are factors outside their own minds that weigh on whether their functionally similar Medicare for All concepts are indeed *the same concept* from the larger communiy's point of view. But these external factors are not necessarily *extramental*: we can zoom outside the conceptual patterns of one subcommunity and argue that conceptual differences appear in the overall speech community that supercede functional resemblance in some subcommunity. Conceptual roles are not solipsistic: the role of the concept Medicare for All for a Sanders supporter is not just a role in *her* mind, but it bcomes a role in *our* minds if we dialogically interact with her.

Insofar as people can make inferences about other peoples' conceptual role "system" — we can figure out the role which a concept plays in somone else's mind, to some approximation, even if analogous concepts play a different role in our own minds — conceptual roles are not private affairs; they have some public manifestation and there is a need for collective reconciliation of role differences, just as we need to identify when different people are using the same words in different ways and use lexical conventions to diminish the chance of confusion. To the extent that they have this public dimension, conceptual roles are not *internal*. But "externalism" in this sense is waranted because we want to look philosophically at entire speech or cognitive communities — it is not automatically a philosophy of conceptual content being external to "mind in general". Conceptual differences that could *potentially* become publicly observable from the vantage point of the *entire* cognitive community warrant consideration for conceptual divorce over dilation — overriding similar roles in some *part* of the community.

In the case of XYZ, insofar as the twin earth cognitive community and our own could *potentially* become part of a single overarching cognitive community, we have potential grounds for drawing comparisons between water and XYZ. Merely by contemplating their planet here on earth we are performatively drawing twin earthers into our cognitive community. By postulating that twin earthers think about XYZ the same way that we think about water — and that we know this — we implicitly assume that their conceptual role patterns are public observables in the context of our own community. If conceptual roles are observable, then there is a concept of a conceptual role: pundits can conceptually analyze how "Medicare for All" plays identical conceptual roles for Sanders and Harris supporters even if the candidates' plans are consequentially different. But this merely says that there are latent differences in two people's conceptual roles that they themselves may not actually experience. The public facet of conceptual roles complicates the notion of conceptual role similarity — two people's patterns of conceptual roles may be observably different as public phenoemena even if they lack resources to realize the difference. Conceptual roles are therefore external to individual minds — but this is by scoping outside individual minds to holistic cognitive communities who can publicly observe our cognitive tendencies. We are still reasoning "internalistically" in the sense of considering cognitive patterns at the scale of an overall cognitive community.

In short, I will take the mantra of an "Externalist" when passing from individual minds and subcommunities to the public nature of conceptual roles and overaching cognitive communities. Once we get to the maximal possible community, however, I am inclined to revert to Internalism: if there is no broadening of communal scope that could make putative external diffrences meaningful to *anyone's* conceptual roles, I see no reason to account for *these* erstwhile externalities in a theory of concepts. If XYZ has *some* not-water-like qualities that a sufficiently large cognitive community could confront — even if XYZ-conceptual-role and earthly-water-conceptual-role is identical for the two isolated communities — I am happy to accept that twin earthers' XYZ-concept is a different concept than earthers' water-concept. Similarly, I accept that Sanders supporters' Medicare for All concept may be a different concept than Harris supporters'. But in both cases I accept concept splitting to ovrride role-similarity because I believe in an overarching cognitive community which has an interest in detecting differences or potential differences in conceptual roles qua public observables, which transcendes our own internal awareness of what our conceptual roles entail. The fact that earthers and twin-earthers might never "discover" a water/XYZ difference is a contingent fact, not an essential structure in policing conceptual maps. When establishing how we should consider redrawing thse maps, we should work from the picture of an overarching comunity — that can subsume isolated communities — as an abstract posit; the parts of the twin earth story that imply earthers and twin earthers could never actually discover their differences are not, I think, compelling as intrinsic features of the analysis. In short, if water and XYZ have some potentially observable differences, then we need to proceed as the community which is aware that these differences exist and that therefore, for us, water and XYZ need different conceptual slots. The only analysis then is how to reconcile the fact that we have multiple conceptual slots whereas twin earthers (and earthers who have not read Hillary Putnam) have just one.

But if we take a *maximal* cognitive community — the sum total of earthers and twin earthers and philosophers — this community *does* distinguish XYZ from water (surrely XYZ plays a different role in Putnam's mind than water). And we should scope to the maximal community when determining whether smaller communities' conceptual roles are truly identical, because conceptual roles are, in part, potential public obervables for any possible supercommunity.

On the other hand, if XYZ is so much like water that *no* community would *ever* have reason to contrast twin-earthers's XYZ-conceptual-role with our water-conceptual-role, then I think these roles are not just *internally* identical for each (twin-) earther, but *publicly* identical for any conceivable cognitive community for whom public observations of (twin-) earthers' conceptualizations are consequential givens. And in *that* case I think XYZ is the same concept as water notwithstanding putative compositional differences.

The whole idea that conceptual roles can be *public* complicates the Internalist/Externalist distinction, because each person's conceptual patterns can be evaluated from a vantage point external to *their* mind but still within the proclivities of a "maximal" cognitive community. Conceptual roles are not private to each person, but are private inclinations that get reshaped, corrected, influenced, or reinterpreted by a larger community. If we understand conceptual roles to include the totality not just of each person's conceptual role attitudes but the totality of how these attituds are observed by others, then we should consider that concepts are not "external" to the *maximal* cognitive comunity. Externalism about *individual* minds can be wrapped inside Internalism at the *maximal* inter-cognitive level.

But, complicating matters further, the maximal community's observations of conceptual-role attitudes is often driven by at least our *beliefs* about external (i.e., extramental, natural-kind) criteria. For example, some companies want to rechristen "corn syrup" as "corn sugar", to make it seem more like a sugar-subconcept. Meanwhile, some dairy companies want laws restricting the use of "milk" for vegan products. In both cases our larger community has a chance to weigh the proper conventions for how our conceptual maps should be drawn. As I argued earlier, both functional and naturalistic criteria play a role in such deliberations. We are poised to distinguish transient situation-specific roles — that one time someone used a hammer as a bottle opener — from functional parallels that stretch across many contexts. Within the parameters of that contrast, we are receptive to redrawing maps on role criteria — allowing milk to subsume vegan milk-substitutes, for instance. But this tendency is balanced by a respect for some notion of coherent natural kinds — the distinct biological properties of vegan milks work against a *maximal* community subsuming them under "milk" outside of special contexts.

Both the Externalist and Internalist points of view have some traffic in the considerations that cognitive communities bring to bear on which conceptual maps should be enorsed by convention. Because ad-hoc conceptual roles can be established for particular situations, we can be conservative about *conventionalizing* concept maps driven by functional correspondancs too far removed from (what we think to be) scintifically endorsed, natural-kind boundaries. In other words, I think we *do* and *should* allow "naturalistic" considerations to be a factor in what concept maps we endorse. But this is not a claim about Externalism as a philosophical paradigm shaping how we should construe the triangulation between mind, world, and language, as a matter of metaphysical ideology. Rather I believe that "externalist" factors should and do come to bear on the deliberations *internal* to cognitive communities' (sometimes but not always explicit) evaluations of how to draw concept and subconcept boundaries and relations — when to split concepts and when to dilate them. Dilate-or-divorce options are pulled by both externalist and internalist considerations, sometimes in competing ways.

As as case-study, the wording "corn sugar" — which implies a "redistricting" wherein the concept "corn syrup" becomes part of the territory "sugar" — may be credible on purely biochemical grounds. But our community may feel that there is enough functional difference between sugar and corn syrup from a commercial and nutritional sense to reject a proposed merger — here functional considerations trump natural-kind ones. Conversely, the community may be sympathetic to claims that milk substitutes should be labeled to clearly indicate how they are are not *literally* milk — here natural-kind considerations trump functional ones.

If we consider language — and communally-endorsed conceptualizations — evolving in practice, then, by light of my claims until here, there is material for both Externalist and Internalist readings. This perhaps leaves room for a theory which accepts that both are partially true — each being logically founded under consideration of two different aspects of how concepts evolve. I will explore this possibility further, but first I want to shore up my account of conceptual roles themselves.

One complication I have glossed so far is that *functional* roles in an enactive and "pragmatic" (in the everyday-world sense) spheres are not *ipso facto* the same as either conceptualizations (conceptual-role-attitudes) or lexicosemantic conventions. These three are interrelated, but we need social and cognitive practices to get situational understandings entrenched in language and in communal concept-maps. Without a theory of this process, to speak of functional roles like *hammer* for *bottle opener* is not a substitute for speaking of conceptual roles *per se*. How to properly link "functionality" in an enactive quotidian sense — the data that various natural and man-made artifacts are used by people for concrete tasks, and we often talk about this — to the cognitive realm of concepts (and their boundaries and subconcept relations)? This is the main theme of Section 2. I will however conclude the present section by reviewing a useful critique of the conventional Externalism/Internalism dialectic. I will focus in on Orlin Vakarelov's "Interface Theory of Meaning", developed over several recent papers, which I will also (somewhat indirectly) use as a kind of metatheoretic guide when presenting my own thoretical attachments later on.

1.2 *Orlin Vakarelov's Interface Theory of Maning*

Vakarelov's theory (which I'll abbreviate to ITM) both critiques and suggests ways around the Externalism/Internalism impasse:

> An externalist theory focuses on constraints outside of the user of the informational state. Particularly, it focuses on the relation between the informational state and the sources or object of the information. The meat of the semantic connection derives from some nomic (or teleonomic) connection between the source system and the information medium (receiver) system. The focus of semantics for an externalist theory is the determination of the way the world is. ... An internalist theory, on the other hand, considers as the primary constraint of meaning what the information state does for the user. The model of the internalist account is not reference fixation and fact determination, but message interpretation. The question that an internalist asks is not *what m means*, but *what m means to a given user*. Of course, for *m* to be informative about the world, it better be sufficiently correlated with a source, but this is not a constitutive condition of the meaning of *m*. It is a condition of a good interpretation system. ... One strategy for reconciling externalism and internalism is to take a hybrid account of meaning/content. Such hybrid theories are motivated by an observation that external or internal considerations are not sufficiently fine grained. ... Such hybrid theories of meaning have targeted cognitive information media — languages, mental states (beliefs), etc. This analysis of meaning cannot easily transfer to the domain of dynamical semantic information. In the case of dynamical semantic information, the externalist and internalist conceptions of meaning collapse into a single notion. The

> reason for this is the codetermination of macrostate structure of informational systems. [94, pp. 13-14]

He then presents his ITM alternative (for terminological clarification, his symbol M roughly matches what I have called "cognitive frames", and S roughly matches our environing situations):

> It follows that neither an external relation between M and S, nor an internal function of "selecting conditional readiness states" is sufficient to provide a general notion of meaning, for they don't even fix the syntax of the information system independently. To specify the meaning of a state m we must do something different. What does M really do in the information system? It acts as an *interface* between the (external) world and the control system. It structures influences to allow focused purposeful control. If any sense of significance can be given to a particular state m of M, it must be related to this interface function. The significance of m is neither that it tracks something external nor that it can affect the control mechanisms of the system, but that it can connect one to the other. ... Let us go back to the observation that the definition collapses the external and internal conception of meaning. Specifying the differential interface function of a state requires looking at the entire system/environment complex. We can think of the datum state m as participating in a process of interaction where causal effects from the environment are channeled through the internal M-P control pathway to produce actions, which actions modify the system's behavior, and which in turn changes the state of the environment (including the relations between the system and other external systems). [94, pp. 15-16]

Finally he extends this definition of *meaning* toward language itself:

> The story gets more interesting when ... the system utilizes different sub-systems that act as information media. The system may have [different] media, each with different roles and interface connections. Some media may be connected to different external systems or different aspects of the same systems, others may interface with other media, yet others may be connected with effectors or control the states of other media, etc. When the system is organized as a complex network of information media, complex interface (sub-)functions can emerge. Some can depend almost exclusively on external connections to outside sources, others can be analyzed entirely in terms of their control role or effects on other media. I conjecture that the canonical examples of information media that shape many of our intuitions about semantics are media that exist (within an information system) as only one of a large network of other information media that jointly control the system's behavior. Thus, to take correspondence theories of meaning as an example, it is tempting to say that the word 'chair' means a property of external objects. Thus, in the expression, "This is a chair", the meaning is given by some fact in the world that the object depicted by the indexical has the property of chairhood. In an information system using language we can analyze this idea in a different way. The language medium, whose datum may be some structural equivalent to the expression "This is a chair", interacts with other nonlinguistic media connected to perception, allowing the system to identify and interact with patterns in the world that can be clustered through some data state of some internal media. To make Fodor happy, we can assume that there is a single medium that gets in an information state uniquely correlated with chairhood — a kind of a concept of "chair". The language system, in this picture, is not interfaced with the world (or some abstract realm of propositions). It is interfaced with other information media. The properties of the interface relations look a lot like the properties that a correspondence semantics may have, but these interface relations do not capture the true interface roles of the language datums for the information system. To determine the true interface role, we need to link all local interfaces and see how the entire complex participates in the purposeful behavior. [94, p. 17]

Interestingly, Vakarelov speaks not of "prelinguistic" cognition but of "precognitive" systems. This is partly, I belive, because Vakarelov wants to understand cognition as adaptation: "Nature, in its nomic patterns, offers many opportunities for data systems that can be given semantic significance, it offers ubiquitous potential datums, but it does not offer any well-defined and complete data sets" [94, p. 4]. As I read it, Vakarelov conceives cognitive systems as dynamic systems that try to adapt to other dynamic systems — these latter being the environments where we (taking humans as example cognitive systems) need to act purposefully and intelligently. The "nomic patterns" are latent in our surroundings, and not created by intellect. So *this* kind of worldly order lies "outside" cognition in an ontological sense; it is not an order which exists (in itself) in our minds (though it may be mirrored there). Consciousness comports to an "extramentally" ordered world. However, "precognitive" does not necessarily mean "extramental": there is a difference between being *aware* of structural regularities in our environment, which we can perhaps deem a form of pre-cognitive mentality, and trying to *interpret* these regularities for practical benefit (and maybe a subjective desire for knowledge).

When distinguishing "cognitive" from "precognitive", however, we should also recognize the different connotations that the term "cognitive" itself has in diffrent academic communities. In the context of Cognitive Linguistics, the term takes on an interpretive and phenomenological dimension which carries noticeably different implications in the "semantics of the theory" than in, say, conventional AI research. Vakarelov's strategy is to approach *human* cognition as one manifstation of structured systems which we can visualize as concentric circle, each ring implying greater sophistication and more rigorous criteriology than its outer neighbor:

> What is the function of cognition? By answering this question it becomes possible to investigate what are the simplest cognitive systems. It addresses the question by treating cognition as a solution to a design problem. It defines a nested sequence of design problems: (1) How can a system persist? (2) How can a system affect its environment to improve its persistence? (3) How can a system utilize better information from the environment to select better actions? And, (4) How can a system reduce its inherent informational limitations to achieve more successful behavior? This provides a corresponding nested sequence of system classes: (1) autonomous systems, (2) (re)active autonomous systems, (3) informationally controlled autonomous systems (autonomous agents), and (4) cognitive systems. [95, p. 83]
>
> The most rudimentary design problem begins here: if there is cognition, there must be a system. Without a condition allowing a system to exist as an entity discernible from its environment and persisting sufficiently long as that same entity to allow qualification of its dynamical behavior, the question of cognition does not arise. The first design question that must be examined is: What allows systems to persist as individual entities? More specifically: For which of those systems that persist is a capacity of cognition relevant? [95, p. 85]

But this intuition that human cognition can thematically extend out to other "cognitive systems" and then other structured systems — out of which *cognition* emerges by adding on criteria: is the system autonomous; reactive; information-controlled — suggests we are dealing with a different concept than in Cognitive Linguistics or Cognitive Phenomenology. For Vakarelov, "cognition, like most other biological categories, defines a gradation, not a precise boundary — thus, we can at best hope to define a direction of gradation of a capacity and a class of systems for which the capacity is relevant; [and] cognition is an operational capacity, that is, it is a condition on mechanisms of the system, not merely on the behavior of the system — to say that a system is cognitive is to say something general about how the system does something, not only what it does" (p. 85). Conversely, the qualities that make "grammar", say, "Cognitive" seem uniquely human: our sociality in the complexity of social arrangements and cultural transmission; our "theory of other minds". Certainly animals can have society, culture, and emapthy, but the human mind evidently takes these to a qualitatively higher level, making language *qua* cognitive system possible.

This argument does not challenge Vakarelov's programme directly, but perhaps it shifts the emphasis. Our cognition may be only one example of cognitive systems — which in turn are examples of more general autonomous/reactive/information-controlled systems — but there may still be distinct phenomenological and existential qualities to how *we* achieve cognition, certainly including human language. I think there are several distinct features we can identify with respect to *human* "cognitive frames", which call for a distinct pattern of analysis compared to generic "M" systems, in Vakarelov's terms.

I'll mention the following:

Multi-Scale Situationality We understand situations as immediate contexts for our thoughts and actions, but we also recognize situations as parts of larger contxts, and connected to each other in chains stretching into past and future. For example, as a train pulls into a subway station, our immediate situation may be needing to determine if this is the train we need to board. But this is linked to the larger situation of traveling to our destination; and situations are strung together as enactive episodes: once I determine which is the correct train, I need to enact the process of boarding and getting comfortable on the train, then get ready to reverse the process and disembark at my station. All of this inter-situational orchestration can be planned and facilitated, to the degree that multiple people are involved, through language.

Conversational Frames Our *cognitive* frames modeling situations and our immediate environments include models of ongoing *conversations*. I think this is an example of what Vakarelov calls "sub-systems": within our intellectual "systems" that track outside reality, there is a part that specifically tracks what people are saying — so that we can take note of what they believe, how they are using different words, what they consider or would deem relevant to the current topic (or situation) — all of which helps us use language to reason through situations intersubjectively. I will discuss the architecture of conversation frames more in Section 3.

Conceptual Roles We have, I believe, a unique ability to fuse perceptual and conceptual detail in understanding situations. That is, we identify objects perceptually while also placing them in a contextual matrix, where functional properties may be foregrounded above directly perceptual ones. If, say, we hear someone ask for a glass of water and see someone else hand her one, we understand the glass not only through its sensate qualities — or even through our pragmatic/operational interpretations, like believing that the solidity of the glass prevents the water from leaking out — but we also intrpret people's practical intensions and mental attitudes. We infer that the first person was thirsty and the second cooperated by providing her with water to quench her thirst. Interpreting the situation at that interpersonal level, not just at a sensory/perceptual or a force-dynamic level, enables us to understand situational variations, like responding to requests for a *glass* of water by bringing a *bottle*.

In short, to undrstand *how* our cognitive frames align with environing patterns we have to understand the role language plays in this process: a role which can be intersubjective, empathic, context-sensitive, defined by conceptual substitutions and interpersonal cues as much as by rigid rules.

And yet, I think Vakarelov's larger point remains in force: we need to get beyond both Externalism and Internalism in the sense that we need to get beyond a debate as to whether *words* have "intramental" or "extramental" *meanings*. For instance, we need to think past an apparent choice between deciding that the word "water" has a *meaning* which is either intramental (determined by the sum of each person's beliefs and dispositions about water) or extramental (determined by how our water-experiences are structured, even beyond our knowldge, by the physical nature of water). In place of either option, we should say that the meaning of the word *water* — or *chair*, in Vakarelov's example — depends on all the cognitive systems interacting with linguistic understanding. The word or concept does not exist in our "language-processing system" in isolation; so its meaningis not just *linguistic* meaning but how word-tokens and concept-instances become passed from system to system.

Insofar as we have a token of the word *water* — presumably tied to a concept-instance — the specific fact of our hearing the word is joined in with a plethora of other perceptual and rational events. Say, we hear someone ask for water, and soon after see someone bring her a glass. We instinctively connect our perceptual apprehension of the glass of water with the word heard spoken before, and we presumably remain vaguely aware of the situation as things unfold — if we see her drink from the glass, we connect this to our memory of her asking for water, indicating thirst, and then getting a glass in response. We do not need to track these affairs very attentively — it's not like we should or need to stare at her intently while she drinks — but it fades into the background rationality that we tend to attribute to day-to-day affairs. Her glass of water — how it continues to serve a useful purpose, how she and maybe others interact withbit — becomes a stable if rather mundane part of our current situation.

In Vakarelov's words,

> To determine whether a particular macro-state of S is informationally relevant, i.e. whether it is differentially significant for the purposeful behavior of the system, we must trace the dynamical trajectories of the system and determine ... whether the microstate variation within the macro-states is insignificant for the purposeful behavior.... Let us call such macro-states *informationally stable*. [94, p. 15]

An intrinsic dimension of situational models, surely, is that they recognize the relatively stable patterns of situations: a glass placed on a table will typically remain there until someone moves it. Situations are, in this sense, large compilations of distinct quanta of relative stability: in a dining context, every glass or plate or knife, every chair or table, every seated person, is an island of relative stability, whose state will change gradually if at all. So a large part of our cognitive processing can be seen as recognizing and tracking these stabilities. Stability is the underlying medium through which situational models are formed.

Utlimately, many cognitive systems contribute to such models: quanta of stability lie in the cross-hairs of multiple cognitive modalities. So we connect the water spoken about to water in a glass. If we have our own glass we connect both the linguistic and visual content to the tactile feel of the glass and the kinaesthetic intentionality exercised as we pick it up. We can imagine concepts like *this water* pinging between these various cognitive registers.

I take Vakerlov's ITM model (or metatheory, maybe) as saying that we should look at *meaning* through the interstices between systems, not as some semiotic accounting summed up either "inside" or "outside" the mind. The meaning of a broad concept like *water* is subsidiary to the meaning of more context-bound concepts like *glasss of water*, *body of water*, *running water*: and to excavate conceptual meanings in these situationally anchored cognitions we need to think through the *conceptual roles* we instinctively pin onto the concept-exemplified: whether manifest as an element of language or perception/enaction, or both.

2 Conceptual Space Theory and the Interface Theory of Meaning

The phraseology that language is an "interface" — to some (at least partly) prelinguistic cognitive faculties — is inspired by Vakarelov's "interface theory of meaning", which I described at the end of Section 1. Here I want to explore something like an ITM as an extension to (or perhaps a foundation for) older language-philosophy paradigms, like Cognitive Grammar and Conceptual Role Semantics. I'll spend this section forecasting how that might work.

Conceptual Space Theory, on the other hand, originates with Peter Gärdenfors's books and articles — especially 2000's *Conceptual Spaces: The Geometry of Thought* — but has branched from linguistics to disciplines like computer science and the Philosophy of Science. Conceptual Space Theory emerges from Cognitive Linguistics, and therefore resists simple AI paradigms of language following essentially mechanical rules, or logically decoding and processing symbols. But at the same time, Gärdenfors argues that we can find some *quantitative* structure in conceptual structures — including identifying axes of variation where notions of prototype and exemplars can be formally modeled; and representing perceptual and spatial features through numeric measures, like the color double-pyramid (which grounds the Hue, Saturation, Value color space widely used for computer graphics).

To the extent that perceptual and spatial features can be quantified, it is easy to develop intuitions for prototype theories and conceptual similarity: for example, an exemplary *red tablecloth* would have a certain almost-red hue and rectangular dimensions. Varying the color or making the shape too large or small, or oblong, corresponds to moving from the "prototypical" space of the concept to borderline cases. These examples are appealing because they suggest that conceptual dispositions can be systematically modeled; the behind-the-scenes mental gears that classify something as *tablecloth* or *knife* seem to have some scientifically tractable lawfulness, not just a cognitive black box that linguistics takes for granted.

As I see it, the challenge for Conceptual Space Theory is how to generalize outside the intuitively trenchant but rather narrow examples of conceptual "quantification", like color and shape, to model the full range of details — including functional and conceptual roles as well as perceptual form — which influence conceptualization. After all, while there *are* spatial differences between a *tablecloth*, *placemat*, and *ribbon* — or between a *knife*, *sword*, and *cleaver* — these represent different *concepts* because the objects serve different enactive ends. Their various spatial morphologies are byproducts of practical design, and do not *cause* differences in conceptualization, although it is often via spatial form that we *recognize* an object as a knife, etc. Integrating Conceptual Spaces into a multifaceted *cognitive* linguistics would seem to call for examining Conceptual Spaces not just as vehicles for *object recognition* but within the spectrum of interpersonal, enactive, and situational understanding that lies behind linguistic signification and performance.

Research in the overall context of Conceptual Space Theory has, however, examined these more situational and functional dimensions. There are several tactics for cashing the basic "Geometry of Thought" metaphor outside the obvious geometric model of, say, prototypical tablecloths having prototypical rectangular dimensions.

One option is to consider conceptual "space" as encompassing enactive dimensions as well as spatial/perceptual ones. We can do certain familiar things with tablecloths: place them over a table, fold them, launder them; and with knives: place them on a table, sharpen them, wash them under running water, use them to cut food. The more that two objects share a similar set of affordances, the more that they are likely to be conceptually similar. As such, conceptual *roles* can substitute for "metrizable" dimensions (like color and shape, which can be directly quantified in a distance space) as a ground for modeling similarity and prototypicality.

Another idea is to consider the kind of (canonically perceptual) attributes which via Conceptual Spacs we can analyze quantitatively as *triggers* to more multi-faceted cognitive activity. When we see an object which *looks* like a prototypical knife or tablecloth, this spurs further conceptualizations — and/or enactive engagement with the object — that thematize the object more functionally and situationally. The perceptual triggers then need to be analyzed as part of the overall cognitive process. In that case the "geometric" space where concepts can be situated represents not so much the definitive cognitive stature of the object, but a *provisional* conceptualization which unfolds into more complex (and less directly perceptual) machinations.

This latter model actually integrates well with Vakarelov's ITM: as I already argued in Section 1, language is best viewed as an integration of multiple cognitive subsystems. One such subsystem, which acts like a perceptual-cognitive interface, maybe well-served by a Conceptual Space model that stays close to Gärdenfors's original geometric metaphor. Other subsystems, engaged more with the list of affordances embodied in a concept (and, concretely, in its tokens) needs to be modeled with a more abstract/functional kind of "space".

Given this possibility, I believe that the systematizing gambits of ITM and Conceptual Space Theory can be integrated. In this section I will argue that formal attempts to implement Conceptual Spaces in computational settings are consistent with the ITM architecture. This does not mean, however, that a Conceptual Space/ITM hybrid can be unproblemmatically lifted to a computational model for human cognition. The idea that our overall cognition *integrates* many subsystems means that a computational theory of any one subsystem is not necessarily a step toward genuine AI. It may be that there is something salienty human about how we *integrate* the totality of our cognitive dispositions into socialized, context-sensitive, empathic behaviors.

So in this section I will generally approach efforts to *operationalize* Conceptual Spaces — and look back to Vakarelov's paradigm as well — with a mixture of critique and endoresement. In general I think that these thories are useful models — or at least useful starting-points — for understanding components within cognitive systems which are *locally* structured and formalizable. This does not mean I endorse a *holisitic* picture of human cognition as simplistically computational or simulatable. In any kind of "interface theory", there is an implicit distinction between *local* analysis and *global* systematic qualities. An interface is, canonically, poised between two other structures: it can be analyzed internally through the lens of its own structures — how it effects translations and routing between the structures of other systems which the interface interconnects — but this "local" analysis does not address how local structures fit into the "semantics" of the whole.

The "semantics of the whole" is often where science gives way to Philosophy of Science — or even to Phenomenology. The "local" language of chemistry, for example, principally describes phenomena at the molecular level, like chemical bonds and intermolecular forces. Analogously, the local language of biology describes phenomena at the cellular level, like compounds diffusing in the blood stream. The chemistry-scale phenomena may provide causal-explanatory grounds for the biological — chemical properties of blood and alchohol, for example, dictate how alchohol enters the blood stream. But we need a holistic integration to perceive this at a higher level, as an empirical phenomenon affecting the organism as a whole: alchohol enters the bloodsteam and can impair our normal cognitive functioning, even causing harm if consumed at toxic levels. We need the everyday concepts and language — e.g., describing someone as *drunk* or *posioned* — to orient the biological and chemical languages to empirical reality. Biology and chemistry are not abstract systems; they are intended to explain phenomena in the world, but *which* phenomena they are explaining is not something captured "locally" in either biological or chemical language.

To the degree, then, that we can ("metascientifically") analyze the interaction between biological and chemical laws/properties as an *interface*, an "interface theory" of this relationship — of biology supervening on chemistry, for instance, goes hand-in-hand with a *holistic* theory of the worldly phenomena which biology and chemistry (and their interaction/reuction) explain. The interface theory is not a self-contained explanation, but a *local* analysis which needs an overarching holistic picture to cement its explanatory value.

I believe this biology/chemistry case is a good metaphor for cognitive science in relation to Cognitive Linguistics and to phenomnology. We can theorize various cognitive subsystems, analogous to chemistry and biology — suppose we take both perceptual and affordance-based Conceptual Space models, Vakarelov's M and S subsystems, and the proto-computational frameworks like *feature vectors* or *expectations* developed in a Conceptual Space framework as I will mention below — so these thories become analogs in the explanation of human *mind* to chemistry and biology in explanations of the human *body*. But these are still local analyses, and we need an overarching account of how different cognitive subsystems "interface together" to yield, as an emergent totality, what we experience as human mind and consciousness.

Ultimately, I believe this holistic picture needs to be developed at a philosophical level, rooted in fields like phenomenology and Cognitive Grammar. This means that these fields should recognize the formal merit of scientific — even computational — analyses of *aspects* of cognition while arguing against reductive theories of cognition and consciousness as a holistic reality. In the absense of a phenomenological paradigm which is willing to both engage and transcend subsystem analyses, our *holistic* picture of mind tends to be dominated by AI and logical or computational reductionism. That's a subject for the next section; my goal here is to look at Conceptual Space theory as a useful but partial "subsystem" theory.

2.1 ***Conceptual Space Theory and Phenomenology***

Towards the end of Section 1 I noted the contrast between how the word "cognitive" itself seems to do different "theoretical work" in Cognitive Linguistics compared to, say, AI research. I also argued that the differences are not necessarily irreconcilable: while humans are not the only cognitive system, there is a distinctly human way of *being* a cognitive system. Analogously, while humans are not the only communicative species — actually, we are not the only *linguistic* species; it seems counter-productive not call bird sounds or cetacean and primate vocalizations as a kind of language — there is however a distinctly human way of *being* linguistic. Not all language is *human* language; but language which *is* human absorbs the specificity of human sociality and consciousness into its signifying processes. It is on *that* level, I would argue, that we should read the "cognition" in Cognitive Grammar, Cognitive Linguistics, or

Cognitive Phenomenology.

Taking Langacker's Cognitive Grammar as canonical, I think scholars in that tradition would agree that we instinctively reach for cognitive frames to interpret linguistically-encoded situations. Research can uncover structural features of linguistic understanding by identifying frequent structural primitives of these frames: consider the landmark-trajector structure in (20), the force-dynamic contrast in (21) vs. (22) and (23) vs. (24), and the spatial/geometric variations in (25)-(27):

- (20) Our house is across the lake.
- (21) I poured wine from a decanter.
- (22) Some wine spilled from the decanter.
- (23) I put spackle on the wall with a knife.
- (24) Paint spattered all over the wall after a can droppped.
- (25) There's a purple-and-blue color pattern all over the wall.
- (26) There are drawings all over the wall.
- (27) There's a plastic sheet all over the wall.

There are underlying perceptual gestalts which seem apparent in these examples, and their linguistic expression seems to take these as cognitive-perceptual primitives rather than grist for analysis (compare to a case like wanting the Leafs to win, when asked about the Jets (??, above)). This is consistent with the phenomenological intuition that consciousness includes a primordial structural awareness, and the role of intellect and attention is to focus on local regions of the whole structural cloth of experience, for enactive deliberateness and/or information extraction at a level of precision that "raw" experience cannot provide. The important phenomenological contrast is not between "sense data", on the one hand, and intellectually filtered or reified world-apprehension, on the other; but rather between a structured cognitive-perceptual complex which we feel as *ambient* experience and, within that, an actively thematized attentional focal-region that we experience ourselves to be forcefully studying and interacting with.

For phenomenology, then, ambient "background experience" is already richly structured and is not really "pre-cognitive", because its structure evinces the "grammar" of cognitive frames. On the other hand, there are other intellectual traditions where "cognitive" carries more of a rational-analytic overtone. I suspect those who identify as Cognitive Linguists understand the word in a more phenomenological mien, whereas the AI and formal logic community places greater emphasis on how cognitive *systems* may be formally tractable. This can yield confusion in linguistics proper, where AI (at least in the sense of Natural Language Processing) and Cognitive Linguistics co-exist. One solution is to qualify "cognitive" in contexts where confusion could arise, e.g. "cognitive-perceptual" as a more phenomenological sense and "cognitive-analytic" as a more computational sense.

Not, however, that the re-occurance of "cognitive" in both terms is accidental: as suggested by the terminological pattern, I think we should see "cognitive-perceptual" and "cognitive-analytic" as part of a spectrum whose "axis" represents attention and dispositional structurality. That is to say, on the more cognitive-percepetual side we may be aware of structural details (cf. Vakarelov's "nomic patterns") but do not consciously attend to them, such that they remain latent as the manner of disclosure of sensate content: for example, the way in which a certain car appears as red is to appear as a metallic red hue with a glinting lighter patch following the length of the car. This perceptual complex has geometric structure — it is not an undifferentiated red-sensation — but I comport to such content specificity in a passive manner. Towards the other (cognitive-analytic) end of the spectrum, I deliberately seek out awareness of structural forms, analyzing them in relation to schemas and prototypes (consider a rock-climber planning how to scale a wall). Within this spectrum I think there are continuous gradations; and such a picture seems more phenomenologicaly well-motivated than a cognitive/pre-cognitive duality.

Concepts qua cognitive tools are influential across this spectrum. An architect analyzing the facade of a historic builing will experience its structure in greater detail and attention than a bystander who's meeting a friend in front of the building. The concept "facade" will nonetheless shape how both people make sense of their surroundings. The bystander may have a more passive acknowledgment that she is before the facade, compared to the architect (but it will nonetheless be part of her relatively deliberate attempt to coordinate with her friend's expectation that they meet in front of the building). Moreover, a child who had not yet learned the word "facade" would see the characteristics of buildings' exterior that fall under the concept, but more passively still. Merely learning the word presumably alters our perception of exteriors qua facades vs. "ordinary" exteriors, even if we are not currently using the word in any conversation — just as the word "hail" sharpens our perception to how hail differs from snow, since we have a compilations of beliefs specific to *hail* (apart from *snow*), and thinking (even if passively) that some precipitation is the former, not the latter, triggers us to activate those hail-specific beliefs. Another analogous case would be identifying milk as actually almond milk, or water as actually salt-water: the more granular our inventory of lexicalized concepts, the more precise becomes the package of prior knowledge we instinctively make on hand in the current situation.

Insofar as knowledge of the word reinforces the concept, we can assume the concept and our disposition to name it lexically is latent in situations where the concept *may* be relevant. Thus the friend might comment on the facade once they have met in front of the building: making explicit something that hitherto the parties, we assume, had just passively noticed. This is an example of the kind of unstated assumptions about others' beliefs that lie beneath explicit linguistic content: "I love this building's facade" presuposses both that the hearer sees the facade and understands the concept.

I use the "facade" example stratgically, to reference Martin Raubal's analysis of this word via Conceptual Space Theory [71]. Raubal proposes a "conceptual vector space" to distinguish *facades* from other spatial arrangements that (for instance) we might encounter outdoors in an urban setting. His apparent goal is to quantitatively model the terrain of "facade" in contrast to other, lexically related words, which would yield a basically mechanical, computationally tractable account of how to recognize a facade — perhaps for programming a robot, or a navigation tool for people, as he proposes.

Such potential applications trade on the possibility that we can reach beneath the nuance of language and uncover logically straightforward encodings of, or critriology for, concepts — not unlike my earlier idea of a genetic/vinological "CF" for "Cabernet Franc". Obviously, finding a logical matrix beneath the surface fluidity of language is an essential first step toward legitimate Natural Language Processing.

But trying to map an everyday (e.g., non-technical) concept to a readily-enumerated "feature vector" is not without problems, I think. Conceptual Space Theory is not the same as a prototype-based semantics, but it could share some of its problems when dealing with shape-shifting everyday concepts; the likes of *house* or *restaurant* or *water*. A prototype (or feature-vector) theory of *house* would need to unify mansions with hovels but exclude hotels, tents, apartments, apartment-buildings, and historical estates that have become museums. The criteria for "house" and "restaurant" seem mostly functional, although we are still aware in English of a conceptual incongruity in extending the concept on purely functional terms. We can acceptably use "house", really, for any place of residence — and restaurant for anywhere to buy prepared meals:

- (28) I'm going to a party at my brother's house (suppose he actually lives in an apartment).
- (29) This restaurant has the best Hokkien noodles (said of a stall in a Chinatown food court).

These feel (at least to my ears) like idiomatic expressions, however, as if we know not to casually overstretch the concepts. As I proposed earlier, our criteria for concept-mappings seems to be *mostly* functional but to incorporate spatial, configurational, visual, and natural-kind features also as *secondary* criteria. I would argue that a Conceptual Space model intuitively grounded on these latter features would supplement, rather than displace, a Conceptual Role theory (Conceptual Space Theory does account for functional roles, but arguably a little awkwardly).[2]

But setting this objection aside, we can defer to Raubal's analysis to the effect that a "conceptual vector space" can model our disposition to actively or passively identify concept-instances as such. Standing before a building, the proper synergy between properties of a a facade and my own mental "vector" of the colors, spatial arrangements, patterns, and so forth iconifying the idea

[2] For instance, Raubal says that "Meanings of concepts change over time and depending on the context in which they are used. In a conceptual vector space it is possible to account for these changes by adding or deleting quality dimensions and by assigning different saliencies (as weights) to the existing dimensions" [71, p. 5]. For sure, our readiness to (continuing my example) accept "house" for any place of residence varies with context: the idiomatic usage in (28) is less proper in the contxt of real estate transactions, or assessing property tax (an available apartment should not be called a "house for sale"). But while "assigning different saliencies" may capture the relative weight of functional vs. more prototype-based classifications, attempts to quantify functional dimensions themselves as if they were, say, colors and spatial geometries — which do have convincing quantitative models (e.g. "red" on an HSV color pyramid) — strike me as forced and unpersuasive.

"facade" — if the synergy resonates enough — primes me to know instinctively that the exterior is a facade, a pasive belief which could potentially be "activated" should that become relevant. One way this could happen is if a conversation partner says something about "this facade" — entering that referent in the "ledger" of dialogically salient things and topics.

So the efficacy of the concept lies not just in the reality available for us to peceive, nor in our minds, but in a synergy between reality-structures and activatable conceptual models. This kind of partial-but-not-total externalism is perhaps roughly what Vakarelov considers to be "precognitive": the phenomenon of our perceiving an exterior as a "facade" depends on both mental and extramental factors. Gärdenfors Conceptual Space Theory can be seen in this context as an attempt to imagine an "abstract geometry" to quantify (or to suggestively intimate the possibility of quantifying) the world-to-word fit that predetermines (and is witnessed by) well-founded conceptualizations. Gärdenfors's "geometry of thought" can accordingly be seen as an attempt to capture via quantitative intuition an insight Vakarelov's ITM broaches qualitatively: the idea that cognition is a structural *correlation* between the reality out there and what we're equipped to conceptualize.

Perhaps, then, Conceptual Space Theory is (or can be applied for) one example of a Vakarelov-style ITM. Raubal proposes conceptual vector spaces not just as theoretical explanantia but as technological artifacts; he envisions software employing these vectors as assistive technologies capable of some natural-language understanding. A computational system which properly activated the "facade" concept, let's say, given sufficiently proximate feature-vectors, would perhaps exemplify Vakarelov's idea of an "information system" that resembles human cognition, to some functional degree. The fact that such-and-such an environmental given resembles (in the conceptual-space-vector metric) a prototypical facade, or falls in the facade "region" (in a high-dimesnional concept-vector space), acts as a kind of input or signal. For Vakarelov, such quasi-cognitive (or actually cognitive, like the human mind) systems are organized in layers; it is consistent with his subsystem model to say that concept-vector metrics would be recognized by one subsystem, as "effectors", generating signals to be received by other subsystems. One such signal would be, say, a passive awareness that — based on distances in some feature vector — we are now standing before the facade of a building.

Another computational strategy for Conceptual Space Theory is suggested by Kenneth Holmqvist's chapter on "conceptual engineering" (mentioned by Raubal's paper I've cited, but also noteworthy as an unusual attempt to apply computational methods to Cognitive Linguistics). Whereas Raubal skirts around functional-role issues, Holmqvist acknowledges that functionality can be the decisive factor in conceptual frames. He cites the example of a knife, which can on the one hand be prototyped spatially and mereologically (e.g., the relative sizes of blade and handle and the knife's status as the sum of those parts), but also functionally — "Take the lexical unit *knife* as an example ... *blade* and *handle* are clearly parts of *knife* [which also] has *silverware* as a *whole*: *knife* is one of the parts in collections making up silverware. But *knife* can also have *cut* as a whole, because *knife* can be the agent ... of the cutting process" [38, p. 155]. As is clear, Holmqvist adopts mereology as a very broad domain of relations, representing different functional and aggregative connections as special cases of part/wholeness. But more significant is that Holmqvist (given this generality) is prepared to model a broad range of relationships — even if these can in principle be expressed mereologically (like a knife as part of a silverware set), we are not restricted to only visual or physical partonomies.

The parts of Holmqvist's analyses that are more perceptually grounded are also the more prototype-like. He comments, for instance, that "saying ... *blade* is part of *knife* is not sufficient. We must characterize this part-whole relation closer. For instance, the relative sizes of the blade and knife must not deviate outside certain limits. The relative spatial position of the blade and knife must also be correct, i.e., the blade must be correctly attached". This implies that the criteria for classifying something as a knife can be quantified, and regions on certain peceptual axes — say, the shape, length, and position of the handle and the blade — carve out (no pun intended) the conceptual space of *knife* from peer concepts like *sword*, *cleaver*, and *spatula*. Certainly such clusters of related lexemes suggest conceptual "terrains" that can be "mapped" — as in my earlier discussion of concept-mapping for water and milk — and Conceptual Space Theory draws on our intuition that such mappings are particularly elegant when there is a readily quantifiable system of dimensions that can be identified, like blade-length distinguishing knives from swords. Again, however, functional pragmatics, more than spatial form in itself, seems to dictate when and how we identify concept-instances with their concepts.

Holmqvist however recognizes this possibility by talking not only of perceptual part/wholes (like blade/knife) but of mereologies with more functional inflection, like a knife in a silverware set or as part of "cut" insofar as "cutting" something can be a perceptual-operational gestalt, whose "parts" are both the agent and patient of cutting. These more abstract mereologies find linguistic expression in cases like:

- (30) He had to cut the crusty bread with a serrated knife.
- (31) The museum had antique butter knives with intricate carvings.

The implied situational picture in each case is structured, in part, mereologically: a museum-piece knife potentially part of a valuable cutlery set; and when slicing bread with a serrated knife the knife is part of an enactive process. However, I'd say the functional position of the knives in these various situations is the key detail, over and above the partonomic significance of situational wholes. A butter knife rests in a different niche in culinary situations than a bread knife. Their roles are however similar enough that we can subsume them under a common knife-concept, although we can likewise distinguish them, *bread*-knife and *butter*-knife forming two sub-concepts.

We should highlight the functional roles because these dispose us to recognize the concept and the subconcepts. We reach for a butter knife if we want to butter bread; it is that practical goal which primes us to see the butter knife as a knife, in general, and a butter knife, in particular. Insofar as there is a synergy between our mind and our environment, manifest in the adequacy of concepts like "butter knife", this is primarily a matter of — in this case — the object conceptualized as a butter knife being suited for that task. Of course, part of the reason *why* it is so suited is how it is shaped and manufactured. Geometric and physical details are therefore relevant for our inclination to identify (butter) knives. Mostly, however, these details are derivative on functional roles, rather than the preeminent criteria of conceptualizations.

Having said that, an unused butter knife is still a butter knife. Table settings include butter knives so we can conveniently reach for one as needed. Our appreciation that we *might* need a butter knife, or how *some* diners might need one, and how they are used, informs our conceptualizing dispositions. It is true that perceptual details like color and shape provide visual cues to the nature of objects — partly because they need the design and material composition they have to perform their intended purpose. But we don't just troll sense-data looking for cues; our perceptual awareness is not a matter of decontextualized equations like "shiny and sharp means *knife*", "liquid and clear means *water*", etc. Our receptivity to concept-instances depends on our awareness of current situations. It's not like we are prepared to see examples of every kind of object that we are familiar with in every situation. We anticipate finding butter knives on a dining table, or in a kitchen. Situational awareness brings with it a selective anticipation — knowing what kinds of objects are likely to be associated with each situation prevents our having to devote excess thought to identifying objects, or misidentifying similar-looking ones.

So even if we accept features like color and shape as "triggers" for concept-recognition, our receptivity to these triggers is conditioned by situational understanding — which is an example of cognitive frames. These frames, moreover, are defined in terms of functional roles: the salient characteristic of a bread knife is the fact that it can cut bread, and the salient characteristic of a butter knife is the fact that it can spread butter. The situation provides the conceptual slots that objects can fit into.

There is, notwithstaning my suggestions to this point, a version of prototype theory which *is* broadly applicable. Situational understanding, we can say, *does* proceed from *situational* prototypes, so here is a domain where prototype theories are appropriate. Instead of a prototypical *knife* (or house, restaurant, corkscrew, etc.), I think we have *prototypical situations* where knives (etc.) play a role. Any particular knife is conceptualized against such a background: one kind of scenario is someone at the head of the table ceremonially carving a roast, wherein the knife is a "carving knife"; another scenario is someone spreading butter, wherein it is a "butter knife"; etc. Each situation-prototype is an architecture of roles, where for instance there is a person enacting the carving ritual, the instrument she uses, the food being carved, and so on. The building-blocks of these architectures then become solicited within language, for instance via case-markers like benefactive, locative, patientive: "carving *the turkey* for *grandma* with *the knife* at *the counter*".

In practice, our sensitivity to functional roles allows for ad-hoc practical configurations, like using a hammer as a bottle-opener. To the degree that situation-prototypes are *abstract* models, we nonetheless have narrower appraisals of functional roles: the lexeme "bottle opener" covers objects playing that role in *prototypical* situations, which is why it does not cover hammers. This is one reason why we should accept conceptual-role talk as more parsimonious than functional-role talk: conceptual roles *are* functional roles, but tapered down by the prototypicality of situations abstractly conceived.

In practical affairs, of course, we comport to real situations — that may embody situational prototypes, but no real context, with its idiosyncratic details, is entirely prototypical. This concreteness has a pair of distinct implications for my current analysis. First, we accept localized expansions of conceptual roles, like bottle-opener-to-corskcrew or even -to-hammer. Second, conceptual roles offer templates that allow cognitive-perceptual judgments to be passive or instinctive — we reach for a butter knife without being aware of concluding that said instrument is a butter knife, or even really being aware of knowing that a butter knife is there.

So the practical purpose of curating a "library" of conceptual-role accounts is to prime us, given each situation, to identify objects fulfilling conceptual roles *passively*, as part of unattended, background consciousness. Once we become aware of specific enactive needs — the thought that we need a knife or a corkscrew, part of some practical task being now phenomenologically active, a focus of attention — the more passive perceptual details (like a knife's shape and color) are poised to trigger more active conceptual recognition. Now we become consciously aware of the butter knife nearby, and of picking it up and using it.

Perceptual details can certainly be triggers of conceptual recognition, but a complex interleave of situational awareness, situational prototypes, pre-learned conceptual roles, and moment-to-moment enactive needs and processes, all establish an infrastructure within which perceptual content can actually "trigger" determinate conceptualizations. Most of this activity is prelinguistic — it establishes a cognitive baseline that language builds off of. But there is enough commonality between different persons' situational models that we can understand how these cognitive processes are working for other people, and therefore can draft them into the circle of language: if we, holding a slice of bread, ask someone for a butter-knife, we trust they will instinctively grasp both my enactive requirements and have the cognitive resources to help achieve them.

In sum, our ability to convert passive situational awareness and "background consciousness" perception, mediated hy situation-prototypes, into active cognitive-perceptual conceptualizations and pragmatic representations (of the "here's a butter knife I can use" variety) is itself, in total, a cognitive system which can be *targeted* by language, however much it is itself prelinguistic. That analysis, if it holds water, would make language an *interface* to the aforementioned cognitive system. Under that interpretation, my reading, originating in Conceptual Space Theory and then pivoting to Conceptual Roles, also presents as a flavor of ITM. I envision this hybird theory as a kind of synthesis of Conceptual Space Theory, Conceptual Role Semantics, and (at least some variation on) Vakarelov's Interface Theory of Meaning.

Situational awareness, and situationally-mediated object recognition and associated conceptualizations, are highly subtle and multifacted cognitive faculties — especially in our purposeful, socially normative, often emotionally charged human world. Some aspects of this overall architecture may be interestingly modeled or emulated with computers. Examples include Raubal's and Holmqvist's implementations based on Conceptual Spaces, or Holmqvist's approach also intended to present computational models of Langacker-style Cognitive Linguistics, a goal shared by some other work, like Matt Selway's [79]. To this we could add certain models embraced by phenomenologists like Barry Smith and his collaborators (notably [13]) and Jean Petitot. I am skeptical that computer implementations will ever achieve more than a rough approximation of human enaction or language understanding — valuable perhaps as a research case-study and for specific useful tools, but nothing like robotic substitutes for human bodies and minds. But computer tools can still play an important role in research, by giving formal outlines to cognitive architectures which appear to have some formal dynamics, even if the raw materials of cognition — like sensation, situational awareness, and empathy — may not be formally tractable.

2.2 *The Chinese Room Revisited*

John Searle's "Chinese Room" argument — about someone who behaves like he understands Chinse by matching characters to responses from a vast table — is often understood as claiming that "symbol processing" by itself can never produce real understanding, which is *semantic* and *conceptual*. Modern technology makes this thought-experiment less hypothtical: automated telephone systems often use a template mechanism that is practically like Searle's Chinese Room, understanding a limited range of sentencs and producing a limited range of responss. But there are two different kinds of questions we can ask in relation to Searle's argument: some more philosophical and some more practical.

On the philosophical side, we should properly assess the important questions as being qualitative and not quantitative: it's not as if a synthesized phone system is just not a very *good* conervsationalist; it's that a software machine simply isn't the *kind of thing* that we can say actually understands language. This is plausible if we say that emotions and empathy are intrinsic to language; that we can't properly understand language if we do not grasp the emotions residing behind expressions. Indeed, as the case of Grandma's window shows, our status as comptent interlopers depends on reading intentions behind expressions, and it sems hard to do this if we can't experientially empathize with our linguistic partners.

Maybe we are now just pushing the important questions back to reappear: Ok, can computers be programmed to feel emotions? Is there a meaningful distinction between meaningfully, experientially having emotions and just behaving as if you hav them? Are emotions themselves somehow functionalizable apart from their chemical/hormonal substrate so that systems with very different physical realization than ours be said to have emotions? I can see how this dbate can go different ways. But I'd also argue that any ell-organized dialog about these questions will be only tangentially about language — in which case, neither linguistics nor philosophy of language themselves can answer questions about what kind of systems (on metaphysical criteria) actually "do" language. That would imply that affirming a computer's linguistic capabilities as *real* linguistic understanding is a disciplinary non-sequitor for linguistics proper. Nothing in the linguist's arsenal either dmeonstrates or depends on AI agents actually *being* part of our linguistic community or just mimicking language-use to some (sometimes helpful) degree.

The more practical questions raised by Searle's Chinese Room come into play to the degree that the philosophical trail I just sketched turns many analyses into a nonstarter. Consider these two questions to a hypothetical automated telephone service:

- (32) What time does the office open?
- (33) What time does train 100 depart from Newark?

While we can see a template holding canned responses for both cases, (33) needs to do more than just fit the input to the nearest pattern; it has to pull out the dynamically variant details (train *100* from *Newark*) and use those to fill in details in the response. This is something like *parsing* the original question. So we can add bits and pieces of genuine linguistic processing to a minimal response-template system — a real version of what Searle appeared to imagine in the Room. With enough added features the primitive template-driven kernel can evolve into a complex AI-powered Natural Language Processor.

In that case we may imagine that "language understanding" exists on a spectrum. The primitive telephone service and an erudite bard may lie on opposite ends of a spectrum, but they share a spectrum between them. In this case, their differences are quantitative more than qualitative. The bard just has more *features* we associate with total linguistic behavior.

However, this quantitative view still leaves open the question of where among the "features" do we have something that actually drives language competence? Searle's Chinese Room helps point out these questions: it's reasonable to say that the simplest template-response system does not really understand language at all, since it is a pattern-matching system that does not have any structural relation to language itself. Analogous capabilities can be developed for a system which matches any kind of input to a pattern directing an output, based on any metric of similarity. The patterning reflects an actual *linguistic* parse only insofar as it selects elements via syntactic criteria, like grasping the non-template variables as *100* and *Newark*. So, even if the holistic behavior different systems lies on a linguistic-competence sclae, not all *parts* of the system seem to bear the weight of actually *realizing* linguistic competence equally.

One reading of the Chinese Room is that *no* part of a system is truly linguistic. This includes the argument that holistically the Chinese Room *does* speak Chinese: Searle's discussion suggests that no *part* understands Chinese, but if we can imagine the entire room as a single system this "entity" can be treated as a fluent Chinese speaker. Even if we reject that analysis, we could agree that, even among humans, *parts* of our language system arguably do not understand language: not nerve cells, not neural clustes for auditory processing, or sytax, or conceptualization, etc. It is us, the whole system, that uses language. The reason why "holistic" claims that "the entire room" speaks Chinese sound dubious may not be because something is *structurally* lacking in that whole system, but because it's not the kind of whole system — with one body, one consciousness, one personhood — that we think of as a conversant.

Those who find Searle's analysis compelling probably believe that there *is* some meaningful difference between us (or at least people fluent in Chinese) and the Chinese Room. A further alternative, however, is that *we* are not language-usrs, at least not in the way we think we are. This claim can be expounded as follows: the philosophy of language, interactively with linguistics, seems to be looking for some essntial kernel of linguistic capability that distinguishes us from AI engines or template-response system. That is, AI-skeptics want to sift through all the models of processes within languages, the central domains in linguistics, and find the few genreas of linguistic processing that are unique to human language — and computationally intractable. These would be the smoking gun evidnce that no artifical system can equate to human language-use because there is some essential stage in the linguistic pipeline that computers computationally can't realize.

However, even if we accept premises that the Chinese Room case suggests this analysis and moreover it agrees with our underlying intuitions, there remains the possibility that computers are indeed lacking some stage associated with language — but it is not a *linguistic* stage. If something like an Interface Theory of Meaning is correct, all linguistic processing is intermediary to some other cognitive layer: and perhaps the human quintessence lies on the far side, so it both limits what computers can linguistically achieve and lies outside of linguistics proper.

2.3 *Distinguishing Computational Models From AI*

I contend we need to tease apart the pursuit of valuable computational tools and models from an (often reductionistic) paradigm of seeking artifical, computationally engineered replicas of human cognition. *Computational* does not have to equal *AI* [100].

Holmqvist's and Selway's research that I have cited are good examples of paradigm-overlap between cognitive and computational linguistics. I will cite other scholarship which also finds philosophical inspiration in cognitive linguists like Langacker, Gärdensfors, George Lakoff, and Eleanor Rosch, but which also target cognitive-science formalizations and "cognitive architecture": [52], [101], [44], etc. A recurring pattern in this scholarship is to *first* propose a structural intermediate representation — a model of intellectual structures which plausibly embody the processing of language and cognitive-perceptual content, partly abstracted from surface-level sensory or signifying details — and *second* propose algorithmic or software models of how our minds translate linguistic and perceptual givens to abstract, or partly-abstract, schema.

I have argued that we bring abstract situational prototypes to bear on understanding all of the world and social situations around us, and that language taps into these models so that people can coordinate situation-appropriate activity. Given that there is an abstract and scehmatic dimension to how we understand situations, we should expect a partially abstract sheen to how we intellectually engage objects and concepts once they are situationally "located". Having identified objects as butter or carving knives, pitchers or glasses of water, wine or beer bottles, corkscrews and bottle openers — identifications themselves mediated by situational awareness, viz. if we are hosting or attending a dinner party — we no longer often attend actively to sense-perceptual minutiae. Our mental map of our surroundings — there's the corkscrew, there's the carving knife — pulls these referents outside the register of sensate consciousness and into the pragmatic hum of worldly activity. Insofar as they nestle in our intellectual faculties in that semi-abstract state, it seems fair to capture the schematic, structural appearance they have in this intellectual register — phenomena without the full-cloth phenomenology.

This in turn seems to invite us to imagine how the structural essentials of such "pragmatic appearance" may be captured by computers. We do not need to endow computers with human consciousness or emotions, because our mental traffic with the corkscrew or carving knife at some point evolves outside the sensate and passionate fabric of momentary consciousness. There is a schematic and mechanical dimnsion of human action, and we can imagine computers simulating human intelligence at least on *that* theatrical level.

Or at least, such seems to be the intuition behind attemps to model our human representations of objects and concepts in terms of abstract structures. But even a feasible theory of these semi-abstract layers of cognitive processing is only half the story. Suppose we agree that there are legitimate cognitive insights in Holmqvist's model of cognitive frames, incorporating (but also extending, including in a more pragmatist direction) Conceptual Space Theory — employing a generalized mereology that renders objects and concepts as *parts* of situations (I have suggested a more conceptual-role account for analogous phenomena). Suppose also we find plausible cognitive-frame models in Selway's intermediate representation for natural language, via which his proposed implementation can potentially map natural language to formal specifications. In these cases we have potentially valuable Intermediate Representations which capture cognition, in effect, mid-stream, or in-the-act: neither conscious phenomenology nor neurophysical hardware.

However, Holmqvist's and Selways' work appears to operate in an environment where these Intermediate Representations are valued primarily because and insofar as they allow human cognition to be mechanically recapitulated. This of course demands not only that compuers *represent* IR models, but also *create* them — that is, when presented with an artifact of natural language, or the visual data of a scene, that computers should *automatically* map these givens to the theorized IR models, as if retracing the steps of human intelligence.

But just because IR models can be given computational form and representations, it does not automatically follow that automated generation of IRs is possible or effective. We can and should thereby distinguish the computational *study* of cognitive Intermediate Representation from the AI vision of programming computers not just to *host* but to *derive* Intermediate Representations. For instance, given a theory of the correct model for parsed Natural Language sentences, we can use computers to *study* and *present* parses — but this is separate from attempting to program computers to parse NL samples to such models on their own, without human intervention. I am sympathetic to the former methodology but skeptical of the latter.

I also believe that most research in, e.g., computational linguistics, ends up conflating those two goals. In that case, IR models are judged based on whether they facilitate automated, AI-driven generation of IR, not on whether the IRs are insightful suggestions of how human cognition itself builds an intermediary cognitive register — paricularly if we accept Vakarelov's overall picture of language as an interface between speech-givens and prelinguistic cognitive faculties. Interface theories and Intermediate Representations tend to go together — the IR is the representation of some input during intermediate processing yielding an output; a structure between two other structures, where the role of the interface is to bridge the structures as well as to activate the correct capabilities via the output. This is the architecture of an "interface theory", in science or computer programming; it carries over to linguistics if we take Vakarelov's ITM seriously.

An equally intrinsic aspect of interface theories, however, is that the processes operative at the intermediate level are theoretically distinct from the realms which the interface bridges. For example, the theory of programming-language compilers and runtimes is distinct both from the theory of programming-language parsers and specifications, and from the theory of CPU architecture and system-kernel development. Runtime engineers can work through the medium of IR models, and compiler design itself is split between parsing surface-level source code *to* IR and mapping IR structures to their proper runtime paths of execution. It would be a breach of design architecture to attempt to solve source-to-IR problems within modules devoted to IR-to-runtime engineering.

Unfortunately, I get the sense that AI research does not respect a comparably disciplined Separation Of Concerns. There are multiple parts to a typical AI platform — modules for representing information (or knowledge/facts/beliefs, or the state of the system's physical or digital environs, etc.); for populating these representations with data deliberately introduced by human users or absorbed via some real-time engineering from the outside world; for analyzing representations to glean insights or calculate a course of action. Individual parts of the overall architecture can evince noteworthy engineering achievements, separate from the goals of the overall system. In this sense the pursuit of AI can yield positive contributions in other branches of computer science and other disciplines, without the stated rationale of AI realizing (and monetizing) systems that exhibit humanlike intelligence.

So perhaps "AI" is best understood as shorthand for a suite of research agendas across several aspects of computer science, not restricted to the fields — like Machine Learning, Robotics, and Artificial Neural Networks — that are publicly associated with the term. This is not, however, how AI seems to be represented by companies and institutions (including in academia) who have a vested interest in the products AI may yield. A benevolent reading would be that institutions understand the diversity of research that can be loosely aggregated under the AI umbrealla, but use the particularly science-fictional facets of this science to excite public support: visions of humanoid conversationalists and robots provide a compact story that is more meaningful to non-experts than technical outlines of the intermediate machinery beneath the hopefully-intelligent surface. However, a more cynical interpretation is that AI is valued as a cash cow, and residual disciplines which contribute to the engineering infrastructure that AI requires — but are agnostic as to the AI vision itself — are appreciated only so much as needed to keep the AI project moving forward. On that interpretation support for AI-agnostic research becomes lukewarm and transactional, and actual innovation in such areas may not be properly celebrated.

Whatver the reality, the technological infrastructure affording support for cognitive science/linguistics, or cognitive humanities/phenomenology, and so forth, is led by frameworks that seem to fall into one of two categories. On the one hand, there are "Cognitive AI" projects that realize different theortical/proposed models of mental architecture as software systems, emulating our rational behaviors — Natural Language Processing, classification, judging similarity, optimizing problem-solving, and so on — to various degrees; simulative success or failure then becomes a litmus test for warranting or revising the implemented theory of intlligence. In the domain of linguistics, these projects serve as a paradigmatic complement (and sometimes testing-ground) for thories of how linguistic processes are computationally tractable.

On the other hand, there are technologies that fall under the rubrick of "proof assistants", like Coq and Agda, which allow programmers to specify data structures with mathematical precision and potentially prove structural properties. Such technologies have computational models and type theories which overlap with general-purpose programming languages, like Haskell and Idris, and in that guise serve as linguistic research tools. That is, linguists have used tools like Coq directly or have achieved comparably rigorous analyses by developing linguistic models in rigorous languages like Haskell (representative are [6] and [47], respectively). These applications trade on the parable of language as *formal system*, and allow theories of *what* formal structures actually apply to language to be tested in environments well-established in other formal sciences, like mathematics and systems engineering.

In the specific context of linguistics, these two groups of technologies — AI platforms, and proof-assistants (or modeling frameworks in mathematically inspired programming languages) — reflect *computational* and *formal* analogies respectively: language *qua* computational or *qua* formal system. This generalizes to other applications buttressing cognitive science: most concrete technology deployed in a research-oriented context projects either or both of these analogy/paradigms.

I believe that both analogies are flawed, although they may have value as indirect, theortically productive models for *parts* of language and human intelligence. I think there are several theoretical frameworks, with at least partial realization in computational settings, that *do* avoid the reductive ideologies of bpth formalism and computationalism which yielding rigorous technological models: Barry Smith and colleagues' Granular Partition models [13], David Spivak's "Ologs" ("Ontology Logs") [89], Conceptual Space Markup Language [3], or the "Image-Schema Language" described in [4]. But in general there is a lack of adequate tooling which embraces *computational* representations of cognitive processes — for example, models of Intermediate Representations and Interface Theories — while simultaneously, mostly, rejecting both the formal and the computational metaphors. How this absence of "non-AI computational" projects may be explained, and what such projects might look like, is a question that will inform my discussions in the next section and then Section 7.

Part II

While the first half of this paper was built around a review of semantic theories, this part will attend equally to grammar. As I argued at the end of Section 3, we can find logical form in language — even subtle, visual, "narrative" language — but *how* language often evokes its logical form reveals the limitations and the reductionist effect of semantic theories that reify logical form over against the full cognitive spectrum of linguistic processes. Insofar as our semantic theory is shaped by a vision of cognitive-linguistic processes, tied together to create aggregate comprehension (of sentences, for example), a natural *syntax* paradigm to ground such a "procedural" or "interface" semantics would be Link or Dependency grammar: syntax as a graph of associations between language elements rather than a compositional hierarchy of words and phrases. This is the conception of the syntax/semantics interface that I will examine in following several sections.

3 Cognitive and Computational Process

Any attempt to bridge Computational Linguistics and Cognitive Grammar or Phenomenology must solicit one or several "founding analogies", linking phenomena on the formal/computational side with those on the cognitive/computational side. Here, I will start from the analogy of *cognitive* and *computational process*, or generically "process" (of either variety). Processes, per se, I will leave undefined, although a "computational" process can be considered roughly analogous to a single procedure implemented in a computer programming language. The story I want to tell goes something like this: understanding language involves many cognitive processes, many of which are subtly determined by each exact language artifact and the context where it is created. Properly understanding a piece of language depends on correctly weaving together the various processes involved in understanding its component parts, and the structure of the multi-process intergration is suggested by the grammar of the artifact. Grammar, in a nutshell, uses relationships between words to evoke relationships between cognitive processes.

My formal elaboration of this model will be inspired at an elementary level by process *algebra* in the computational setting, but more technically by applied *type theory*. Inter-process relations are the core topic of Process Algebra, including sequentiality (one process followed by another) and concurrency (one process executing alongside another). In practice, detailed research around Process Algebra seems to focus especially on concurrency, perhaps because this is the more complex area of application (designing computer systems which can run multiple threads in parallel). It is likewise tempting to imagine that cognitive-linguistic processes exhibit some degree of parallelism, so that the various pieces of understanding "fall into place" together as we grasp the meaning of a sentence (henceforth using *sentence* as a representative example of a mid-size lanuag artifact in general). Nevertheless, I will focus more on *sequential* relations between processes, suggesting a language model (even if rather idealized) where cognitive processes unfold in a temporal order.

On both the cognitive and computational side, temporality is relative rather than quantified: the significant detail is not "before" and "after" in the sense of measuring time but rather how one process logically precedes another in effects and prerequisites. No theoretical importance is attached to *how long* it takes before processes finish, or how much time elapses between antecedent and subsequent processes (in contrast to subjects like optimization theory, where such details are often significant). We can set aside notions of a temporal continuum where subsequent processes occupy disjoint, extended time-regions; instead, one process follows another if anything affected by the first process reflects this effect at the onset of the second process. Time, in this sense, only exists as manifest in the variations of any state revelant to processes — in the computational context, in the overall state of the computer (and potentially other computers on a network) where a computation is carried out. Two times are different only insofar as the overall state at one time differs from the state at the second time. Time is *discrete* because the relevant states are discrete, and because beneath a certain scale of time delta there is no possibility of state change.

Analogously, in language, I suggest that we set aside notions of an unfolding process reflecting the temporality of expression. Of course, the fact that parts of a sentence are heard first biases understanding somewhat; and speakers often exploit temporality for rhetorical effect, elonging the pronunciation of words for emphasis, or pausing before words to signal an especially calculated word choice, for example. These data are not irrelvant, but, for core semantic and syntactic analysis, I will nonetheless treat a sentence as an integrated temporal unit, with no value atributed to temporal ordering amongst words except insofar as temporal order establishes word order and word order has grammatical significance in the relevant natural language/dialect.

While antecedent/subsequent inter-process relations are among those formally recognized in Process Algebra, this specific genre of relation is implicit to other models important to computer science, such as Type Theory and Lambda Calculus. If $\mathfrak{t}$ is a type, then any computational process which produces a value of type $\mathfrak{t}$ has a corresponding ("functional") type (for sake of discussion, assume a "value" is anything that can be encoded in a finite sequence of numbers and that "types" are classifications for values that introduce distinctions between functions — e.g., the function to add two integers is different than the function to add two decimals; more rigorous definitions of primordial notions like "type" and "value" are possible but not needed for this paper). Similarly a process which takes as *input* a value of $\mathfrak{t}$ is its own type. If two processes have these two types respectively — one outputs $\mathfrak{t}$ and the other inputs $\mathfrak{t}$ — then the two can be put in sequence, where the output from the antecedent becomes the input to the subsequent. In this manner inter-process sequential relations become subsumed into "type systems" can can be studied using type-theoretic machinery rather than Process Algebras or Process Calculii as such.

There also exists a robust type-theoretic tradition in (Natural Language) semantics, which is disjoint from but not entirely irrelevant to the type systems of formal and programming languages. Semantic types are recognized at several different levels of classification, but some of the most interesting type-theoretic effects involve medium-grained semantic criteria that are more general than lexical entries but more specific than Parts of Speech. For example, the template *I believed X* generally requires that X be a noun (?*I believed run*), but more narrowly a certain *type* of noun, something that can be interpreted as an idea or proposition of some kind (?*I believed flower*). Asher and Pustejovsky point out the anomaly in a sentenc like "Bob's idea weighs five pounds" [7, example 2, p. 5], which possesses a flavor of unacceptability that feels akin to Part of Speech errors but are not in fact syntactic errors. The object of *weigh* is "five pounds" and its subject is "Bob's idea", which is admissible *syntactically* but fails to honor our semantic convention that the verb "to weigh" should be applied to things with physical mass (at least if the direct object denotes a quantity; contrast with *Let's all weigh Bob's idea*, where the *idea* is object rather than subject). These conventions are analogous to Part of Speech rules but more fine-grained: there is a meaning of *weigh* which has (like any transitive verb) to be paired with a subject and object noun, but beyond just being nouns the subject must be a physical body (in effect a sub-type of nouns) and the object a quantitative expression (another subtype of nouns). Potentially, type restrictions on a coarse scale (e.g. that the subject of a verb must be a noun) and those on a finer scale (as in this sense of *to weigh*) can be unified into an overarching theory, which spans both grammar and semantics — for instance, both Part of Speech rules and usage conventions of the kind often subtly or cleverly subverted in metaphor and idioms (see *flowers want sunshine*, *my computer died*, *neutrinos are sneaky*, as rather elegantly compactified by assigning sentient states to inert things). This is one way of reading the type-theoretic semantic project.

Along with Process Algebra, my take on linguistic understanding is informed by type theory (in both computational and linguistic contexts), but particularly by the merged notion of *typed* processes. So if we say that something has the *type* of a physical-body noun — that "Physical Body" is a type in the overall semantics of language — then I propose a corresponding type of cognitive (perceptual and conceptual) processes characteristic of perceiving and reasoning about physical things. A particular designatum — a bag of rice, say — is subsumed under the semantic type insofar as our perceptual encounters with that thing — and/or our concepual exercises pertaining to its properties and proclivities (like being difficult to carry) — are roughly prototyped by a certain generic kind of cognitive process. This assumes that there is a similitude among processes of perceiving and thinking about physical bodies (at least the mid-sized, quotidian physical things that tend to enter nonspecialist language) sufficient to subsume them under a common prototype, which I then argue forms the cognitive substratum for the semantic type "Physical Object". Moreover, I contend a similar cognitive substratum can be found for other mid-scale semantic types that underlie analyses of semantic acceptability and metaphoricality, like "Living Thing", "Sentient Living Thing" ("flowers want sunshine" is metaphorical because it ascribes propositional attitudes to something whose type does not literally support them), and "Social Institutions" ("The newspaper you're reading fired its editor" exhibits a "type coercion" where *newspaper* is read first as an object and then as a company). One feature of semantic types is the lexical superposition of different types to produce what (in a slightly different context) Gilles Fauconnier calls a "blend": in "Liverpool, which is near the ocean, built new docks", the city is treated as both a geographic region and a body politic.

"Weighs", too, as a verb, can be given a typed-process interpretation. In its least metaphoric sense, "to weigh" connotes a practical action of measuring some object's weight by using something like a scale; as *cognitive* process the verb embodies are ability to plan, reflect upon, or contemplate this practice. So an "idea weighing 5 pounds" is anomalous because it is hard to play out in our minds a form of this practical act where the thing being weighed is mental. Howevere, there are plenty of more figurative uses related to "weighing ideas", "heavy ideas", and so forth, so we are able to isolate the dimension of "judging" and "measuring" which is explicit in literal "weighing", and abstracting from the physical details use "weigh" to mean "measure" or "assess" in general. The phrase "weigh an idea" therefore connotes its own cognitive process — imagining someone thinking about the idea in an evaluative way — but this figurative "script" is closed off by "5 pounds" which forces us to conceive the weighing literally with a scale, not figuratively as a kind of mental assessment. Once again, the type anomaly can be seen as a failure to map the linguistic senses evident in a sentence to an internally consistent set of cognitive procedures for dilating the semantic content seeded within each word.

Notice that I am treating cognitive processes, in themselves, as semantic more than grammatical phenomena. Literally, weighing something is a multi-stp act (lifting it on the sale, reading the measurement), and even in our mental replay of hypothetical weighing-acts it seems impossible not to imagine distinct phases (just as it is impossible not to picture left and right sides of an imaginary cow). Howevere, I assume that the cognitive script is figured by the lexeme "weighs" as a connotative unit: whatever internal structure our mental script of "weighing something" has, this structure is not a *linguistic* structure that must be encoded grammatically. Similarly, the concept *buttered toast* suggests a confluence of perceptual, physical-operational, and conceptual aspects — we are incljed to regard toast as *buttered* if it looks a certain way and also if we have seen someone apply butter to it (or have done so ourselves) and also if we are in a context where we expect to find toast that may be buttered (we are not disposed to call a piece of bread in a grocery store "buttered toast" even if it has that appearence). So the adjective *buttered* introduces multiple cross-modal parameters in addition to the underlying concept *toast*; but I feel that the lexeme aggregates these parameters into a single *linguistic* unit. In Langacker's terms, the various elements of "buttered" do not suggest *constructive effort*, as if deliberate *linguistic* processing were needed to unpack the linguistic entity to its constituent parts. Instead, "buttered" functions *semantically* as a unit (and likewise syntactically as the unit entering relations with other words — e.g. buttered-toast is an adjective/noun pair, not the noun *butter* at the root of the adjective) — even if its cognitive process is multi-faceted. Indeed, this is precisely the signifying economy of language: it captures complex cognitive procedures by iconic, repeatable lexical units.

On that theory, tieing specific word-senses to stereotyped cognitive processes is a matter of semantics, not grammar per se. Grammar, I contend, comes into play when multiple processes need to be integrated. The concept "buttered toast", for example, seems to start from a more generic concept (toast) and then add extra detail (the buttering, with all that implies conceptually, pragmatically, and sensorially). This is suggested by the substitutability of just *toast* for *buttered toast*:

(34) I snacked on toast and coffee.

(35) I snacked on buttered toast and iced coffee.

Because the first sentence is perfectly clear, it seems that the ideas expressed (at least in this context) by *toast* and *coffee* are reasonably complete in themselves, so the adjectives have the effect of starting with a complete idea and adding on extra detail. Procedurally, then, it seems like we have some process which takes us to "toast" and "coffee" and then, subsequent to that (logically if not temporally) we add the wrinkle of re-conceiving the toast as buttered and the coffee as iced. In short, the adjective-noun pairing is compelling us to run a pair of cognitive processes in sequence, one establishing the noun-concept as a baseline and one adding descriptive detail by an "adjectival", a specificational process.

Counter to that analysis, someone might judge that phrases like "buttered toast" and "iced coffee" are conventional enough that we don't interpret them through two meaningfully disjoint processes. This is entirely possible, given how erstwhile aggregate expressions bcome established units — what Langacker calls *entrenchment*. Different phrases ehibit different levels of entrenchment:

(36) I snacked on toast and instant coffee.

(37) I snacked on toast and Eritrean coffee.

Arguably "instant coffee" is a de facto lexical unit, partly because reading it in terms of constituent parts is rather nonsensical (there's no non-oblique way to understand "coffee" being qualified as "instant"). Surely, however, *Eritrean coffee* is heard as a compound phrase (at least in 2019 — it is unlikely, but not impossible, that future Eritrean coffee growers will be so successful that we hear the phrase as a brand name or culinary term of art, like "Hershey's kisses" or "French toast"). The status of *iced coffee* is probably somewhere between these two. But to the degree that a language element (whether word or phrase) is entrenched and generally processed linguistically as a unit, I maintain, it tends to be governed by an integrally complete cognitive process — not necessarily one without inner structure, but where the elements of this structure piece togther perceptually and situationally, rather than seeming to be *linguistically* disjoint conceptualizations that are brought together by the shape of linguistic phrases. Conversely, where a cognitive process has this integral character, discursive pressures nudge the language toward entrenching some descriptive phrase as a quasi-lexeme; what starts being heard as a compound designation evolves to the point where language users don't attend to constituent parts.

Obviously, this theory presupposes that there is an available distinction to be drawn between a "procedural" synthsis of disparate cognitive processes and a perceptual and/or conceptual synthesis constitutive of individual cognitive episodes. Phenomonology seems to back this up — there are some conceptual compounds that come across as more episodically fused than others. Buttered toast may evoke a temporally not-quite-instantaneous conceptualization — at the core of the concept is a practical activity that takes a few seconds to complete — but we also can imagine the buttering-act apprehended in one sole episode. On the other hand, "Eritrean coffee" ties together concepts of much more scattered provenance; the perceptual unity of *coffee* (in the sense of a specific liquid in a specific container) along with the geopolitical "background knowledge" implicit in the adjective *Eritrean*. As a cognitive synthesis *Eritrean coffee* is conceptual rather than perceptual. Provisionally we can treat this in the context of *buttered toast* being a partially-entrenched phraseology while *Eritrean coffee* is undeniably a phrasal compound, something whose constructive form must be parsed linguistically rather than figuratively.

This analysis, though, needs many caveats. After all, many bonafide *phrases* (not "quasi-lexemes") nevertheless exhibit significant phenomenological unity — i.e., they evoke integral perceptual complexes: *big dog*; *hot coffee*; *speeding car*; *red foliage*. Linguistically these seem like an underlying concept acquiring perceptual specificity via adjectival modification: "hot" was how the coffee came to my experience because I experienced it as hot (it wasn't like I experienced the coffee and then had to contemplate whether it is hot or cold). Coffee can't *not* be experienced as hot, cold, or lukewarm; it cannot be experienced without temperature (assuming I am coming into contact with it and not just looking at it). Similarly a car must be seen as at rest, moving slowly, or speeding along; foliage must be seen as having some color(s).

I have argued, however, that unless entrenched as idiomatic phrases adjective-noun pairs like *hot coffee* or *buttered toast* should be read as grammatical complexes and accordingly (in my theory) as junctures between distinct cognitive processes. On the other hand, I argued that "instant coffee" was effectively entrenched *because* there is no simplistic concepual unity between *instant* and *coffee*, which makes it harder to hear the phrase as descriptive. Instead, the semantics of that particular adjective-noun connection are circuitous and a little hyperbolic: "instant" coffee is coffee as a substance (not a drink, in that state) from which coffee the drink can be quickly (but not instantaneously) prepared. There is a lot going on the semingly simple "instant coffee": the shift from coffee-as-substance to coffee-as-drink; the "instant" exaggeration. In this case, the adjectival modification has *so many* moving parts that, I'm inclined to argue, it is hard to cover the whole scenario with a dscriptive phrase; which in turn creates selective pressures for some pseudo-lexical unit to emerge (which turned out to be *instant coffee*) as a mnemonic for the whole conceptual multiplex. Indeed conceptually intricate wholes tend to quickly acquire pithy conventional nominalizations simply for rhetorical convenience ("Brexit"; "Quantum Gravity"; "International Transfer Window"; "#metoo").

Notwithstanding these variations, I still find a certain logic in the relation between phenomenological unity and semantic entrenchment. Perceptually integrated wholes may correlate with linguistically aggregate constructions insofar as there is a transparent logical destructuring in the perceptual unity: in the case of substance-attribute pairs (like *hot coffee*) — deferring in the phenomenological context to Husserl's account of dependent moments — there is a basically unsubtle distinction between an underlying concept (like coffee) and the qualities which are its mode of appearance as well as conceptual predicates (like hot, cold, black, or light, describing sensory properties innate to the experience of a coffee-token as well as state-reports that can be propositionally attributed to it). Although the minimal sensate intention of the coffee and the predicative disposition toward ascriptions like *black* and *hot* are consciously intertwined, surely I am aware of a logicality in experience that gives the sensate and predicative dimensions different epistemic status. I don't think of my experience of the coffee's being hot as just a hot sensation qua medium of my sensorily apprehending the coffee, but rather as the sensate mechanism by which I observe the apparent fact that the coffee is hot, as a state of affairs and not just as subjective impression. We are constantly extrapolating our perceptual encounters to propositional content along these lines.

As such, I contend such an (in some sense) innate perception-to-predication instinct grounds the procedural slicing of linguistic processes: *hot coffee* retraces in a linguistic construction the logical order of a coffee perception which on one level is a raw perceptual encounter but is simultaneously a predicative attribution. "Hot coffee" denotes a substance that can be experienced in the mode of a base concept (coffee) which is given predicative qualification (the coffee *is* hot). The fact that there may be no noticed temporal gap in *experience* between the sensate perception and the epistemic posture does not preclude a certain logical antecedent-subsequent ordering: the concept *coffee* is the predicative base for my propositional attitude that what I am dealing with here is hot coffee, not hot-sensations-disclosing-coffee or coffee-I-experience-as-hot (but who knows, maybe I'm hallucinating) or any other artificial skeptifying of my actual experience, which is of raw perception pregnant with propositional content.

So I wish to justify claims that (non-entrenched) phrase complexes like "hot coffee" are unions of disjoint cognitive processes by noting that while such phrases evoke a certain perceptual unity, they evoke a *kind* of unity which we habitually regard *conceptually* as divided into sensate givenness founding epistemic attitudes. Cognitive processes are not exclusively perceptual; they are some mixture of perceptual and conceptual (and enactive/kinaesthetic/operational). A perceptual unity can cover two conceptual aspects, like a sheet covering two mattresses. So the perceptual unity of hot coffee can become the conceptual two-step of coffee as substance and hot as attribute; committing this unity to cognition as an overarching lifelong faculty involves registering a thought-process of coffee as a substance which can, in acts of logical predication, be believed to be hot or cold, black or light, etc. The apprehension of the substance is a different cognitive process than the predication of the attribute, in terms of how these mental acts fit within our epistemic models, even if these two processes are experientially fused. Typically we see the coffee before we touch or taste it, so already the coffee has a logical status apart from the heat we predicate in it.

Likewise, even if the black color is inxtricable from our perceiving (apart from odd situations where we drink the coffee without looking at it), we know the color will change if we add milk (even if just in principle because, preferring black coffee, I don't actually do so); so we know the coffee has a logical substrate apart from its color too. All of this ideation is latent in the coffee-perceptions notwithstanding whatever perceptual unities we experience that cloak logical forms like substance/attribute under the inexorable togetherness of disclosure (the phenomenological impossibility of spatial expanse without color, say). In short, disjoint cognitive processes can be required to reconstruct a perceptually unified situation or episode, insofar as we are not just living through the episode but prototyping, logically reconstructing, signifying it — the perceptual unity in the moment does not propagate to procedural atomicity in absorbing the episode into rational exercises.

Experience, then, presents *both* perceptual unities and cognitive-propositional multiplicity; language can inherit both holism on the perceptual side and compositionality on the rational side, even in a single enactive/perceptual episode. Depending on how we via language want to figure and express experience, we can bring either unity or compositionality to the fore. Our linguistic choices will evoke perceptual unity if they select entrenched word-senses or quasi-lexical forms; they will evoke compositionality if they gravitate toward compound phrases and complex, relatively rare lexicalizations and modes of expression. To the degree that we are interested in a cognitive-phenomenological *semantics*, we can attend to the first part of this equation, to how the understood atomicity of a word sense or a conventionalized phrase often suggests an object or phenomenon consciously apprehended as an integral whole; we can trace phenomenologically the apperceptive unity that seems to drive the linguistic community's accepting lexical atoms in this sense. Conversely, to the degree that we are interested in a cognitive-phenomenological *grammar*, we can attend to how logically composite predication emerges even within perceptual unity, because our encounter with phenomena is not (save for exotic artistic or meditative pursuits) the "*dasein*" of irreflective sensory beings immersed in a world of pure experience but the deliberate action of epistemic beings carrying (modifiable but not random) propositional attitudes to perceptual encounters.

Modeling grammar as a coordination between cognitive processes may be an idealization, precisely because the compositive and integrative faces of consciousness are two sides of the same coin: it's not as if we work through a thought of *coffee* or *toast*, abstract and without sensory specificity, noticeably prelude to conceived/perceived attributes like *hot*, *cold*, or *buttered*. But we can still ascribe to linguistic-understanding processes an idealized, "as if" temporality, treating the elucidating of a sentence as a sequence of procedures leading from bare concepts to well-rendered logical tableau, suffused with some level of descriptive and situational particularity. So we go from *coffee* to *iced coffee* to *butterred toast and iced coffee* to *snacking on butterred toast and iced coffee*; each link in the chain stepping up toward propositional totality.

My point is not that the logical form of the sentence is composed from logically primitive and abstract parts, which is fairly trite; my point is that such logical composition is only apparent after a pattern of cognitive integration that is more subtle and exceptional. Extramentally, buttered toast is just toast with butter on it, a fairly simplistic logical conjunction. Read as a baton passed between two acts of mind, however — conciving toast and then conciving it buttered — the conjunction is more elaborate; the cognitive resources of *buttered* are not just "something with butter on it" but the implication of a sensory summation (the flavor, color, scent) and operational narrative (we have seen or performed the deliberate act of applying the butter). Similarly a person dressed up is not just someone whose torso is encircled by articles of clothing; a barking dog is not just an animal making random noises; a stray cat is different from a lost cat. In their interpenetration, cognitive processes develop (in the photographer's sense) narrative and causative threads that are latent in worldly situations but reduced out of logical glosses; that is why it seems incomplete, lacking nuance, or beside the point to explicate semantic meanings in logical terms, like "bachelor" as "unmarried man" (we can certainly imagine a sentence like *My best friend has been married for years but he's still a bachlor*, to imply he still has the habits and attitudes of his single days).

A theory of sentences building from conceptual underspecification to logical concreteness does not preclude there being different scales of specificity. *I snacked on toast and coffee* is just as acceptable as *I snacked on buttered toast and iced coffee*. The communication conveys as much situational detail as warranted in the conversational, pragmatic context. Language always has the *capability* to push further and further into specificty; how exhaustively the language user avails of this capability is a matter of choice. As theorists of language we must then analyze how language possesses the *latent* capacity to draw ever finer pictures; the adjectival *buttered* toast and *iced* coffee takes the granularity of signifying at one level (the level of the *I snacked on toast and coffee* sentence) and layers on (or really layers *within*) a yet more specific level. The architecture of how this happens is well addressed by type-theoretic methods (both coarse and mid-grained).

The remainder of this section, and indeed of the second part of this paper, will try to expand on this type-theoretic intuition. My central thesis is that language understanding involves integrating diverse "cognitive procedures", each associated with specific words, word morphologies (plural forms, verb tense, etc) and sometimes phrases. The form of type theory appropriate in this context is therefore one closely associated with procedural typing and resolution: that is, assigning types to procedures, and differentiating procedures based on the types of their "arguments" or "parameters" (input and output data).

3.1 *Interpretive Processes and Triggers*

The type-theory/procedural perspective I will mostly work from here contrasts with and adds nuance to a more "logical" or "truth-theoretic" paradigm which tends to interpret semantic phenomena via formal logic — for example, singular/plural in Natural Language as a basically straightforward translation of the individual/set distinction in formal logic. Such formal intuitions are limited in the sense that (to continue this example) the conceptual mapping from single to plural can reflect a wide range of residual details beyond just quantity and multitudes. Compare *I sampled some chocolates* (where the count-plural suggests *pieces* of chocolate) and *I sampled some coffees* (where the count-plural implies distinguishing coffees by virtue of grind, roast, and other differences in preparation) (note that both are contrasted to mass-plural forms like *I sampled some coffee* where plural agreement points toward material continuity; there is no discrete unit of coffee qua liquid). Or compare *People love rescued dogs* with *People fed the rescued dogs* — the second, but not the first, points toward an interpretation that certain *specific* people fed the dogs (and they did so *before* the dogs were rescued).

The assumption that logical modeling can capture all the pertinent facets of Natural-Language meaning can lead us to miss the amount of situational reasoning requisite for commonplace understanding. In *People fed the rescued dogs* there is an exception to the usual pattern of how tense and adjectival modification interact: in *He has dated several divorced millionaires* it is implied that the ladies or gentlemen in question were divorced and millionaires *when* he dated them: that the events which gave them these properties occurred *before* the time frame implied (by tense) as the time of reference for the states of affairs discussed in the sentence (jokes or rhetorical flourishes can toy with these expectations, but that's why they *are*, say, jokes). But we read "people fed" in *People fed the rescued dogs* as occurring before the rescue; because we assume that *after* being rescued the dogs would be fed by veterinarians and other professionals (who would probably not be designated with the generic "people"), and also we assume the feeding helped the dogs survive. We also hear the verb as describing a recurring event; compare with *I fed the dog a cheeseburger*.

To be sure, there are patterns and templates governing scope/quantity/tense interactions that help us build logical models of situations described in language. Thus *I fed the dogs a cheeseburger* can be read such that there are multiple cheeseburgers — each dog gets one — notwithstanding the singular form on *a cheeseburger*: the plural *dogs* creates a scope that can elevate the singular *cheeseburger* to an implied plural; the discourse creates multiple reference frames each with one cheeseburger. Likewise the morphosyntax is quite correct in: *All the rescued dogs are taken to an experienced vet; in fact, they all came from the same veterinary college* — the singular on *vet* is properly alligned with the plural *they* because of the scope-binding (from a syntactic perspective) and space-building (from a semantic perspective) effects of the "dogs" plural. Or, in the case of *I fed the dog a cheeseburger every day* there is an implicit plural because "every day" builds multiple spaces: we can refer via the spaces collectively using a plural (*I fed the dog a cheeseburger every day — I made them at home with vegan cheese*) or refer within one space more narrowly, switching to the singular (*Except Tuesday, when it was* *a turkey burger*).

Layers of scope, tense, and adjectives interact in complex ways that leave room for common ambiguities: *All the rescued dogs are [/were] taken to an experienced [/specialist] vet* is consistent with a reading wherein there is exactly one vet, and she has or had treated every dog. It is *also* consistent with a reading where there are multiple vets and each dog is or was treated by one or another. Resolving such ambiguities tends to call for situational reasoning and a "feel" for situations, rather than brute-force logic. If a large dog shelter describes their operational procedures over many years, we might assume there are multiple vets they work or worked with. If instead the conversation centers on one specific rescue we would be inclined to imagine just one veterinarian. Lexical and tense variation also guides these impressions: the past-tense form (*...the rescued dogs were taken...*) nudges us toward assuming the discourse references one rescue (though it could also be a past-tense retrospective of general operations). Qualifying the vet as *specialist* rather than the vaguer *experienced* also nudges us toward a singular interpretation.

What I am calling a "nudge", however, is based on situational models and arguably flows from a conceptual stratum outside of both semantics and grammar proper; maybe it is even prelinguistic. Consider

- (38) People fed the rescued dogs.
- (39) Vets examined the rescued dogs.

There appears to be no explicit principle either in the semantics of the lexeme *to feed*, or in the relevant tense agreements, stipulating that the feeding in (38) was prior to the rescue — or conversely that (39) describes events *after* the rescue. Instead, we interpret the discourse through a narrative framework that fills in details not provided by the language artifacts explicitly (that abandoned dogs are likely to be hungry; that veterinarians treat dogs in clinics, which dogs have to be physically brought to). For a similar case-study, consider the sentences:

- (40) Every singer performed two songs.
- (41) Everyone performed two songs.
- (42) Everyone sang along to two songs.
- (43) Everyone in the audience sang along to two songs.

The last of these examples strongly suggests that of potentially many songs in a concert, exactly two of them were popular and singable for the audience. The first sentence, contrariwise, fairly strongly implies that there were multiple pairs of songs, each pair performed by a different singer. The middle two sentences imply either the first or last reading, respectively (depending on how we interpret "everyone"). Technically, the first two sentences imply a multi-space reading and the latter two a single-space reading. But the driving force behind these implications are the pragmatics of *perform* versus *sing along*: the latter verb is bound more tightly to its subject, so we hear it less likely that *many* singers are performing *one* song pair, or conversely that every audience member *sings along* to one song pair, but each chooses a *different* song pair.

The competing interpretations for *perform* compared to *sing along*, and *feed* compared to *treat*, are grounded in lexical differences between the verbs, but I contend the contrasts are not laid out in lexical specifications for any of the words, at least so that the implied readings follow just mechanically, or on logical considerations alone. After all, in more exotic but not implausible scenarios the readings would be reversed:

- (44) The rescued dogs had been treated by vets in the past (but were subsequently abandoned by their owners).
- (45) Every singer performed (the last) two songs (for the grand finale).
- (46) Everyone in the audience sang along to two songs (they were randomnly handed lyrics to different songs when they came in, and we asked them to join in when the song being performed onstage matched the lyrics they had in hand).

In short, it's not as if dictionary entries would specify that *to feed* applies to rescued dogs before they are rescued, and so forth; these interpretations are driven by narrative construals narrowly specific to given expressions. The appraisals would be very different for other uses of the verbs in (lexically) similar (but situationally different) cases: to "treat" a wound or a sickness, to "perform" a gesture or a play. We construct an interpretive scaffolding for resolving issues like scope-binding and space-building based on fine-tuned narrative construals that can vary alot even across small word-sense variance: As we follow along with these sentences, we have to build a narrative and situational picture which matches the speaker's intent, sufficiently well.

And that requires prelinguistic background knowledge which is leveraged and activated (but not mechanically or logically constructed) by lexical, semantic, or grammatical rules and forms: *rescued dogs* all alone constructs a fairly detailed mental picture where we can fill in many details by default, unless something in the discourse tells otherwise (we can assume such dogs are in need of food, medical care, shelter, etc., or they would not be describd as "rescued"). Likewise *sing along* carries a rich mental picture of a performer and an audience and how they interact, one which we understand based on having attended concerts rather than by any rule governing *along* as a modifier to "sing" — compare the effects of *along* in *walk along*, *ride along*, *play along*, *go along*. Merely by understanding how *along* modifies *walk*, say (which is basically straightforward; to "walk along" is basically to "walk alongside") we would not automatically generalize to more idiomatic and metaphorical uses like "sing along" or "play along" (as in *I was skeptical but I played along (so as not to start an argument)*).

We have access to a robust collection of "mental scripts" which represent hypothetical scenarios and social milieus where language plays out. Language can activate various such "scripts" (and semantic as well as grammatical formations try to ensure that the "right" scripts are selected). Nonetheless, we can argue that the conceptual and cognitive substance of the scripts comes not from language per se but from our overall social and cultural lives. We are disposed to make linguistic inferences — like the timeframes implied by *fed the rescued dogs* or the scopes implied by *sang along to two songs* — because of our enculturated familiarity with events like dog rescues (and dog rescue organizations) and concerts (plus places like concert halls). These concepts are not produced by the English language, or even by any dialect thereof (a fluent English speaker from a different cultural background would not necessarily make the same inferences — and even if we restrict attention to, say, American speakers, the commonality of disposition reflects a commonality of the relevant cultural anchors — like dog rescues, and concerts — rather than any homogenizing effects of an "American" dialect). For these reasons, I believe that trying to account for situational particulars via formal language models alone is a dead end. This does not mean that formal language models are unimportant, only that we need to picture them resting on a fairly detailed prelinguistic world-disclosure.

There are interesting parallels in this thesis to the role of phenomenological analysis, and the direct thematization of issues like attention and intentionality: analyses which are truly "to the things themselves" should take for granted the extensive subconscious reasoning that undergirds what we consciously thematize and would be aware of, in terms of what we deliberately focus on and are conscious of believing (or not knowing), for a first-personal exposé. Phenomenological analysis should not consider itself as thematizing every small quale, every little patch of color or haptic/kinasthetic sensation which by some subconscious process feeds into the logical picture of our surroundings that props up our conscious perception. Analogously, linguistic analysis should not thematize every conceptual and inferential judgment that guides us when forming the mental, situational pictures we then consult to set the groundwork for linguistic understanding proper.

These comments apply to both conceptual "background knowledge" and to situational particulars of which we are cognizant in reference to our immediate surroundings and actions. This is the perceptual and operational surrounding that gets linguistically embodied in deictic reference and other contextual "groundings". Our situational awareness therefore has both a conceptual aspect — while attending a concert, or dining at a restaurant, say, we exercise cultural background knowledge to interpret and participate in social events — and also our phenomenological construal of our locales, our immediate spatial and physical surroundings. Phenomenological philosophers have explored in detail how these two facets of situationality interconnect (David Woodruff Smith and Ronald McIntyre in *Husserl and Intentionality: A Study of Mind, Meaning, and Language*, for instance). Cognitive Linguistics covers similar territory; the "cognitive" in Cognitive Semantics and Cognitive Grammar generally tends to thematize the conception/perception interface and how both aspects are merged in situational understanding and situationally grounded linguistic activity (certainly more than anything involving Artificial Intelligence or Computational Models of Mind as are connoted by terms like "Cognitive Computing"). Phenomenological and Cognitive Linguistic analyses of situationality and perceptual/conceptual cognition (cognition as the mental synthesis of preception an conceptualization) can certainly enhance and reinforce each other.

But in addition, both point to a cognitive and situational substratum underpinning both first-person awareness and linguistic formalization proper — in other words, they point to the thematic limits of phenomenology and Cognitive Grammar and the analytic boundary where they give way to an overarching Cognitive Science. In the case of phenomenology, there are cognitive structures that suffuse consciousness without being directly objects of attention or intention(ality), just as sensate hyletic experience is part our consciousness but not, as explicit content, something we in the general case are conscious *of*. Analogously, conceptual and situational models permeate our interpretations of linguistic forms, but are not presented explicitly *through* these forms: instead, they are solicited obliquely and particularly.

What phenomenology *should* explicate is not background situational cognition but how attention, sensate awareness, and intentionality structure our orientation *vis-à-vis* this background: how variations in focus and affective intensity play strategic roles in our engaged interactions with the world around us. Awareness is a scale, and the more conscious we are of a sense-quality, an attentional focus, or an epistemic attitude, reflects our estimation of the importance of that explicit content compared to a muted experiential background. Hence when we describe consciousness as a stream of *intentional* relations we mean not that the intended noemata (whether perceived objects or abstract thoughts) are sole objects of consciousness (even in the moment) but are that within conscious totality which we are most aware of, and our choice to direct attention here and there reflcts our intelligent, proactive interacting with the life-world. Situational cognition forms the background, and phenomenology addresses the structure of intentional and attentional modulations constituting the conscious foreground.

Analogously, the proper role for linguistic analysis is to represent how multiple layers or strands of prelinguistic understanding, or "scripts", or "mental spaces", are woven together by the compositional structures of language. For instance, *The rescued dogs were treated by an experienced vet* integrates two significantly different narrative frames (and space-constructions, and so forth): the frame implied by "rescued dogs" is distinct from that implied by "treated by a veterinarian". Note that both spaces are available for follow-up conversation:

- (47) The rescued dogs were treated by an experienced vet. One needed surgery and one got a blood transfusion. We went there yesterday and both looked much better.
- (48) The rescued dogs were treated by an experienced vet. One had been struck by a car and needed surgery on his leg. We went there yesterday and saw debris from another car crash — it's a dangerous stretch of highway.

In the first sentence "there" designates the veterinary clinic, while in the second it designates the rescue site. Both of these locales are involved in the original sentence (as locations and also "spaces" with their own environments and configurations: consider these final three examples).

- (49) The rescued dogs were treated by an experienced vet. We saw a lot of other dogs getting medical attention.
- (50) The rescued dogs were treated by an experienced vet. It looked very modern, like a human hospital.
- (51) The rescued dogs were treated by an experienced vet. We looked around and realized how dangerous that road is — for humans as well as dogs.

What these double space-constructions reveal is that accurate language understanding does not only require the proper activated "scripts" accompanying words and phrases, like "rescued dogs" and "treated by a vet". It also requires the correct integration of each script, or each mental space, tieing them togther in accord with speaker intent. So in the current example we should read that the dogs *could* be taken to the vet *because* they were rescued, and *needed* to be taken to the vet *because* they needed to be rescued. Language structures guide us toward how we should tie the mental spaces, and the language segments where they are constructed, together: the phrase "*rescued* dogs" becomes the subject of the passive-voice *were treated by a vet* causing the two narrative strands of the sentence to encounter one another, creating a hybrid space (or perhaps more accurately a patterning between two spaces with a particular temporal and causal sequencing; a hybrid narration bridging the spaces). It is of course this hybrid space, this narrative recount, which the speaker intends via the sentence. This idea is what the sentence is crafted to convey — not just that the dogs were rescued, or that they were taken to a vet, but that a causal and narrative thread links the two events.

I maintain, therefore, that the analyses which are proper to linguistics — highlighting what linguistic reasoning contributes above and beyond background knowledge and situational cognition — should focus on the *integration* of multiple mental "scripts", each triggered by different parts and properties of the linguistic artifact. The *triggers* themselves can be individual words, but also morphological details (like plurals or tense marking) and morphological agreement. On this theory, analysis has two distinct areas of concerns: identification of grammatical, lexical, and morphosyntactic features which trigger (assumedly prelinguistic) interpretive scripts, and reconstructing how these scripts interoprate (and how language structure determines such integration).

In the case of isolating triggers, a wide range of linguistic features can trigger interpretive reasoning — including base lexical choice; word-senses carry prototypical narrative and situational templates that guide interpretation of how the word is used in any given context. *Rescued*, for example, brings on board a network of likely externalities: that there are rescuers, typically understood to be benevolent and intending to protect the rescuees from harm; that the rescuees are in danger prior to the rescue but safe afterward; that they need the rescuers and could not have reachd safety themselves. Anyone using the word "rescue" anticipates that their addressees will reason through some such interpretive frame, so the speaker's role is to fill in the details descriptively or deictically: who are the rescuees and why they are in danger; who are the rescuers and why they are benevolent and able to protect the rescuees. The claim that the word *rescue*, by virtue of its lexical properties, triggers an interpretive "script", is a proposal to the effect that when trying to faithfully reconstruct speaker intentions we will try to match the interpretive frame to the current situation.

The "script" triggered by word-choice is not just an interpretive frame in the abstract, but the interpretive *process* that matches the frame to the situation. This process can be exploited for metaphorical and figurative effect, broadening the semantic scope of the underlying lexeme. In the case of "rescue" we have less literal and more humorous or idiomatic examples like:

- (52) I'm going to rescue her from that boring conversation.
- (53) The trade rescued a star athlete from a losing team.
- (54) Your invitation rescued me from studying all night.
- (55) New mathematical models rescued her original research from obscurity.
- (56) Discovery of nearby earth-like planets rescued that star from its reputation as ordinary and boring and revealed that its solar system may actually be extraordinary.
- (57) His latest comments rescued him from the perception that he never says anything controversial.
- (58) The Soviets rescued thousands of people from a basically-defeated Germany and sent them to Siberia.

Each of these cases subverts the conventional "rescue" script by varying some of the prototypical frame details: maybe the "danger" faced by the rescuee is actually trivial (as in the first three), or the rescuee is not a living thing whose state we'd normally qualify in trms of "danger" or "safety", or by overturning the benevolence we typically attribute to rescue events. In the penultimate sentence someone is described as rescuing *themselves*, but the effect is ironic: he actually caused trouble for himself, or so the speaker clearly believes. And in the final sentence the speaker clearly believes the "rescue" was not needed, that it was not benevolent, and that the "rescuees" ended up worse off: so the choice of word "rescue" is clearly both ironic/sarcastic and implies a mockery of attempts to portray the rescuers as benevolent.

But in these uses subverting the familiar script does not weaken the lexical merit of the word choice; instead, the interpretive act of matching the conventional "rescue" script to the matter at hand reveals details and opinions that the speaker wishes to convey. The first sentence, for instance, uses "rescue" to connote that being stuck in a boring conversation (and being too polite to drift away with no excuse) is an unpleasant (even if not life-threatening) circumstance. So one part of the frame (that the rescuee needs outside intervention) holds while the other (that the rescue is in danger) comes across as excessive but (by this very hyperbole) communicating speaker sentiment. By both invoking the "rescue" script and exploiting mismactches between its template case and the current context, the speaker conveys both situational facts and personal opinions quite economically. Similarly, *rescue a paper from obscurity* is an economical way of saying that research work has been rediscovered in light of new science; *rescued from a bad team* is an economical way of connoting how an athletic career is less fulfilling on a poor team, and so forth.

All of these interpretive effects — both conventional and unconventional usages — stem from the interpretive scripts bound to words (and triggered by word-choice) at the underlying lexical level — we can assess these by reference to lexical details alone, setting aside syntactic and morphological qualities. Of course, then, a host of further effects are bound to morphological details when they *are* considered. Case in point are plurals: for each plural usage we have a conceptual transformation of an underlying singular to a collective, but how that collective is pictured varies in context. One dimension of this variation lies with mass/count: the mass-plural *coffee* (as in "some coffee") figures the plurality of coffee (as liquid, or maybe coffee grounds/beans) in spatial and/or physical/dynamic terms. So we have:

- (59) There's some coffee on your shirt.
- (60) There's coffee all over the table.
- (61) She poured coffee from an ornate beaker.
- (62) There's too much coffee in the grinder.
- (63) There's a lot of coffee left in the pot.
- (64) There's a lot of coffee left in the pot — should I pour it out?

These sentences use phrases associated with plurality (*all over*, *a lot*, *too much*) but with referents that on perceptual and operational grounds can be treated as singular — as in the appropriate pairing of *a lot* and *it* in the last sentence. With count-plurals the collective is figured more as an aggregate of discrete individuals:

- (65) There are coffees all over the far wall at the expresso bar.
- (66) She poured coffees from an ornate beaker.
- (67) There are a lot of coffees left on the table — shall I pour them out?

So mass versus count — the choice of which plural form to use — triggers an interpretation shaping how the plurality is pictured and conceived (which is itself trigggered by the use of a plural to begin with). But if we restrict attention to just, say, count-plurals, there are still different schemata for intending collections:

- (68) New Yorkers live in one of five boroughs.
- (69) New Yorkers reliably vote for Democratic presidential candidates.
- (70) New Yorkers constantly complain about how long it takes to commute to New York City.

The first sentence is consistent with a reading applied to *all* New Yorkers — the five boroughs encompass the whole extent of New York City. The second sentence is only reasonable when applied exclusively to the city's registered voters — not all residents — and moreover there is no implication that the claim applies to all such voters, only a proportion north of one-half. And the final sentence, while perfectly reasonable, uses "New Yorkers" to name a population completely distinct from the first sentence — only residents from the metro area, but not the city itself, commute *to* the city.

These examples demonstrate a point I made earlier, that mapping singular to plural is not a simple logical operation. We need to invoke narrative frames, interpretive scripts, and prelinguistic background knowledge to understand what *sort* of plurality the speaker intends. To be sure, the more subtle plurals can still be read in logical terms, and we can imagine sentences that hew more crisply to a logical articulation:

- (71) All New York City residents live in one of five boroughs.
- (72) The majority of New York voters support Democratic presidential candidates.
- (73) Many New York metro area residents complain about how long it takes to commute to New York City.

According to truth-theoretic semantics, sentences compel addressees to believe (or at least consider) logically structured propositions *by virtue of* linguistic shape replicating the architecture of the intended propositional complexes, as these would be represented in first-order logic. This view on linguistic meaning is consistent with the last three sentences, which are designed to map readily to logical notations (signaled by quasimathematical phrases like *the majority of*). But most sentences do not betray their logical form so readily: these latter sentences actually sound less fluent, more artificial, than their prior equivalents.

It is also true that the more "logical" versions are more, we might say, dialectically generalized because they do not assume the same level of background knowledge. Someone who knew little about New York geography could probably make sense of the latter sentences but might misinterpret, or at least have to consciously think over, the former ones. So we may grant that exceptionally logically-constructed sentences can be clearer for a broad audience, less subject to potential confusion, and indeed such logically cautious language is a normal stylistic feature of technical, legal, and journalistic discourse. But for this reason such discourse comes across as self-consciously removed from day-to-day language. As I argued from multiple angles earlier, in the typical case — i.e., stylistically neutral, day-to-day language — syntactic composition does not neatly recapitulate logical form.

My prior analysis demonstrated warrants for this idea by highlighting narrative and imagistic aspects of language used to convey ideas, like "come out against" providing the verb-phrases in reports of people criticizing something. Here, examples like (68)-(70) point to a similar conclusion, but from a more lexico-semantic orientation: words like *borough* and *commute* carry a space of logical details that tend to force logical interpretations one way or another (e.g., the detail that the territory of a city is fully partitioned by boroughs, *so*, it is *all* citizens who live in a borough). This part of the logic is however not reflected in sentence-structure; it is, rather, latent in lexical norms and assumed part of understanding relevant sentences only because linguistic competence is understood to include familiarity with the logical implications of the lexicalized concepts: e.g. that the quantification in "New Yorkers live in one of five boroughs" is *all*, but the quantification in "New Yorkers vote democratic" is *most*.

Here I'll also add the following: the current examples show how if addressees *have* the requisite background knowledge, linguistic structure does not have to replicate logical structure very closely to be understood. The content which addressees undrstand may have a logical form, and language evokes this form — guides addressees toward considering specific propositional content — but this does not happen because linguistic structure in any precise way mimics, replicates, reconstructs, or is otherwise organized propositionally. Instead, the relation of language to predicate structures is evidently oblique and indirect: language triggers interpretive processes which guide us toward propositional content, but the structure of language is shaped around fine-tuning the activation of this background cognitive dynamics more than around any need to model predicate organization architecturally. In the case of plurals, the appearance of plural forms like *New Yorkers* or *coffees* compels us to find a reasonable cognitive model for the signified multitude, and this model will have a logical form — but the linguistic structures themselves do not in general model this form for us, except to the limited degree needed to activate prelinguistic interpretive thought-processes.

I make this point in terms of plural *forms*, and earlier made similar claims in terms of lexical details. A third group of triggers I outlined involved morphosyntactic *agreement*, which establishes inter-word connections which themselves trigger interpretive processing. Continuing the topic of plurals, how words agree with other words in singular or plural forms evokes schema which guide situational interpretations. So for instance:

- (74) My favorite band gave a free concert last night. They played some new songs.
- (75) There was some pizza earlier, but it's all gone.
- (76) There were some slices of pizza earlier, but it's all gone.
- (77) There were some slices of toast earlier, but there's none left.
- (78) There was some toast earlier, but they're all gone.
- (79) That franchise had a core of talented young players, but it got eroded by trades and free agency.
- (80) That franchise had a cohort of talented players, but they drifted away due to trades and free agency.
- (81) Many star players were drafted by that franchise, but it has not won a title in decades.
- (82) Many star players were drafted by that franchise, but they failed to surround them with enough depth.
- (83) Many star players were drafted by that franchise, but they were not surrounded with enough depth.
- (84) Many star players were drafted by that franchise, but they did not have enough depth (around them).

Plurality here is introduced not only by isolated morphology (like *slices*, *players*, *songs*), but via agreements marked by word-forms in syntactically significant pairings: was/were, it/they, there is/there are. Framing all of these cases is how we can usually schematize collections both plurally and singularly: the same set can be cognized as a collection of discrete individuals one moment and as an integral whole the next. This allows language some flexibility when designating plurals (as extensively analyzed by Ronald Langacker: see his discussion of examples like *Three times, students asked an interesting question*). A sentence discussing *slices of pizza* can schematically shift to treating the pizza as a mass aggregate in *it's all gone*. Here the antecedent of *it* is *slices* (of pizza). In the opposite direction, the mass-plural "toast" can be refigured as a set of individual pieces in *they're all gone*. The single *band* becomes the group of musicians in the band. In short, how agreements are executed invites the addressee to reconstruct the speaker's conceptualization of different referents discussed by a sentence, at different parts of the sentence: linking *it* to *slices* or *cohort*, or *they* to *the band* or *the toast*, evokes a conceptual interpretation shaped in part by how morphosyntactic agreement overlaps with "semantic" agreement. Matching *they* to *the band* presents agreement in terms of how we conceive the aggregate (as a collection of musicians); using "it" would also present an agreement, but one schematizing other aspect of the band conecpt.

In the last five above cases, *it* similarly binds (being singular) to *the franchise* seen as a single unit — here basic grammar and conceptual schema coincide — but *it* also binds to the *core of young players*. The players on a team can be figured as a unit or a multiple. The franchise itself can be treated as a multiple (the various team executives and decision-makers), as in *they failed to surround the stars with enough depth*. The last sentence is ambiguous between both readings: "they" could designate either the players or the franchise. Which reading we hear alters the sense of "have": asserting that the star *players* lack enough depth implies that they cannot execute plays during the game as effectively as with better supporting players; asserting that the *franchise* lacks depth makes the subtly different point that there is not enough talent over all. The variant which would include "around them" nudges toward the second reading; but it is still permissible to, according to speaker intent, parse the last *they* as designating the *franchise* and the last *them* as the *players* — i.e., that final *they*/*them* pair having different antecedents.

The unifying theme across these cases is that when forming sentences we often have a choice of how we figure plurality, and moreover these choices can be expressed not only in individual word-forms but in patterns of agreement. Choosing to pronominalize *slices of pizza* or *cohort of players* as *it*, or alternatively *they*, draws attention to either the more singular or more multitudinal aspects of the aggregate in question. But this effect is not localized to the individual *it*/*they* choice; it depends on tracing the pronoun to its antecedent and construing how the antecedent referent has both individuating and multiplicity-like aspects. Thus both individuation and plurality are latent in phrases like *slices of* or *cohort of*, and this singular/plural co-conceiving is antecedently figured by how subsequent morphosyntax agrees with the singular or, alternatively, the plural.

Moreover, these patterns of agreement invoke new layers of interpretation to identify the proper conceptual scope of plurals. In *The band planned a tour, where they debuted new songs* we hear the scope of "they" as narrower than its antecedent "the band", because only the band's *musicians* (not stage crew, managers, etc.) typically actually perform:

- (85) The band planned a tour, where they debuted new songs.
- (86) The team flew to New York and they played the Yankees.
- (87) The city's largest theater company will perform "The Flies".

Likewise in (86), only the athletes are referenced via *they played*; but presumably many other people (trainers, coaches, staff) are encompassd by "the team flew". And in (87) we do not imply that the Board of Directors will actually take the stage (the President as Zeus, say). Even in the course of one sentence, plurals are reinterpreted and redirected:

- (88) The city's largest theater company performed "The Flies" in French, but everyone's accent sounded Quebecois.
- (89) The city's largest theater company performed "The Flies"; then they invited a professor to discuss Sartre's philosophy when the play was over.

In the first sentence, the "space" built by the sentence is wider initially but narrows to encompass only the actual actors on stage. In the second, the "space" narrows in a different direction, since we hear a programming decision like pairing a performance with a lecture as made by a theater's administrators rather than its actors. I discussed similar modulation in conceptual schemas related to plurality and pluralization earlier; what is distinct in these last examples is how the interpretive processes for cognizing plurality are shaped by agreement-patterns (like *it* or *they* to a composite antecedent) as much as by lexical choice, or morphology, in isolation.

I have accordingly outlined a theory where lexical, morphological, and morphosyntactic layers all introduce "triggers" for cognitive processes, and it is these procsses which (via substantially prelinguistic perception and conceptualization) ultimately deliver linguistic meaning. What is *linguistic* about these phenomena is how specifically linguistic formations — word choice, word forms, inter-word agreements in form — trigger these (in no small measure pre- or extra-linguistic) interpretations. But as I suggested this account is only preliminary to analysis of how multiple interpretive processes are *integrated*. Linguistic *structure* contributes the arrangements through which the crossing and intersecting between interpretive "scripts" are orchestrated. Hence at the higher linguistic scales and levels of complexity, the substance of linguistic research, on this view, should gravitate toward structural intgration of interpretive processes, even more than individual interpretive triggers themslves.

This higher scale is my focus in the next section — seen from the perspective of formal and computational models as well as everyday language use.

4 Procedures and Integration

So far I have criticized paradigms which try to account for linguistic meaning via concordance between linguistic and proppositional structure. The logical dimension to language is real, but it is not neatly ordered in the syntax/semantics interface. My slogan is that *syntactic comppsition does not recapitulate logical form.*

I believe that a lot of linguistics and philosophies of language obscure this point by virtue of commitments to two reasonable theses: *one*, that logical form is an important (and often the central) dimension of meaning, and *two* that language is compositional. But while language expresses propositional content — i.e., in many cases language "means" the way that propositions "mean" — language is not *compositional*, in general, the way that propositions are compositional. So compositionality and logicality have to be disentangled, and I contend linguistics and philosophies of language have failed to do so. Moreover, as I argued in Section 4, I think this can be explained by the historical roots of philosophy of language — and by extension linguistics — in Analytic Philosophy, which in turn has a specific history and collaboration with formal logic.

This critique has two dimensions: first, although a predicate structure, a predicative specificity, does indeed permeate states of affairs insofar as we engage them rationally, such logical order is not modeled by language itself so much as by cognitive pictures we develop via interpretive processes — processes *triggered* by language details but, I believe, to some not insubstantial degree pre- or extra-linguistic. Moreover, second, insofar as we *can* develop formal models of language, these are not going to be models of predicate structure in any conventional sense.

Cognitive-interpretive processes may have formal structure — structure which may even show a lot of overlap with propositional forms — but these are not *linguistic* structures. Insofar as language triggers but does not constitute interpretive "scripts", the scripts themselves (i.e., conceptual prototypes and perceptual schema we keep intellectually at hand, to interpret and act constructively in all situations, linguistic and otherwise) are not linguistic as such — and neither is any propositional order they may simulate. Language *does*, however, structure the *integration* of *multiple* interpretive scripts, so the structure of this integration *is* linguistic structure *per se* — and formally modeling such integration can be an interesting tactic for formally modeling linguistic phenomena. However, we should not assume that such a formal model will resemble or be reducible to formal logic in any useful way — formalization does not automatically entail some kind of *de facto* isomorphism to a system of logic (if not first-order then second-order, modal, etc.).

Instead, I want to focus in on branches of computer science and mathematics (such as process algebra, which I have already referenced) as part of our scientific background insofar as the *structural integration* of diverse "processes" (computational processes in a formal sense, but perhaps analogously cognitive processes in a linguistic sense) can be technically represented.

In "truth-theoretic" semantics, artifacts of language are intuitively pictured in terms of propositional structure. The guiding intuition compares word meanings to logical predicates; e.g. *John is married* is typically said when the speaker believes that, in fact, the predicate *married* applies to the speaker *John*. Switching to a more "procedural" perspective involves intuiting word-meaning more in terms of interpretive procedures than logical predicates. The change in perspective may not yield substantially different analyses in all cases, but

I believe it does affect many cases.

Even a simple predicate like "married" reveals a spectrum of not-entirely-logical cases in ordinary language:

- (90) John is married to a woman from his home country, but he had to get the marriage legally recognized here.
- (91) John married his boyfriend in Canada, but they live in a state that does not recognize same-sex marriages.
- (92) John has been married for five years, but in many ways he's still a bachelor.
- (93) Every married man needs a bachelor pad somewhere, and wherever yours is, you need a mini-fridge.

We can make sense of these sentences because we do not conceptually define lexemes like *married* or *bachelor* via exhaustive logical rules, like *a bachelor is an unmarried man*. Instead we have some combination of prototypical images — familiar characteristics of bachelors, say, which even married men can instantiate — and a conceptual framework recognizing (and if needed distinguishing) the various legal, societal, and dispositional aspects of being married.

Intuitionwise, then, we should look beyond potential logical glosses on meanings — even when these are often accurate — and theorizee semantics as the mapping of lexical (as well as morphosyntactic phenomena) to interpretive scripts and conceptual or perceptual/enactive schema — which we can collectively designate, for sake of discussion, as "cognitive procedures".

The truth-theoretic mapping of words to predicates (and so phrasal and sentence units to propositional structures) provides an obvious way to formalize linguistic structure by borrowing the analogous structuration from predicate complexes. Substituting a procedural semantic model allows a comparable formalization of linguistic structure through theories exploring procedural integration, for instance the interactions between computational procedures. Analysis of *computational* produres can yield interesting ideas for linguistic theories of *cognitive* procedures — without endorsing a reductive metaphysics of cognitive procedures as "nothing but" computational procedures implemented in some sort of mental software.

I earlier used computing procedures roughly sketched — like code which may open a file (**??**) — as loose metaphors for cognitive processes; my point before was that both cognitive and computational processes can be hard to gloss logically because they are often dealing with incomplete logical information. More seriously — because *incomplete* logical information is not necessarily outside of logic; there are logical systems which can model information partiality in systematic ways — processes which occur in the midst of logically incomplete spaces (in the context of message-passing, function-routing, etc.) do not nessarily *operate* logically. That is, local rules for message-passing or function-routing systems do not seem to be (in their "native" semantics) logical rules. In the current context, I want to consider in greater detail the interoperation *between* computational procedures, to consider how procedures form "networks" and whether this is a useful analogy for cognitive/linguistic processes.

4.1 *Procedural Networks as a Cognitive/Linguistic Metaphor*

The notion of computational procedures is certainly not foreign to symbolic logic or to analyses often associated with logistical models (in linguistics and philosophy, say), like Typed Lambda Calculus. In those paradigms we certainly have, say, an idea of applying formulae to input values (where formulae can be seen as referring to or as compact notations for computational procedures). Comparing the results of two formulae yields predicates (e.g., equalities or greater/less-than relations of quantity) that undergirds predicate systems. Furthermore, combining formulae — plugging results of one formula into a free variable in another — yields new formulae that can in turn be reduced to different forms or to single values, either for all inputs or for particular inputs. In short, a large class of computational procedures can be modeled in predicate and equational or formula-reduction terms. I point this out because shifting to a "procedural" intuitive model does not *by itself* take us outside of logistic and truth-thoretic paradigms.

And yet, in computer science, theories of procedural networks begin to branch out from formal logic or lambda calculii when we move past the "mathematical" picture of procedures — as computations that accept a collection of inputs and return a collection of outputs — and theorize procedures more as computational modules that input, output, and modify values from multiple sources, in different ways. In practical technology, this includes developments like Object-Oriented computer languages and programming techniques such as Exceptions and mutable references. Likewise, real-world code can pull information from many sources — like databases, files, and networks (including the internet) — in addition to values input as parameters to a function. Conversely, functions have many ways to modify values — many ways to manifest side-effects — beyond just returning values as outputs. Collectively these various channels of communication — wherein different procedures can exchange values in different ways — are often described as "inpure", by contrast to "pure" functions which use only a single input channel for (non-modifiable) input parameters and a single output channel.

The design and implementation of computer programming languages — sometimes called "Software Language Engineering" — is partly a theoretical discipline (because programming languages are based on formal systems that can be studied mathematically, like Lambda Calculus), but also very pragmatic. Computer languages are judged by practical considerations, like how efficiently they allow programmers to create quality software. The impetus for new programming techniques often comes from the practical side: mainstream languages began to incoporate features like Object-Orientation and Exceptions (which are a mechanism to interrupt normal program flow when coding assumptions are violated) because these features proved useful to programmers. At the same time, various "inpure" features can still be modeled at the theoretical level — there are extensions to Lambda Calculus with Exceptions and/or Objects, as well as "effect systems" that systematically model functional side-effects via Type Theory. In this case, though, the thoretical models are partly isolated or even lag behind the evolution of practical coding techniques.

It is also true that "inpure" code can always be refactored into a code base that uses only "pure" functional-programming techniques. That is, at least if we exclude the "cyberphysical" layer — the body of code that directly measures or alteres physical data, like writing text to a computer screen or reading the position of a mouse — any self-contained collection of "inpure" functions can always be re-implemented as a system of pure "mathematical" functions, using only one-dimensional, immutable input and output channels (this is not necessarily true of single functions, but abstractly true of complete code *bodies* encompassing many functions, i.e., many implemented procedures). Analogously, any computing environment based on a type system that incorporates impure function-types can be recreated on top of a different type system that recognizes only pure functions. For sake of discussion, define a *procedure space* as a self-contained network of computational procedures, where each procedure has the ability to invoke other procedures in the network. We can then say that any procedure space developed with the benefit of "impure" coding styles (like Objects, Exceptions, and side-effects) is *computationally isomorphic* to a procdure space implemented exclusively in a pure-functional paradigm.

This principle might suggest that the pure/impure distinction is superficial, and so that any computing environment is actually manifesting a purely logical framework, because it is (in one sense) isomorphic to a structur which *can* be thoroughly modeled via formal logic. However, this reductionism actually reveals the limits of "computational" isomorphism in the abstract. Impure procedure-spaces are not *equivalent* to their pure isomorphs. The whole rationale for "impure" coding techniques — Object-Orientation, functions with side-effects, etc. — is that the resulting code better models empirical phenomena and/or how programmers themselvs reason about software design. Any notion of computational isomorphism which is *itself* prejudiced toward formal logic will fail to model how systems which are isomorphic *on these* (already logical) *terms* will nevertheless vary in how organically they model empirical and mental phenomena. If engineers discover that Object-Oriented paradigms produce more effective software for managing biomedical data — that is, biomedical concepts are usefully modeled in terms of semiautonomous computational "objects" whose properties and functionality are enginereed via many discrete, partially isolated software components — this suggests how Object-Oriented structures may be a more natural systematization of the underlying biomedical reality. Object-Oriented software can *in principle* be redesigned without Objects, but the resulting code base would then be a weaker semantic "fit", a less faithful computational encoding, of the external information spaces that the software needs to model and simulate.

I contend that this duality between Object-Oriented and pure-functional programming is analogous to the paradigmatic contrast between cognitive and truth-theoretic semantics. On this analogy, pure-functional programming can be associated with truth-theoretic semantics in that both are founded on formal systems that more or less straightforwardly operationalize first-order logic — a logic with quantification and with sets or types modeling collections, but whose foundational units are boolean predicates and elementary formulae rather than proceures with multiple "channels of communication" and potentially many intermediate states. Reducing impure (e.g., Object-Oriented) code to pure-functional procedure spaces is analogous to providing truth-theoretic reconstructions of linguistic meanings, as in (revisiting examples from prior sections):

- (94) People had fed the rescued dogs (i.e.: before they were rescued).
- (95) New Yorkers vote democratic (i.e.: the majority of registered voters in New York do so).
- (96) There is milk in that coffee (i.e.: almond milk).
- (97) I handed him a bottle opener (i.e.: a butterfly corskscrew).
- (98) That wine is Fabernet Franc (i.e.: "W is CF").

Propositional reconstructions of sentences like these can capture a logical substrate that contributes to their meaning, but completely *reducing* their semantics to such logical substrata jettisons, I have argued, interpretive and contextual schemata which are equally essential to their meaning. Analogously — considered in relation to data that it must curate and model (so that pople may manage and aggregate data; for instance, collect biomedical data to ensure proper diagnoses and implement tratments) — software does not only represent the logical substrata undrlying information systems. It needs to capture conceptual and operational/logistical phenomena as well.

Along these lines, note that Object-Oriented techniques originally emerged from scientific-computing environments, to model complex systems, with multiple levels of organization, emergent structure, and so forth (in the 1990s these techniques were then applied to more enterprise-style applications, for User Interface design, business operations workflows, etc.). The effectiveness of Object-Oriented models suggests that as a form of computing environment, and a framework for coding procedure-spaces, Object-Orientation captures structural properties of complex systems more richly than paradigms that reduce procedural implementations to a purely logical substratum. This observation can then generalize to the whole range of modern-day programming techniques and all the various domains where software is used to monitor, simulate, and manage information about natural and human phenomena.

Technically, the multi-dimensional structure of computational procedures implemented with modern coding techniques — multi-dimensional in the sense of multiple forms of channels of communication and functional side-effects — demands new conceptualizations of the formal architecture of computing environments as such. Rather than seeing computer software, for example, as a complex system built architecturally from predicate logic, we need to undrstand software as a procedure-space or procedural network receptive to external information. On this account, a software application internally possesses a set of capabilities, and achieves this functionality by invoking different procedures which are implemented in the software; the application as a whole is the aggregate of its procedural building-blocks. Which procedures get invoked depends on user actions — we use a mouse, keyboard, and other input devices to trigger responses from the software. Applications are therefore built around an "event loop": the software can enter a passive state, performing no operations apart from monitoring physical devices to detect user actions. Once an action does occur — we press a letter on a keyboard, say, or press a mouse button — the application responds by invoking a specific procedure, which in turn may trigger a complex cascade of other procedures, to complete whatever operation we requested via our action (saving a file, selecting one record to visualize from a database, etc.). Via such networks of procedures and functionality, software models and simulates empirical phenomena — at least enough so that we can maintain databases, remotely operate machines, and in other ways track and manipulate physical states.

Consequently, computer models of empirical phenomena can take the form of *procedural networks*, and we can designate the design and theory of such models as *procedural modeling*. I have argued that procedural networks are not reducible to logical predicate systems even though procedure-spaces in general are (in a certain sense) isomorphic to procedure-spaces which are more purely logical, or employ pure-functional type systems. The "isomorphism" relevant here, I am arguing, eliminates semantic and simulative structures that make procedural models effective constructions conveying the organization and behavior patterns of complex, real-world phenomena. On this theory, procedural modeling is a more effective tool for representing real-world systems than are computing environments built more mechanistically from predicate logic.

Interestingly, however, the predominant contemporary paradigms for modeling real-world information systems — particularly what has come to be called the "Semantic Web" — is built on a framework of description logic and "knowledge graphs" rather than (at least except very indirectly) anything that could be called "procedural data modeling" [96], [8], [88]. There is, of course, a robust ecosystem of network-based code-sharing that provides a viable infrastructure for a more procedural data-sharing paradigm. To illustrate the contrast, consider the problem of biomedical data integration: of merging the information known to two different mdical entrprises, as when a patient moves between two different hospital systems. We can assume that each hospital uses a different set of software tools to store patient records and manage data from their various secondary or constituent sources (diagnostic labs, specialized departments, outside clinics, etc.). Such multi-faceted data then needs to be translated from formats native to the prior hospital's software to formats needed by the new hospital.

Such data-intgration problems tend to be conceptualized in one of two ways. One approach is to seek a common representation, or an overarching unified model, which can reconcile structural differences between the two systems. If both hospitals use the same biomedical "Ontologies", for example, then those Ontologies serve as a logical paradigm through which the distinct systems can be bridged. In effect, structural differences between the systems are treated as superficial variations on a common or unified logical "deep structure" — analogous to translating between natural languages by mapping sentences to a propositional core. Indeed, the field of "Ontology Engineering" can be seen as a way of marshaling abstract logic into a form that is practically useful for information storage and extraction, in open-ended environments where data may be aggregated from many heterogeneous sources. The term "Ontology" in this context is not wholly unrelated to its philosophical meaning, bcause "knowledge engineers" assuming that the primordial structuring paradigms of such "universal" logical systems are relations and distinctions investigatd by the philosophical ontological tradition — substance and attribute, part and whole, time-point vs. time-span, spatial region vs. spatial boundary, subtype and supertype, and so forth. Abstract Ontological systems are then formalized into logical rules that provide an axiomatic core — sometims called "Upper" Ontologies — which are then extended via empirical models or "domain-specific" rules to create Domain-Specific Ontologies used to integrate data in concrete enterprise/scientific fields (medical information, government records, and so forth).

The overarching paradigm of such Ontology-based integration is the idea of a logical model that recognizes superficial differencs between incompatible (or at least not fully compatible) data sources. An alternative approach to data integration problems is to treat these as issues of procedural capability. In order to import data from one hospital into a second hospital system, for example, assuming their respective software and databases are at least somewhat incompatible, you need to perform certain procedures that translate data from the first format to the second. Insofar as this is possible, the two software systems have a certain procedural synergy: the capabilities of the first system include exporting data in a format the second can use, and the capabilities of the second system include integrating data presented in formats that the first can export. This synergy does not need to be theorized in terms of an overarching logical ur-space which both systems indirectly manifest; instead, it reflcts how some subset of the overall procedural network germane to each respctive software system includes — either by deliberate cooperative enginering or because the two systems are guided by similar standards and technical orientations — procedures on the two ends that can be aligned in terms of the kind of data and data-formats they produce and/or consume. In short, targeted (and potentially cooperatively-engineered) procedural alignments — rather than overarching logical commonalities — form the bedrock of data integration.

These contrasting paradigms are not only theoretical. Computer scientists hafve actually tried to promote data sharing and data integration to improve governance, health care, urban infrastructure (via "smart cities"), sustainable development, and so on. Insofar as we see data integration in terms of Ontology Engineering, these practical goals can be met with the curation and publication of formal Ontologies that can guide software and database development. Data sharing is then driven by Ontological alignment — the Semantic Web, for example, designed as an open repository of raw data annotatd and structured in accord with publishd Ontologies, data which can be reused and integrated into different projects more readily because it adopts these published models. On the other hand, insofar as we see data sharing in terms of *procedural alignment*, we prioritize the curation and publication of procedure implementations, in the form of software libraries, open-source code repositories, and other building-blocks of modular software design. Consider again the case of data integration between two hospitals: to integrate data between the two, programmers may need to implement special "bridge functions" that reconcile their respective formats. This implementation is simplified insofar as the respective software systems are well-organized and transparent — so that programmers can examine import and export functions in the two code bases and write new procedures, extending their respective capabilities, so that import functionality on one end can be aligned to export functionality on the other. These new procedures can then be shared so that similar data integration problems — for instance the first hospital sharing data with a third — can be solved more readily, reusing some of the code thereby developed. This approach to data integration emphasizes transparency, modularity, and code-sharing.

Rather than seeing the Semantic Web as a network of raw data conforming to published Ontologies, the more procedural perspective would see endeavors like a Semantic Web as driven by code sharing: open repsoitories of procdural implementations that can be used to reconcile data incompatibilities, pull data from different sources, document data structure and representation formats, etc. Decentralized networks like the Semantic Web would then be characterized by the free exchange of procedural implementations, so that enginers can pull procdures providing different capabilities togther, to assemble fully-featured software platforms. Code libraries would play a homogenizing role in this paradigm analogous to Ontologies in the Semantic Web. And, indeed, there exists a mature and sophisticated technical infrastructure for publishing software componenrs and maintaining code repositories, forming the productive underbelly of the Open-Source ecosystem ("git" version control, the GNU Compiler Collection, Linux distributions, etc.). However, the Semantic Web and Open Source development communities are largely separate, apart from the practical given that many Semantic Web technologies are distributed as Open-Source software. Despite the *practical* adoption of Open-Source norms, the Semantic Web community has arguably not engaged the Open-Source community at a deeper theoretical level, in terms of how the curation of public, collaborative code libraries can promote data integration analogous in effect to (but arguably semantically more accurate than) Semantic Web Ontologies — in light of critiques that the logical intuitions behind the Semantic Web create a distorted and oversimplified theory of what semantics is all about (in the words of Peter Gärdenfors, "The Semantic Web is not very Semantic").

4.2 *Phenomnology and the Semantic Web*

These questions bear directly on phenomenology, because philosophers in the phenomenological tradition have directly influenced the evolution of the Semantic Web — notably Barry Smith, who has both published sophisticated theoretical work on Ontologies in the Semantic Web sense and also spearheaded practical initiatives like the OBO (Open Biological and Biomedical Ontology) Foundry. The OBO Foundry emerged in the mid-2000s, on the heels of a renewed interest in phenomenology as a philosophical basis for Cognitive Science and other practical/technical disciplines, like knowledge engineering. It is not hard to see practical artifacts like the OBO system as concrete realizations of theoretical goals articulated in volumes such as 1999's *Naturalizing Phenomnology*. This association is not only at the level of scholarship — the academic papers describing OBO, for example — but also the design and organization of Semantic Web tools like the OBO Foundry, as technologies and platforms.

Seen in those terms — and if we restrict attention to work done by scientists like Barry Smith and his colleagues who are actively enagaged in both the phenomenological and computer-science communities — Semantic Web technology suggests a paradigm wherein "Naturalizing" Phenomenology involves isolating logical structures which are at once essential to modeling empirical data and also emerge organically from phenomenological accounts of perception and cognition — that is, capturing the logical order of our experiencing the world as well as of the facts experienced. A case in point is formalizing systems of "mereotopology" — combining the mereological account of part vs. whole with "topological" models of spatial continuity, locality, and boundary — which reflect both perceptual schema and information gestalts. So one the one hand the fusion of mereological and topological relations gives us a vocabulary for describing how we experientially apprehend spatial forms — the continuity, regionality, intersections, and disjunctions between visual (and sometimes tactile) elements that gives logical articulation to visual/tactile sense data (never experienced only as "raw" sensation since we fundamentally experience space and visual continuity in these structured forms). Meanwhile, on the other hand, Mereotopology provides a semantic matrix for representing facts and relations in biological, geographical, and other scientific data, so it serves a practical information-management role. In short, isolating logical gestalts and then codifying them in practically useful forms serves to "Naturalize" phenomenology by anchoring phenomenological reflection in applied science.

The general implication of this "Naturalizing" strategy is that phenomenology becomes naturalized, or reconciled with the physical sciences, insofar as structures of consciousness can be aligned with logical systems. This strategy seems to extend beyond just the Semantic Web projects I have highlighted; it is likewise evident for example in Kit Fine's logical mereology in Barry Smith and David Woodruff Smith *Cambirdge Companion to Husserl* [30]. Indeed Husserl himself invites us to consider the logical formalization of phenomenological systems in works like the *Formal and Transcendental Logic*, which appears to suggest that human conceptual systems are an even more refined manifestation of logical systems than are "formal" logics which get entangled in model-thoretic problems like the Löwenheim-Skolem thorem. In other words, systems of formal logic are codifications of a mental order and therefore natural cadidates for a technical representation of the mental realm in its structure and specificity.

However, we can also observe that Husserl was writing at a time when abstract logic was still the preeminent phenotype for systematic exposition of formal structures in general — this was before computer programming and even before mathematical developments like Category Theory. In the first half of the last century, someone hoping to create a formal and systematic representation of cognitive processes would gravitate toward symbolic logic simply because mathematicians and philosophers at the time followed the general intuition that *any* formal structure was essentially characterized by its logical/axiomatic foundations. A century later, formal logic has been displaced from the germinal origins it was once assigned. For mathematicians, logic itself is revealed to be a kind of emergent system that depends on Categorial definitions like limits and colimits, and can vary across Categories — there are different logics for different kinds of Categories. As such it is not logic itself but the properties and contrasts between Categories which is the truly primordial foundation of logico-mathematical thought. A contemporary logico-mathematical formulation of phenomenology may therefore try to establish a Category-Theoretic grounding rather than a logical one as ordinarily understood. A case in point would be how Jean Petitot situates phenomnological analysis in certain soecific genres of Categories, like sheaves and presheaves, in his "Morphological Eidetics" chapter in *Naturalizing Phenomenology* [66] and elsewhere.

Petitot's and Barry Smith's formalizing projects were parallel and collaborative to some extent. Maxwell James Ramstead in a 2015 master's thesis reviews the history elegantly:

> Now, the "science of salience" proposed by Petitot and Smith (1997) illustrates the kind of formalized analysis made possible through the direct mathematization of phenomenological descriptions. Its aim is to account for the invariant descriptive structures of lived experience (what Husserl called "essences") through formalization, providing a descriptive geometry of macroscopic phenomena, a "morphological eidetics" of the disclosure of objects in conscious experience (in Husserl's words, the "constitution" of objects). Petitot employs differential geometry and morphodynamics to model phenomenal experience, and Smith uses formal structures from mereotopology (the theory of parts, wholes, and their boundaries) to a similar effect.

Except, there are interesting contrasts between the Cognitive-Phenomenological adoption of mereotopology (by Barry Smith and also Roberto Casati, Achille C. Varzi, Kit Fine, Maureen Donnelly, etc.) — which stays within a more classical logical paradigm — and Petitot's Morphological Eidetics, which is more Category-Theoretic.

Meanwhile, contemporary formalizations of phenomenological analyses can also gravitate toward a more concrete and computational framework — simulating cognitive processes via software or comparing artificial constructions of perceptual objects (via Virtual Reality, 3D graphics, 3D printing, robotics, etc.) to lived experience [72]. In particular, graphics engineers have a rich theory about how to create realistic (albeit not truly life-like) 3D models and scenes. The mathematical and computational elements in this theory — triangular, quadrilateral, and polygonal meshes; shader algorithms; "NURBS" (Non-Uniform Rational Basis Spline) surfaces; textures and *uv*-mapping; camera matrices; diffusion and stochastic processes — create a formal model of perceptual phenomena insofar as these can simulated *to a close approximation*: visual phnomena artificially built with these techniques can be *almost* realistic.

The gaps between such "virtual" scenes and real life may suggest that there are additional facets suffusing "real life" perception, or even that despite their realism the mathematical building-blocks of CGI-like scenes are fundamentally different from the formal structures governing nurophenomenological perception. But nevertheless the almost lifelike realism that *can* be achieved via Computer Graphics is a data-point that phenomenology should acknowledge: that a perceptual world built out of certain rigorously mathematical constituents can feel almost lifelike when apprehended as if it were a real visual-perceptual surrounding. In particular, Computer-Generated Imagery can evoke the same embodied engagement and intentional patterns as non-artificial, ambient perception so long as we accept a certain "suspension of disbelief", or mentally adjust to the phenomenological limitations of seeing visual tableau on a two-dimensional screen — analogous to watching movies or television. Despite the phenomenological chiasma of directing visual attention to a 2D screen — it feels "not quite right" — we can still become engaged and largely immersed in the visual scenes before us; which means that full phenomenological realism is not prerequisite for our intentional comportment toward visual (and auditory) phenomena.

We can then observe that constructed scenes built entirely from mathematical structures carry comparable potential for intentional engagement. Moreover, Panoramic Photography and Immersive Visual Reality present another genre of phenomenological immersion that transcends the limitations of the 2D screen — though still without full realism, because however lifelike the visual content we may perceive with, say, 3D goggles, we still are not engaging tactilely and kinaesthetically with the world in the usual ways.

In short, one route toward a formal framework for elucidating perceptual-phenomenological content is to examine realistic simulations of visual contents as computational artifacts — not in terms of abstract formulations (logical or otherwise) but in terms of concrete computer code and software. With reference to Mereotopology, for example, we can contrast the logical groundwork set out by Barry Smith (for example) with the differential-geometric and category-theoretic landscape considered by Jean Petitot *and also* a more "experimental", software-driven intuition associated with, for example, Virtual Reality research. Looking at mereotopology in particular, this more computational approach can examine how part-whole relations are created within CGI and Computer Aided Design by mesh alignment or texture mapping, or how texture and diffusion algorthms create effects of material continuity and locality. In this case mereotopological notions are not embedded in logical systems — or even, from a computational perspective, in formal Ontologies — but rather latent in graphics code.

For scholars pursuing a "Naturalized" phenomenology, then, we (in the 2010s and 2020s) have several avenues to choose from, including logical formalism (including as practically leveraged in the Semantic Web) but also mathematical formalization (as with Category Theory and Differential Geomtry) and, also, computationally. Computer Aided Design and Computer Generatd Design point to a theory of formal structures producing life-like (if not perfectly realistic) perceptual content. Analogously, computational models of linguistic structure can help represent the organizing principles of our reasoning toward language understanding — even if these formal models are not proposed as direct simulations of natural linguistic cognition.

Simultaneously, real-world applied projects — like the Semantic Web, Virtual Reality, or CGI/CAD technology — can be seen as practical test-beds for the realism and analytic potential of formal-phenomenological frameworks. In some cases, like the OBO Foundary, the link between applied technology and phenomnology is explicit (at least at the level of institutional and intellectual history); in others, as with VR and CGI, this link is more implicit and thematic (but still addressed by interdisciplinary research grounded in phenomenology and Husserl scholarship). But in any case technological experience retroactively seems to shape the direction of phenomenological research, while at the same time phenomenology has, for some researchers, provided a metatheortic and metaphysical guideline.

Here the Semantic Web presents an interesting case-study, because the manifestation of phenomenological themes (e.g., Mereotopology) in a practically useful resource like Biomedical Ontologies suggests an *ex-post-facto* vindication of *logical* formalization as a "Naturalizing phenomenology" project. On the other hand, critiques of the Semantic Web — which have emerged, among elsewhere, from Cognitive Linguistics — can accordingly be studied as potential indications of how classical logical formalism is limited in the phenomenological context. Peter Gärdenfors, for example, has critiqued the Semantic Web on theoretical grounds while also developing a model of Natural Language semantics (via Conceptual Space Theory) that we may find more phenomenologically realistic than the Semantic Web's (as Gärdenfors puts it) "syllogistic" paradigms. Here, I propose a critique from a more "procedural" angle. From my perspective, the foundational characteristic of "information systems" is the existence of *procedures* (say, cognitive and/or computational procedures) which "act on" (aggregate, interpret, reshape) the data at hand. I believe it is a fair critique to say that Semantic Web technology has unduly discounted the procedural dimension of information management — not only in a thoretical sense, but also quite practically. For example, the OBO Foundary does not include a mechanism for code sharing with the goal of curating software libraries that implement datatypes conformant to the various published Ontologies. In the Semantic Web paradigm, defining logical formalizations of standardized concept-systems is considered orthogonal to implementing software components where these formal criteria are realized in practic. In short, *logical specification* is trated as distinct from *implementation*. This is not a universal approach: many technological standards are published at least in part via "reference implementations" which demonstrate standardized concepts and guide other implementations, helping to enforce compatibility between different software components. Moreover, code sharing and code reuse can promote interoperability no less effectively than alignment relative to logically defined standards. So there *are* technological trends that emphasize "procedural alignment" and code-sharing as important contributors to data integration. However, these branches of technology do not appear to have exerted a strong intuitive influence on the Semantic Web.

I argued above that technology has a retroactive influence on phenomenology, or at least on the threads of research that follow the "Naturalizing" project and the reconciliation of phenomenology with Analytic Philosophy. Even if this effect is rather modest, it still bears on the topic that is my primary emphasis at this point, namely the integration of phenomenology with Cognitive Grammar. One of the most prominent practical domains that has influenced phenomenology has been the Semantic Web, insofar as Semantic Web technology (via Ontologies) show some evidence that formal models influenced by phenomenology can be practically useful, which is one criteria to suggest that the models have philosophical or epistemological merit. On the other hand, Cognitive Linguists have tended (if anything) to be critical of the Semantic Web (in contrast to other linguistics branches, which are generally sympathetic to Semantic Web paradigms and incorporate Ontologies into Computational Linguistics software). So a potentially fertile ground for collaboration between phenomenology and Cognitive Linguists has arguably been overlooked insofar as the respective communities have taken competing lessons from the successes and limitations of the Semantic Web, particularly how the Semantic Web leverages classical logical formalisms (particularly Description Logics) rather than "procedural" and/or Category-Theortic foundations.

This problem is not intrinsic to the Semantic Web as a data-sharing platform, however, only to the paradigms through which the current Semantic Web has been conceptualized and implemented. There are competing intellectual frameworks that embrace parallel goals but present alternative technical foundations, and phenomenology would benefit from thematizing these frameworks in a role analogous to the Semantic Web, both a practical application and a retroactive intuition-guide.

A case in point would be the OpenCog project, that presents a Hypergraph-based modeling paradigm related to but technically distinct from Semantic Web labeled graphs (one which is also consistent with procedural-network models) and which also embraces a specific linguistic model (based on Link Grammar). Philosophically, OpenCog appears to celebrate a vision of Artificial General Intelligence which I have already flagged as problemmatic; underestimating the context-sensitivity and empathic intersubjectivity intrinsic to human cognition and intelligence (and difficult to simulate with machines). Nevertheless, formal models designed to *replicate* intelligent behavior can still be useful as structural *models* of cognitive phenomena, even if we believe in a metaphysical gap between the model and the reality. Implementing software on the basis of explanatorarily useful cognitive models does not guarantee that the software will realistically approximate human cognition, but articulating and fine-tuning the models themselves can notwithstanding be a valuable exercise.

In the case of OpenCog, the impetus toward "Artificial General Intelligence" has motivated that project to explore cognitive models that coalesced around several key structures, including Directed Hypergraphs, Link Grammar, and (in my terms) Procedural Networks (as underlying models for Information Spaces). This aggregate of theories can be juxtaposed to Description Logic, Directed Labeled Graphs, and formal Ontologies as the groundwork for the Semantic Web. I'd also argue that the OpenCog model can potentially be a technological improvement over the existing Semantic Web, in the sense that semantic networks built around OpenCog-like structures can be more effective vis-à-vis several important practical concerns, like application design, data integration, and Human-Computer Interaction. These comments do not necesarily apply to the actual OpenCog software — the major OpenCog component, "AtomSpace", is in a practical sense harder to compile and use than most Semantic Web components — but instead to a potential standardization of the core OpenCog data structures as modeling paradigms that can be adopted by heterogeneous information sources and data-sharing initiatives. In this eventuality, the OpenCog model can provide a test-bed for applied phenomenology that stands on a different formal foundation — one less inured to symbolic logic.

Along these lines, then, I contend that a circle of data models analogous to the OpenCog architcture can provide a formal structuration for phenomenological accounts of linguistic processing and information spaces comparable in analytic roles to 3D modeling primitives in a phenomenology of Perception. On one side, mathematical elements like mesh geomtry, NURBS surfaces, and texture mapping/generation point toward formal theories of perceptual *cognition* by allowing for the construction of perceptually realistic *scenes*. These mathematical elements are building-blocks for an (artificial) perceptual *content* rather than (as far as we know) actual neurocognitive subvenants of perceptual *experience*, but their formal specificity still gives us material to work with when trying to consolidate a "scientific" phenomenological research programme. Analogously, I suggest that OpenCog-like structures such as Directed Hypergraphs, Procedural Network models, and Link Grammar are potential building-blocks for formal models of Cognitive Linguistics and "information management" — for our procssing of both linguistic content and the contxts and situations wherein language artifacts are grounded. In other words, these procedural/hypergraph/link-grammar structures can model linguistic "deep structure" and linguistic environments by analogy to how mesh geometry, texture mapping, and so forth model 3D spatial primitives and visual-perceptual environments.

This idea is still somewhat hypothetical because the "procedural/hypergraph/link-grammar" nexus has not been consolidated into a general to the same degree as a common vocabulary of 3D modeling primitives has been incoporated into disparate software and research projects. Having said that, Link Grammar itself does have standing as a distinct and institutionally circumscribed body of research, so it is a reasonable starting point for integration with phenomenological and cognitive-linguistic approaches, an integration which can then be extended to related structures like Procedural Networks and Directed Hypergraphs.

4.3 *Phenomenology as Experiment*

Phenomenology has not usually attended to formal analysis of cognitive models, or models of mental phenomena overall. This is entirely understandable, since exploration of formal systems surely does not belong to phenomenological analysis itself, at least outside the exotic sense of studying what it is like to learn or think about mathematics, say, from a first-person perspective. Nevertheless, even a writer committed to phenomenology does not solely do phenomenological analysis, any more than a Structuralist poeticist devotes all paragraphs to close-readings. Equally intrinsic to the philosophical process is how intra-methodological analyses ("readings" of consciousness or literary works, say, respectively) are placed in a larger context, which can have multiple dimensions: relations to other scools of philosophy, but also other academic disciples and other regimes of knowledge and practice. Pursuit of formal models can help ground and orient phenomenological investigations, and vice-versa.

As a case in point, consider how phenomeneology was among the inspirations for what computer scientists call the Semantic Web and Formal Ontologies — protocols for sharing information and aggregating "knowledge" across computer networks, paricularly the World Wide Web. Although the distinction is not sufficiently discussed, I believe, the Semantic Web idea really has two dimesnions: we can call them *static* and *dynamic*. The *dynamic* aspect of the Semantic Web (and any data-sharing platform) reflects how the technology needs to enable, and verify, correct and useful behaviors. In particular, the Semantic Web needs to treat *information* as an asset that appreciates in value as it is shared and duplicated. Semantic Web technology needs to identify situations where it would be valuable for some aggregate of data present at locality $L1$ to be shared with locality $L2$; and should provide the technological capabilities to ensure that $L1$ and $L2$ can interoperate properly to effectuate this sharing.

These goals and requirements are *dynamic*: they model and implement scenarios where some piece of software concludes that some remote information would be valuable, and initiates a process of acquiring that data, by interoperating with other software which takes steps to respond cooperatively (within the limits of proper data sharing protocols). I will discuss this *dynamic* aspect of the Semantic Web below.

By contrast, the *static* dimension of the Semantic Web reflects the goals of data representation itself: the essential information and structure manifest in data needs to be preserved arocss locations as data is routed and shared. Accordingly, one goal of Semantic Web technology is to design data representations that retain a static meaning across contexts and locations. These representations have to be sufficiently precise and unambiguous that heterogeneous software platforms can interoperate, by sharing the data represented, without distorting or misinterpreted the information encoded in the relevant shared data.

Such information is not only abstract mathematical or technical data: our world is founded on communicating structured knowledge from many human and scintific domains, like medicine and government. We cannot in this context construe data as just bytes and numbers, but rather encodings of human concepts and judgments. Trying to map essentially informal human concepts, like *illness*, to a precise scientific formulation, is of course a foundational concern in philosophy; but computer networks and technology-enhanced knowledge sharing reveal practical applications of these perhaps once purely abstract problems. Scientists use Formal Ontologies to codify conceptual systems underlying human knowledge and beliefs. This, moreover, spans both fairly narrow and concrete propositions (e.g., that the pericardium surrounds the heart) and deeper, more abstract, more cognitively primeval concepts (like what it means for one thing to surround another thing).

In short, part of the requiements of building knowledge "engineering" or "sharing" systems was to give a technical specification for apparently innate concepts or gestalts like *part of*, *inside of*, *surrounding*, and so on. At least one method for approaching this problem was via phenomenology, meaning that phenomenology serves as one tributary among others that can be followed into the technical context of data modeling and data sharing protocols. At the same time, the Semantic Web community has converged on several preferred models and formats — bearing acronyms like OWL and RDF — which in turn have proved controversial. Some researchers, notably Gärdenfors, have critiqued the Semantic Web for a conceptual simplification that does not really capture the semantics of technical domains (like science and medicine), still less of Natural Language. Others from a more implementation-minded perspetive can highlight technical limitations of Semantic Web models, such as how data sharing *between* computing environments can best integrate with data managment *within* particular databases and applications. The Semantic Web — whose underlying representations are based on labeled, directed graphs — has been critiqued by advocates for modestly different graph-like structurres, like Conceptual Graph Semantics and Directed Hypergraphs. These alternative models are arguably more conceptually accurate and/or more practically efficacious, from an engineering perspective, than the paradigms for representing Formal Ontologies and Informations Spaces or "linked data" which emerged as predominant in the community of Semantic Web developers and researchers.

These unfolding perspectives are relevant to phenomenology partly because competing representational paradigms can seem more or less phenomenologically faithful; can intersect with phenomenological accounts in different ways. For example, suppose we judge that an alternative representational model, like the Hypergraph framework associated with the OpenCog project — itself oriented to Artificial General Intelligence — is a more realistic model of conceptual sructures insofar as these intrinsically emerge from and regulate cognitive/perceptual processes as articulated in phenomenology. That is just a claim, of course, but assuming for sake of argument it is plausible, then we have a case of two competing formal models — both reflecting some measure of at least informal influence frpm phenomenological ideas, as far as seeking philosophically well-grounded accounts of ontology and intelligence. These models can be contrasted on philosophical grounds, but also technologically. Neither OpenCog nor the overall Semantic Web are academic theories per se, but technology projects with their own software ecosystems and engineering norms, alongside academic literature and philosophical attitudes or intuitions that can be evaluated theoretically.

Even though phenomenology is *philosophy*, I believe, that doesn't mean considerations from other disciplines as they bear on — to take this one specific case — OpenCog vs. the canonical Semantic Web are not potentially relevant and interesting to the phenomenological project. The relevant contrast here presents two competing computational frameworks, and the ecosystems can be scrutinized side-by-side with an eye to the merits of their technology, to how they are used, extended, and integrated into practical software and respond to technical requirements. These engineering comparisons can co-exist with more philosophical ones: if one paradigm seems superior *both* practicallly and philosophically, this deserves consideration — do the two horns reinforce each other? Conversely, if the more phenomenologically faithful theory proves less implementationally useful, does this shed light on philosophically interesting issues — the weakness of "mind as compuer" analogies, for instance? We may not be able to specify *a priori* what kind of significance to attach to comparisons between formal models on phenomenological vs. engineering grounds. But we should recognize that technical comparsions are at the least nontrivial data points that should at the least be acknowledged in the background while investigating formalizations that incoporate, and insofar as they incorporate, phenomenological intuitions.

If this is plausible, then the disciplinary frontier of phenomenology significantly expands. Phenomenologists can in any cases engage with the *academic* face of, say, OpenCog and Semantic Web projects — texts by Ben Goertzle or Gärdenfors, for instance — read as at least tangentially philosophical ouevres. But any discipline which finds relevance in these *writings* should also find relevance in the technology they are writing *about*, in their concrete form as technical artifacts and (products of) engineering processes. We can therefore approach technologies like AtomSpace (a database associate with OpenCog) and Fact++ (a Semantic Web engine) from an engineering as well as theoretical perspective — how they are implemented, compiled, and interoperate with other applications. Or, as this one example illustrates, we can incorporate within the phenomenological discipline an interest in technical comparison between formal systems which also manifest phenomenological intuitions, so the phenomenological and engineering dimensions of their juxtaposition can be juxtaposed in turn. This represents a new avenue for engagement with formalizations following the example of, let's say, Husserl's *Formal and Transcendental Logic*, which approached from a phenomenological perspective then-contemporary issues in logic and mathematics. But a key difference is that the formalizations Husserl entertained were fully abstract, while the formal systems that can be approached phenomenologically in our century are more concrete and enmeshed in social-scientific practice (health care, environmental policy, etc.). Engaging with these "concretized" formal systems is not a matter of proving theorems, or understanding proofs of prior theorems; it more involves compiling computer code, or writing new code, and understanding the technical structure of programming languages and data representations.

In effect, computer code — software and formal languages (including markup and database query as well as general-purpose programming languages) — has in many contexts supplanted abstract logic as formal foundations of well-structured thought. This even applies to mathematics, where type-theoretic and proof-assistant methods take the place of set theory and predicate logic as foundations. This new reality should be confronted by philosophers as well — what is the philosophical analog of the Univalent Foundations project in mathematics? How should Analytic Philosophers — or indeed phenomenologists — re-evaluate the last century with computers replacing logic as the instuitional mechanization of thought? How should Philosophy be reconsidered if some founding books were reimagined as, let's say, the *Formal and Transcendental Computer Science* or the *Tractatus Computational-Philosophical*? To speak more precisely, what are the consequences propagating across Philosophy if quantification is foundationally conceived as over type-instances rather than sets? What changes when the domain of a quantification has to have a conceptual unity at least to the level of what can be modeled via a formal type theory rather than being open-ended sets? What changes when our reigning paradigm of perfect reasoning is not proofs as a mental exercise, but the engineering of computer systems and then the engineering of (formal representations of) theories and then of apparent theorems so as feed theories and theorems into the aforementioned computer systems for verification? What changes when even mathematics becomes a rather empirical domain that can be experimented with on a computer? What kind of Philosophy can be done by experimenting on a computer?

I will pick up this thread of discussion in a later section, but beforehand will make explicit the potential theoretical integration between linguistics and *procedural networks*, which I have assumed but not directly analyzed to this point.

5 Procedural Networks and Link Grammar

My goal in this section is to incorporate Link Grammar into a phenomenological and Cognitive Grammar perspective, more than to offer a neutral exposition of Link Grammar theory. Therefore I will accept some terminology and exposition not necessarily originating from the initial Link Grammar projects (though influenced by subsequent research, e.g. computational models developed by Matt Selway and Kenneth Holmqvist [79]; [39], [38]). I also want to wed Link Grammar to my own semantic intuitions, set forth earlier, that word-meanings and morphosyntactic interpretations should be grounded on pre- or para-linguistic cognitive "scripts" that are activated (but not structurally replicated, the way that according to truth-thoretic semantics linguistic form evokes-by-simulating propositional form) by linguistic phenomena.

Link Grammar is, depending on one's perspective, either related to or a variant of Dependency Grammar (DG), [23], [22], [24], [62], [37], [5], which in turn is contrasted with "phrase structure" grammars, such as Head-Driven Phrase Structure Grammar (HPSG) [48], [43], [78], [105] (for example). Link and Dependency Grammars define syntactic structures in terms of word-pairs; phrase structure may be implicit to inter-word relations but is not explicitly modeled by DG formalisms — there is typically no representation of "noun phrass" or "verb phrases", for example. Phrase structure is instead connoted via how relations fit together — in *rescued dogs were fed*, for instance, the adjectival *rescued-dogs* relation interacts with the *dogs-fed* (or *dogs-were* plus *were-fed*) predication, an interaction that in a phrase-structure paradigm is analyzed as the noun-phrase *rescued dogs* subsuming the noun *dogs*. Dependency analyses often seem more faithful to real-world semantics because, in practice, phrases do not *entirely* subsume their constituent parts. Linguistic structure is actually multi-layered, where semantic and morphosyntactic connections resonate between units within phrases separate and apart from how linguistic structure is organized into phrasal units themselves.

Except for phrases that coalesce into pseudo-lexemes or proper names (like "United Nations" or "Member pf Parliament"), or indeed become shortened to single words (like "waterfall"), we perceive phrases both as signifying units and as aggregate structures whose detailed combinative rationale needs contectualization and interpretation. In short, phrases are not "canned" semantic units but instead are context-sensitive performances that require interpretive understanding. This interpretive dimension is arguably better conveyed by DG-style models whose consituent units are word-relations, as opposed to phrase-structure grammars which (even if only by notational practice) give the impression that phrases conform to predetermined, conventionalized gestalts.

While Link and Dependency Grammars are both contrasted with phrase-structure grammars, Link Grammar is also distinguished from mainstream DG in terms of how inter-word relations are conceived. Standard DG recognizes an assymetry between the elements in word-relations — one element (typically but not exclusively a word) is treated as "dependent" on another. The most common case is where one word carries greater information than a second, which in turn adds nuance or detail — say, in *rescued dogs* the second word is more essential to the sentence's meaning. This potentially raises questions about how we can actually quantify the centrality of one word or another — in many cases, for instance, the conceptual significance of an adjective is just as trenchant as the noun which it modifies. In practice, however, the salient aspect of "head" vs "dependent" assymetry is that any inter-word pair is "directed", and one part of the relation defined as dependent on another, however this dependency is understood in a given case.

By contrast, Link Grammar dos not identify a head-dependent assymetry within inter-word relations. Instead, words (along with other lexically signifant units, like certain morphemes, or punctuation/prosodic units) are seen as forming pairs based on a kind of mutual incompleteness — each word supplying some structural or signifying aspect that the other lacks. Words, then, carry with them different varieties of "incompleteness" which primes them to link up with other modls. Semantic and grammatical models then revolve around tracing the *gaps* in information content, or syntactic acceptability, which "pull" words into relation with other words. This approach also integrates semantic and syntactic details — unlike frameworks such as Combinatory Categorical Grammar, which also treats certain words as "incomplete" but identifies word connctions only on surface-level grammatical terms — Link Grammar invites us to explore how semantic and syntactic "completion" intersects and overlaps.

Words can be incomplete for different reasons and in different ways. Both verbs and adjectives generally need to pair up with nouns to form a complete idea. On the other hand, nouns may be incomplete as lexical spotlights on the extra-linguistic situation: the important point is not that people feed dogs in general, but that *the rescued* dogs were fed prior to their rescue. So *dogs* "needs" *rescue* for conceptual specificity as much as *rescue* needs *dogs* for anchoring — while also *dogs* needs *the* for *cognitive* specificity, because the discourse is about some particular dogs (presumed known to the addressee), signaled by the definitive article. In other cases, incompleteness is measured in terms of syntactic propriety, as in:

- (99) We learned that people fed the rescued dogs.
- (100) No-one seriously entertained the belief that he would govern in a bipartisan manner.

In both cases the word *that* is needed because a verb, insofar as it forms a complete predicate with the proper subject and objects, cannot always be inserted into an enclosing sentence. *People fed the rescued dogs* is complete as a sentence unto itself, but it is not complete as a grammatical unit when the speaker wishes to reference the signified predicate as an epistemic object, something believed, told, disputed, etc. A connector like *that* transforms the word or words it is paired with syntactically, converting across part-of-speech boundaries — e.g. converting a proposition to a noun — so that the associated words can be included into a larger aggregate.

The interesting resonance between Link Grammar and Cognitive Grammar is that this perspective allows us to analyze how syntactic incompleteness mirrors semantic incompletenss, and vice-versa. "Incompleteness" can also often be characterized as *expectation*: an adjective "expects" a noun to produce a more tailored and situationally refined noun (or nominal "idea"); a verb expects a noun, to form a proposition. Analogously,when we have in discourse an adjctive or a verb we expect a corresponding noun — so via syntactic norms language creates certain expectations in us and then communicates larger ideas by how these expectations are met. Is a noun-expectation fulfilled by a single noun or a complex phrase? The notion of semantic and syntactic expectations also coordinates nicely with type-theoretic semantics; for example, the verb "believe" pairs with a semantic unit that can be interpreted in epistemic terms — not any noun but a noun of a kind that can be the subject of propositional attitudes (beliefs, opinions, assertions, arguments, etc.).

Kenneth Holmqvist, whom I discussed earlier as integrating Conceptual Space Theory with Cognitive Grammar, made a study of "expectation" in this or a similar sense a central feature of his doctoral dissertation [39]; I'll point out that there is an implicit resonance between *expectations* and link grammar; so Holmqvist's research actually potentially triangulates between Conceptual Space Theory, Cognitive Grammar, and Link Grammar.

Continuing analysis of *that* qua subordinator: the syntactic incompleteness of propositional phrases modified by *that* can therefore be traced to the semantic expectations raised by *believe*, and analogous verbs (opine, argue, claim, testify). The object of *testify*, say, is a statement of potential fact which we know not to take as necessarily true or honestly made (part of the nature of testimony is that it may be deliberately or accidentally fallacious). But to properly pair with *testify*, then, phrases must be semantically reinterpreted as nominalizations of propositions, rather than as mere linguistic exprssion of propositional content via complete sentences. The "epistemic" context transforms sentential contnt into nominal content available for further refinement:

- (101) The Trump campaign colluded with Russia.
- (102) Several witnesses testified that the Trump campaign colluded with Russia.
- (103) Reputable newspapers have reported that the Trump campaign colluded with Russia.
- (104) Most Democrats believe that the Trump campaign colluded with Russia.

The grammatical stipulation that a modifier like *that* is often necessary in such formulations correlates with the semantic detail that the "claimed", "testified", or "believed" content is not being directly asserted by the speaker as if in an unadorned declarative expression, as in (101).

Morphosyntactic transformation similarly models the correlation between semantic and syntactic expectation — as can be demonstrated by a variant of the "believe" forms, via the phrase "believe in":

- (105) I believed in Father Christmas.
- (106) I believed in Peace on Earth.
- (107) I believed in Obama.
- (108) I believed in lies.

Whereas *that* (after *believe*) "nominalizes" propositions, *in* reconceives (type-theoretically we would say "coerces") ordinary nouns into epistemic nouns (compatible with propositional attitudes). Obama is not an *idea*, but the connector *in* triggers an interpretation where we have to read "Obama" as something believed — effectively a type-theoretic tension resolved by understanding *Obama* in this context to designate either his platform or his ability to implement it. Interpretive *tension* is a natural correlary to a mismatch in expectations: *believe* expects something epistemic, but the discourse gives us a proper name. Analogously *budge* expects a brute physical entity in its simplest meaning, but in

- (109) Obama wouldn't budge on reproductive rights.

we get a "sentient" noun, and have to read *budge* metaphorically. In short, *expectation*, *interpretive tension*, and *incompleteness* are interlocking facets of semiotic primitives that gestate into discursive maneuvers via which ideas are communicated economically and context-sensitively.

Link Grammar, proper, represents only the most immediate (mostly grammatical) facet of word links. For sake of discussion, I will discuss links in general as markers of *mutual dependency* between words, so a "link grammar" is essentially a "bi-directional" Dependency Grammar. Mutual dependencies manifest syntactic norms and contextual details that make individual words inadequate signifying vehicles for a particular communicating content. This overall principle becomes concrete in one form via grammatical relations, which is the layer modeled by Link Grammar proper. I have mentioned several ready examples — the syntactic dependency of verbs and adjectives on nouns for them to enter correctly into discourse (correlate with a semantic dependency in the other dirction, to shape noun-ideas to the proper context and signifying intent); also part-of-speech or "subtyping" dependencies reflecting mandates that (in my examples) propositional phrases are coerced to nouns or nouns coerced to "epistemic" nouns. Technical Link Grammars recognize a broad spectrum of "link relationship" — between 50 and 100 for different languages. Parsing a sentence is then a matter of identifying all of the mutual dependencies — at least those evident on a syntactic level — that appear as inter-word links in the sentence. Phrase structure may be implicit in some links in combination — for example verb-subject plus verb-object links generate propositional phrases — but the technical parse is a "graph" of inter-word links rather than a "tree" of phrases ordered heirarchically. The parse-graph itself is only a provisional reading of the sentence, and linguistic understanding exists only insofar as its skeletal outline is filled out with semantic and situational details. But the graph layer articulated by a Link Grammar still provides a useful intermediate representation, showing mutual dependencies in their syntactic manifestations that then point toward thir deeper semantic and situational origins.

For each *syntactic* bi-dependency, on this theory, there is a concordant semantic and signifying bi-dependency, partly conventionalized as a feature of the language and partly hewn to the current discourse context. To leverage Link Grammar in an overall Cognitive Linguistic environment, then, we need to examine the semantic relations that drive syntactic bi-dependency: how the grammatical structure of one word completing another is a codification of *semantic* mutual dependency. The *semantic* bi-dependencies operate on both abstract and concrete levels. Abstractly, it is obvious that an adjective or a verb depends on a linked noun to complete an idea. This abstract prototype of bi-dependency then takes concrete forms in each specific discourse, acquiring detail and specificity from situational contexts.

The crucial dimension in this theory is neither abstract nor concrete bi-dependency but the intersection of the two. The conventionalized lexical, syntactic, and morphosyntactic norms of a language present abstract prototypes of mutual word dependencies. The concrete instantiation of these forms — via word-pairs whose surface presentation indicates the presence of specific link relations (often with the aid of morphology, agreement, spoken inflection, and other morphosyntactic cues) — invites us to consider how an abstract bi-dependency becomes situationally concretized in the present, momentary context. In essence, abstract mutual dependencies are the raw materials from which situational appraisals are created. A pairing like "rescued dogs" uses a certain abstract-bidependent prototype — here the double-refinement of a noun and adjective grounding each other — to trigger the listener's awareness that the speaker's discourse is centered on one specific aspect of the dogs (that they were at some point rescued) with its conceptual corrolaries and unstated assumptions (that, being in need of rescue, they were abandoned, in danger, and so on). Similarly the further link to the definite article — "*the* dogs" — evokes the prototype of a definite article grounding a noun, which in turn communicates the speaker's beliefs about the current state of the discourse.

This last "bi-dependency" deserves further comments, because nouns more often than not reveal some dependency on an article: *some dog(s)*, *the dog(s)*, *a dog*, *many dogs*. These pairings paint a picture both through the choice of article and the presence or absence of a plural. This picture is partly situational — obviously whether the speaker is talking about one or multiple dogs is situationally important — but it is also meta-discursive: selecting the definite article indicates the speaker's belief that the listeners know which dogs are on topic. The lexeme "the" thereby signifies a meta-discursive stance as well as a cognitive framing — both that the collection has enough coherence to function as a conceptual unit in context, as *the* dogs (and not something less specific like "*some* dogs") *and also* that the speaker and listeners share compatible cognitive pictures as a result of the prior course of the discourse. This also introduces several avenues for future discursive evolution — the listeners can respond to the speaker on both cognitive and meta-discursive levels. A direct question like *which dogs?* signifies that the first speaker's meta-discursive presuppositions were flawed — the referent of "the dogs" has not been properly settled by the discourse to that point. Or questions for clarification — like *how many dogs are there?* — indicate the listeners' sense that all parties' respective construal of the situation needs to be more neatly aligned for the discourse to proceed optimally.

The point I particularly want to emphasize here, though, is that these discursive/cognitive effects inhere not only in the word "the" but in its pairing with other words, like *the dogs*. We tend to see the lexical substratum of a language as the ground level of its signifying potential, but we should perhaps recognize bidependent prototypes as equally originating. The communicative content of *the dogs* is ultimately traced not only to the lexical potentialities of *the* and *dogs* as word-senses, but to the abstract prototype of the definite-article bidependence, which becomes concretized in the *the dogs* pairing at the same time as the individual words do.

In order to bring this account full-circle, I would then add that lexical units mutually completed by an instantiated bidependence can also be seen as a tie-in between interpretive procedures. Lexical interpretive scripts — the cognitive processing solicited by *the* and *dogs* in isolation — are themselves open-ended and ungrounded or incompletely grounded.

We can speak metaphorically of "words" being incomplete, or carrying expectations, but it is really the cognitive scripts associated with words that are lacking in detail. The resolution of a merely schematic cognitive outline to a reasonably complete situational construal can be likened to a rough sketch filled out in color — but we have to imagine that a sketch can be completed by pairing it with a second sketch, and the content in each one, crossing over, allows a completed picture to coalesce.

So in the current running example, *the* in itself evokes an interpretive process that on its own logic cannot be completed, and likewise *dogs*; but each script supplies the content missing from the other. In this sense the bidependent form concretized by the pair is actualy evoking an interpretive phenomenon of mutual completion — the language structure here is guiding us toward an interpretive interpenetration where the two scripts tie each other's open ends. Whereas lexical items can be associated with single "scripts", prototypes of mutual dependency model patterns in how script-pairs can become mutually complete.

But unlike lexemes, which are notated directly by language, the instantiation of bidependent script-pairs occurs indirectly. Some paired-up words are of course adjacent, but adjacency between words does not have the same binding determinacy as sequencing among morphemes in *one* word. Instead, word adjaceny is only one signal among many others suggesting that some prototypical inter-word relation applies between two words (which might be widely separated in a sentence). Morphology and syntax also point towards the pairings operative in a sentence — they are to bidependency prototypes what word-choice is to the lexicon.

5.1 *Link Grammar as the Syntax of Procedural-Network Semantics*

Thus far I have made an admittedly *philosophical* and speculative case for "interpretive mutual dependence" as a constituent building block of linguistic understanding. This theory will remain troublingly incomplete if the more philosophical presentation cannot be wed to a more rigorous formal methodology. True, an essential core of this theory is that interpretive "scripts" are largely prelinguistic and so not covered by linguistic formalisms in themselves. However, I have also argued that formal linguistic structures *do* govern how we identify which links apply to which word-pairs, and the general outlines of how word-pairing coordinates cognitive processes associated with single words — the fully contextualized synthesis of lexically triggered cognitive procedures may involve extra-linguistic grounding, but abstract prototypes of bidependnet relations are also prototypes of a synthesis between cognitive/interpretive functions. It would accordingly be reassuring if notions like "bidependency" and "mutual completion" could be employed as foundations for a formal theory of grammar and/or semantics with a degree of rigor comparable to, say, Link Grammar in its computational form, or type-Thoretic Semantics in the sense of Zhaohui Luo or James Pustejovsky. Such a theory — and potentially concrete technologies associated with it — would also then have a reasonable ground of comparison to the Semantic Web and, in the context of phenomenology, to the formalizing influence which Semantic Web paradigms have exerted on projects to unite phenomenology with science and with Analytic Philosophy.

Given these considerations, I propose that formal grammars with the same underlying structure as Natural-Language Link Grammars can indeed be used as a foundation for type-theoretic and programming-language-design methodology. The key step here is to generalize Link Grammar's notion of a "connector" — the aspect of a word or lexeme that allows (or requires) compltion via another word — to a gneric data structure where connections can be made between different parts of a system on the basis of double potentials that must be in some sense "compatible" for the connection to be valid. One way to visualize such a system is via graph theory: imagine a form of graphs where nodes are annotated with "potentials" or "half-edges"; a complete edge is then a union of two half-edges. Half edges are also classified into different families, and there are rules governing when a half-edge of one family may link with a half-edge of another. In the case of Link Grammar, these classifications are based on surface language structure — head/dependent and left-to-right relations — from which a suite of links and connection rules are defined (for instance, abstractly a head/right word must link to a dependent/left word, a rule that then becomes manifest in specific syntactic rules, like how a verb links to its subject). For a more generic model, however, we can stipulate only that there is *some* classification of connectors governed by *some* linkage rules, to be specified in different details for different modeling domains.

Such a graph model expands upon the notion of *labeled* graphs, where edges are annotated with labels that characterize the kind of relation modeled via the edge itself. A canonical example is Semantic Web graphs: the edges in any Semantic Web structure are labeled with "predicates", defined in different Ontologies, specifying what sort of relation exists between its adjacent nodes. That is, in the Semantic Web, nodes are not "abstractly" linked but rather exhibit concrete relations: a person is a citizen of a country, two persons are married, and so forth. These structures are then concrete instances of Labeled Graphs as abstract mathematical structures. Based on Link Grammar, we can then refine this model be splitting labels into two parts, and allowing edges to be incomplete: a fully formed edge is possible when the label-parts on one side are compatible with the label-parts on another. One valid class of graph transforms is then a mapping where a graph is altered by unifying two half-edges into a complete edge, subject to the relevant linkage rules.

Another way of modeling this kind of structure is via edge-annotations and a rule for unifying two edges into an edge-annotation pairing. For sake of discussion, I will express this in terms of Directed Hypergraphs: assume that edges are "hyperedges", connecting *sets* of nodes. In Hypergraph theory, the nodes incident to a hyperedge are divided into a "head set" and "tail set"; these sts can then aggregate as "hypernodes". We can then define a kind of unification where the "tail hypernode" of one hyperedges joins with the "head hypernode" of another, producing a new hypredge whose head comes from the first former hyperdge and whose tail comes from the second. The merged hypernodes, in turn, form a new hypernode which "annotates" the new hyperedge (this new hypernode is not connected to the graph via other nodes, but is indirectly "part" of the graph through the hyperedge it annotates). *Annotated* hyperedges therefore differ from "non-annotated" hyperdges in that the former are the result of a merger between two of the latter. The rules governing when such merger is possible — and how to map a pair of hypernodes into a single "annotative" hypernode (which belongs to the graph through the aegis of its annotated hyperdge) are not internal to the graph theory, but presumed to be specified by the modeling environment where implemementations of such graphs are technologically applied. Annotated Directed Hypergraphs are then "complete" in a sense if every "un-annotated" hyperedge has been subsumed into an annotated hyperedge, via a fusional process we can call a "annotative-fusional transform".

Extending this model further, we can say that the tail of an *un-annotated* hyperedge is a "tail pre-annotation", since it is poised to be merged into an annotation. Analogously, the head of an un-annotated hyperedge is a "head pre-annotation", and "annotative fusion" is the synthesis of a head and a tail pre-annotation (triggering a synthesis of their incident hyperedges). Correlate to annotative *fusion* we can define a notion of annotative *partiality*, referring to the "incompleteness" of pre-annotations which leaves room for their fusion.

It turns out that annotative fusion and partiality in this sense is a non-trivial model for computation in general, and can be extended to a form of type theory and process calculus. The idea is that computational procedures can be modeled as hypergaphs (computer source code can certainly be modeled as hypergraphs which are productions of a certain class of parsing engines). Each "value" affected by a procedure — or more technically the source code symbols and memory addresses that "carry" a value — is then modeled as a hypernode that can link with other hypernodes in the scenario where one procedure calls a different one. Annotative fusion is then a phenomenon of values being transferred from one execution environment (associated with the caller procedure) to a second one (associated with the callee). The "annotations" themselves are then in this context the full set of type coercions, type checks, synchronization (e.g. resource locks or thread blocks depending on whether or not the caller waits for the callee to finish), and any other validations to ensure that the procedure call is appropriate. Annotative fusion also provides a formal basis for developing the intuition that "procedural networks" are rigorous representations of information spaces — annotative fusions capture the precise details of procedures linking (via caller/callee relations) with other procedures.

The constituent units of procedural networks are inter-procedure calls — but procedural networks also reveal dimensions of connectivity and and clustering characteristic of large, complex networks (and the graphs that represent them) in general. What appears as one function-call in source code can actually represent many different inter-procedure connections, a phenomenon reflecting "overloading" and "genericity" in programming language theory. Functions are generic in the sense that any one of their arguments can take multiple types — either because the function is explicitly declared to take a "typeclass" or a single type for that argument, or because an instance of a given type may actually be at runtime an instance of some subtype. The engine which actually implements inter-procedure calls — i.e., the programming-language implementation — needs to factor this genericity into runtime decisions, so a single expression in one function body can branch to many different called procedures. This is the essential core of the "semantics" of programming languages: data structures manipulated by computer code do not *intrinsically* represent real-world, non-digital phenomena, though they are enginered to model external data when used properly. However a code base does *internally* posess a space of implemented functions, and a symbol at one place in source code can match to some set of other functions so as to effect a procedure call. This "matching", and the rules governing how "overload resolution" occurs — "overload" meaning that a given notated procedure call can actually branch to multiple functions, so runtime information is needed to select the right one — are the essential formal principles governing the semantics of computer code.

From this basis, all the same, computer code can model a wide range of empirical phenomena. Generic code represents generic patterns of functional organization, allowing models to be built from varying layers of abstraction. From this perspective, to describe an empirical system it is neessary to identify important behaviors and functional patterns via which the system's observed behavior can be notated and/or simulated. To the degree that systems take on functional organizations that can be abstractly described, similar to the functional dynamics of other systems, their behavior can be represented and/or simulated via generic code. To the degree that there are particular details of a system's behavior that are more idiosyncratic to that system, and need to be modeled precisely, procedures can be crafted specifically for observing and emulating that exact behavior. More generic and more exact procedural implementations can coexist in a single code base, with generic functions calling granular functions narrowed to precise types, and vice-versa. The coexistence of generalization and specificty is an essential feature of code bases and, by extension, of procedural networks, ensuring the flexibility of these networks as tools to model information spaces.

Unfortunately, this kind of "procedural" modeling is hard to intgrate with the more static techniques represendt by the Semantic Web and the current "Big Data" fad. The latter paradigms tend to treat data as a static repository to be mined for patterns and insights, rather than a digital simulation or encoding of dynamic real-world systems. The Semantic Web, as a large, collaborative modeling project, evolved largely apart from the technological community concerned with computer simulations and the programming techniques which emerged from there, like Object-Orientation. This divergence is relevant for linguistics and cognitive science, because I would argue that the more "dynamic" paradigm is actually more "Semantic" in a Natural Language sense. In other words, our cognitive dispositions when interpreting empirical phenomena — and matching these interpretations to linguistic cues — are more like procedural networks capturing functional patterns and layers of genericity in observed phenomena, rather than an accretion of static data. The techniques of procedural data modeling may therefore be relevant for Cognitive Linguistics and Cognitive Phenomenology because they aspire to something which, arguably, the mind does instinctively: build cognitive or computational models of dynamic, functionally organized phenomena.

As a corrolary, the theoretical building-blocks of Procedural Data Modeling — how it leverages type theory, programming language semantics, and so forth — can provide at least analogs or case-studies for corresponding cognitive phenomena. Here I would argue that generalizing Link Grammar from Natural Language to formal languages, type systems, and lambda calculii yields added structures to type theory that are useful toward a more rigorous "theory" of Procedural Data Modeling — a theory of natural linguistics generalized to a theory of general data representation which, in turn, may offer insights onto the cognitive dynamics underlying (prelinguistic) situational/perceptual comportments and interpretation.

Type-theoretically, annotative partiality — which recall is my terminology for the abstract generalization of the mutual "incompleteness" in Link Grammar conncters, driving their link-fusion — extends conventional applied type theory (as in the Typed Lambda Calculus) in parallel to partial-labels extending labeled graph theory. It is paradigmatic in the theory of typed procedures and of "effect systems" that the type of a procedure is determined (up to certain equivalences that may discard overly granular type distinctions) by the types of all values affected by the procedure (including but not necessarily limited to the types of input and output parameters). We can then superimpose on this model an account of annotative partiality. Specifically, on the paradigm that procedure-calls are structurally represented as annotative fusions over Directed Hypergraphs, the values manipulated by a procedure are pre-annotations: they are not (in the *implementation* of a procedure, as a formal object) single values but rather typed spaces that can take on a spectrum of possible values depending on the inhabitants of their types. When a procedure is *called* these values become concretized, but as a formal system procedural networks model software in terms of its capabilities and expected behavior, rather than the state at any moment when the software is actually running. Partiality therefore models how precedures (as formal objects) deal with potentialities — we do not know what values will *actually* be present at runtime (e.g. what specific values passed to a procedure as arguments), so procedural analysis is essentially characterized by a partiality of information.

When one procedure calls another, the caller must build an *expression* — a gathering of values that provide all the information the callee requires — thereby creating a case of mutual-completion: the caller has values but not an algorithm to operate on them; the callee has an algorithm (that's what it implements) but needs concrete values so to produce concrete values. This dual partiality allows the caller to call the callee, via an *expression* which is part of the callee's implementation (represented as a hypergraph) which must in turn match the callee's signature — epigrammatically, we can say that "expressions are annotative-fusional duals of signatures". The point here is that whereas signatures are conventionally understood to be type-declarations assigning types to procedures, with annotative partially we can more precisely recognize signatures as stipulating *pre-annotative* types. The values carried within expressions also have pre-annotative types, but there is a distinction between types in the context of expressions and types in the context of signatures — and moreover this distinction is precisely the manifestation of the abstract head-pre-annotation and tail-pre-annotation contrast in the specific context of procedural networks. Just as signatures unify multiple types into one profile, we can analogously define "expression types" as the aggregate of all types from values affecting the expression — note that this is different from the type of the expression's calculated *result*, just as the type of a function is different from the type of its return value. Expression-types and signature-types are almost exact duals (the complication being default values for optional parameters, which are not directly represented in exprssions — obviously, since then they would not be missing). The "duality" involved here derives from partitioning a type system into "expression annotative partials" and "signature annotative partials", a projection of head/tail duality in an abstract theory of Annotated Directed Hypergraphs (and analogous to head/dependent and left/right partiality in Link Grammar).

6 Channel-Algebraic Grammar

This section will briefly introduce what I call "Channel Algebra" and how it can lead to a theory (and practice, in a sense) of formal and natural-language grammar. Channel Algebra is discussed in greater detail in [20]. It is fairly divergent from other formalizations in computer science, though loosely decended from Process Algebras and from the "sigma calculus", which is a formal model of Object-Oriented programming [1]; [87]; [75]. Channel Algebra may also be seen as distantly related to Santanu Paul's "Source Code Algebra" [64] and to a network of discussions — not necessarily coalesced into technical publications — about how to unify Object Oriented and

Functional Programming. There are many interesting analyses presented by scientists like Bartosz Milewski, on web forums such as Milewski's blog (the address is his full name as a dot-com domain). In general, though, I am developing Channel Algebra in an "experimental" manner, using a concrete software implementation in lieu of a technical or mathematical axiomatic description.

In the present context I want to focus on Channel Algebra as a potential theory in linguistics — particularly Cognitive Grammar — but initially I'll describe the underlying theory in a more computational manner. A lot of the Channel Algebra formalization carries between formal and natural languages.

A key notion in Channel Algebra is *procedures*. As in Part 1, we can think of procedures as either cognitive processes or as functions implemented in a software system, although for exposition the latter interpretation is simpler. So, assume we have a computing environment where many functions are available to be called — in effect, a bundle of software libraries each exposing some collection of function-implementations. For reasons I'll cover momentarily, I'll call thse *ambient procedures*.

At one level, Channel Algebra is conceived as an alternative to data-sharing paradigms like the Semantic Web; so, one kind of analysis is concerned with cases where some body of information (which can be called a *data set*) needs to be transferred between two different computing environments. Channel Algebra takes the view that data does not have intrinsic semantics outside the computational environments where it is used. As I argued in the context of Searle's "Chinese Room", our identification that a software system represents facts — like someone's full name (the example I used over several paragraphs in the earlier discussion) — depends on the software possessing capabilities to display the information (usually visually). In other words, among the totality of all procedures that can be performed by the system, only a small set of procdures are involved in user-interactions where semantic intentions like "this piece of data represents someone's full name" are relevant.

As a consequence, when sharing data that includes information like *full-name*, we should not assume that the raw data, in its semantic interpretation, actually "means" *full-name*, or some kind of propositional assertion about full names. For example, a graph-edge in a Semantic Web resource intended to model the proposition "This person has full name Jane Doe" should not be seen as "meaning" anything about full names. Instead, it represents some computational artifact which *becomes* an asserion of that fact when a procedure is eventually called which converts the full name to a (usually visual) representation which a human user would recognize as a view on a full name (and hence on the proposition).

In sum, the Semantic Web (or any data sharing network) only *has* a semantics because software connected by the network has requisite procedures to make data-views that people can understand. Data does not have semantics (or at least not human-conceptual semantics); *views* do. This is consistent with an Interface Theory: most procedures manipulating Semantic Web data are part of an interface connecting networked data sources to the handful of procedures which create views for human users. Within the local structure of this interface, data does not have a "human" semantics; instead, it must be passed around between proceurs before eventually reaching human-interaction procedures where (what we would call) the "real" procedures come into play.

When data is shared btween localities, then, the procedures that will receive and manipulate this data are logicallly prior to the data itself and constrain when data-sharing is possible. Without the proper network of procedures, the data can never be transformed into the views where non-local semantics are relevant. This motivates my choosing the term "*ambient* procedures", because a certain collection of procedures must be in place on the receiver end of a data-sharing event. This also implies that one important role of data modeling is to indicate which procures a potential receiver needs to have available — i.e., needs to implement — to qualify as a capable recipient of data conforming to the model. Data models should describe what procedural capabilities must be afforded by software libraries in order for the human-level, conceptual semantics of the data can actually emerge from humans' interactions with the system.

Analogous to Ontologies as data model specifications for the Semantic Web, I'll use the term "Ambient-Procedural Ontologies" to express the paradigm that implememting data-sharing protocols involves crafting software libraries around procedural requirements. This has two implications for how we theorize software systems. First, we need to characterize procedures in a manner that expresses the proceural capabilities that a system offers, or must have to satisfy a data-sharing protocol. Second, we can assume that whenever data is sent, received, manipulated, or visualized, there is a collection of procedures available in the system which enact these computational processes.

On this basis, then, I will develop a Type Theory that operationalizes this intuition about "Ambient Procedural Ontologies". The main outlines of this type theory are first that procedures have types; and second that procedures are "ambient" or logically prior to (or at least equiprimordial with) the type system itself. This is not a mathematical type system where every underlying type (like Natural Numbers) and every operation (like arithmetic operators) have to be mathematically described in the theory. Instead, we can always take certain types and procedures as "primitive" or (at least in their inner workings) external to the type theory. For any type system $\mathbb{T}$, whose structure is regulated by a type theory we intend to present or assess, we can say that $\mathbb{T}$ is built around a *kernel* $\mathcal{K}$ of "primitive" types and functions.

In general, an assumption of Channel Algebra is that a significant portion of information, present in some structured system, can be extracted by identifying elements in the system with types in a suitably developd type system $\mathbb{T}$. In the case of Natural Language — specifically Cognitive Grammar — this means that many syntactic and semantic details for each word in a sentence can be provided by mapping words to types. As I have mentioned, linguists like Luo and Pustejovsky have given persuasive analyses of certain type systems for *semantics*, but I intend to apply type theory also to *syntax*. Later in this section I will demonstrate this in practice, but for now I will hust note that such analysis requires a sufficiently complex type system. For example, semantic notions like dot-typs and dependent-product typs, which have proven to be effective in shedding light on common lexico-semantic phenomena, may need to be expressible in a $\mathbb{T}$, *along with* link- or cognitive-grammatic notions like *connectors* and *expectations*.

Similar comments apply to modeling and sharing scientific data. Here, I have in mind projects like Conceptual Space Markup Language, and applications of Conceptual Spaces to study the nature and evolution of scientific theories, as reflected in research by (notably) Frank Zenker and Gregor Strle [32], [90]. Implicit in this research is the philosophy that scientific data models are not just electronic specifications for transmitting raw data, but embody scientific theories in terms of how data is structured and constrained. CSML, for example, defines criteria on data parameters such as ranges, dimensions (called "units" in CSML), and structural protocols (including CSML "scales") [3, p. 6]. As a concrete example, the biomedical concept "blood pressure" is usually understood as a pair of numbers whose dimnsions are each in kilopascals (kPa) and whose first number (systolic pressure) is necessarily greater than the second (diastolic) — technically, the pair is *monotone decreasing*. In conventional Biomedical Ontology, cf. SNOMED-CT or the Vital Signs Ontology, these conditions might be stipulated by defining a "blood pressure measurement" concept subject to the relevant dimensional and range criteria (e.g. diastolic pressure must be greater than zero but less than systolic pressure), and/or by classifying systolic and diastolic pressure as subconcepts of blood pressure (see [83] and [36]). In a kind of Ontology paradigm incoporating type theory, the same conceptual structure can be represented concisely by defining a type whose structure conforms to the semantic requirements on the *blood pressure* concept as it is scientifically understood: i.e., a monotone-decreasing integer pair whose dimensional units are labeled "kPa" or "kilopascals". Note also that the "monotone decreasing" criterion is an example of the structure of dependent-product types (in this case because the valid range for the second number depends on the value of the first), a construction which elsewhere is used for Natural Language semanticcs, e.g. [53, p. 40] and [54].

The point of this example is that many scientific concepts — the semantic norms embedded in how scientific terms are defined and understood and how the concepts are used in scintific theories and research — can be rigorously specified with a suitably expressive type system. Therefore, a sophisticated system $\mathbb{T}$ is both a practical tool for scientific data sharing and scientific computing, but also an expository vehicle capturing theories' conceptual underpinnings. Developing scientifically useful type theories can then serve as a kind of formalized philosophy of science — type theory as metascientific analysis.

So in the past several paragraphs I have discussed the idea of using type attributions to represent semantic and syntactic details in natural language, and also metascientific concepts in scientific theories and data sharing. A suitably developed type-system can, in light of these possibilities, act as a kind of multi-purpose tool capturing semantic principles in a broad array of formal and informal cotexts. This is possible insofar as type theory is developed on a flexible basis so that type systems can expand in different directions for different intellectual environments — dependent sum and product types for Natural Language semantics; "connectors" for Link Grammar; CSML-style units, ranges, and scales for scientific data; etc. The overarching goal of Channel Algebra is to enable these flexible, multi-purpose type systems.

Another way of expressing this idea is that type systems should be *multi-paradigm*. Suppose we are using a collection of types to model the semantics of some linguistic or scientific model. We may realize that there are some crucial semantic formulations that need to be recognized within the type system itself, if this type-oriented modeling is to be comprehensive. For example, in a link-grammar context, we may recognize that, in addition to assigning semantic and/or Part-of-Speech types to individual words, we need to represent the "potentialities" latent in words allowing them to link up (each word has a *connectors* such that a pair of "compatible" connectors can produce a "link"). Or, in a metascientific context, we may rcognize that we need to annotate type-attributions with CSML notions like range, scale, and units. The multi-paradigm criteria means that there would be a mchanism in place to enrich a type system $\mathbb{T}$ so that such semantic details can be seen as structural parts of types modeled via $\mathbb{T}$.[3]

One virtue of organizing a type system $\mathbb{T}$ around *procedures* is that this "multi-paradigm" flexibility becomes easier to achieve when we can directly model requirements on procedures, and how procedures interact with types (for instance, each type needs one or more procedures to construct elements of that type). As I said earlier in this section, we can start from any "kernel" of types and procedures and build new types by describing procedures which create, and/or operate on, values of $\mathcal{K}$-types. However, there are many different ways that procedures can act on values and call other procedures. This means there is a lot of room for extending type systems to represent different kinds of inter-procedural relations. For example, in Link Grammar a Part of Speech type is not just a "function" acting on other types — e.g., adjectives act on nouns; "red apple" modifies the image we have when we conceptualize "apple". The adjective/noun pair also needs the right potentials to create a connector. A type-thoretic model of this idea can involve stipulating that, in some cases, a function-type $\mathcal{F}_t$ is not only defined by the type of its argument(s), but by some added "connector" structure which must math between $\mathcal{F}_t$-instances and the instances of its argument types.

Channel Algebra, as I will now argue, givs us a way to encode "extra information" along these lins in type descriptions.

6.1 *Channels as Type-System Extensions*

In concvtional type theory, every type system has *some* notion of functional types, but these are often treated in a simple form based on Typed Lambda Calculus. Canonically, a function *inputs* one or more values, and *outputs* on or more values (in many concrete type systems, only on output value). We can (still rather informally) talk of these input and output collections as "channels". So, a procedure has an *input* channel — that's where it vgets its arguments from — and an *output* channel, where it provides a result. The term "channel" is usually used in the context of "process algebras" where procedures can run concurrently, and channels may be two-way means of communication between concurrent procedures. For this paper, I will only consider *sequential* procedurs — where two procedurs follow each other in time; no parallelism — and *one way* channels, which carry information from one procedure to another but have a fixed direction. Intuitively, if $\mathcal{P}_1$ sends a value to $\mathcal{P}_2$ via one channel, $\mathcal{P}_2$ cannot send a value back via the same channel (although it can *modify* the value in the channel).

While type theory may conceive functions as (in effect) a combination of input and ouput channels, actual programming practice reveals multiple distinct *kinds* of input and output channels. In Object-Oriented programming, Objects are passed to functions (i.e., "methods")

[3] I refer to "semantic details" even in theories of Natural Language *syntax*, like Link Grammr, because many ideas about language *grammar* are relevant tobthe *semantics* of the linguistic *theory*, which is different than the Semantics of Natural Language which linguistic theories have as their subject matter.

using a different protocol than ordinary parameters. Also, many Object-Oriented languages support Exceptions, which are like non-standard return values that disrupt the normal program flow. This suggests two different *input* channels — I'll call them *lambda* and *sigma* for the calculii which can model their semantics — and two different *output* channeos, which I'll call *result* and *error*, for normal and exceptional return values, respectively.

Furthermore, many languages support "lambda" or "inline" functions which can be "closures", enabling a proceure to modify values in its "surrounding lexical scope". In other words, a *closure* is a procedure implemented inside the implementation of an enclosing procedure, and it has the ability to read and maybe modify data used by the enclosing procedure. We can consider this "handing down" of values from outer to inner procedures to be a kind of input channel, which I will call a "capture" channel. Some programming languages make this value-sharing explicit: in the case of modern-day C++ (since the 2011 standard) lambda functions have, as part of their definition, an explicit documentation of which symbols are "captured" from an enclosing lexical scope — these symbols are listed in square brackets, just as regular arguments are listed in parentheses, which helps reinforce the idea that inputs via symboo-capture are similar to inputs via argument-passing (which I say in Channel Alegebra as *lambda* and *capture* being both input channels).

Nested procedures can also be used to represent branching and control-flow, like *loop* and *if-then-else* formations. For instance, *if-then-else* can be represented as a structure which involves two nested procedures: if some condition (in the outer, enclosing procedure) is true, then the first nested procedure is calld; if not, the second is called. Similarly, a *loop* takes some nested procedure and calls it repeatedly. In the simplest case, the nested procedure is called again and again until the nested procedure returns in a manner that signals the loop should be brocken off (a common keyword for this condition, e.g. in C++, is "break").

To demonstrate with a trivial concrete example, we might have pseudo-code like this:

```
int x = 0;
loop {
    if (x > 10) break;
    ++x;
} // end the loop
```

If we want to analyze the inner code-block as a distinct (but nested) procedure, we would identify how the nested implementation "captures" the x value. We also have to identify how *break* causes the nested procedure to terminate — like *return* in an ordinary channel — but does so as a signal for *loop* (in the outer procedure) to break off. In effect, a nested procedure used as a loop block has a spcial kind of output channel which can represent two possible states: *continue* the loop or *break* the loop. I will call this hypothetical channel a *control* channel after Chung-Chieh Shan [80] and Oleg Kiselyov [45] (although they work in a different underlying context). Most programming language runtimes don't actually support the more "exotic" channels I discuss here, and without runtime implementations they can remain as just theortical descriptions of programming phenomena implemented or analyzed via some theortical framework quite different from what I am calling "Channel Algebra". However, the data set accompanying this text demonstrates a runtine engine where the channel structures I describe here can be directly implemented.

I'll also mention the Link Grammar example, say an adjective as a function modifying a noun. In a formal model, an adjective is therefore a kind of "procedure" which inputs a noun and outputs a noun. In my terminology, a bread-and-butter input channel is called *lambda*, and a bread-and-butter output channel is called *return*. However, Link Grammar also recognizes various link kinds, each driven by connector-pairs. For example, consider a simple link-grammatic analysis of adjectives in the spirit of [81, p. 16]. Note that most nouns take adjectives, but some words we might want to classify as nouns don't seem to:

- (110) Today is Tuesday.
- (111) The big departmental meeting is Tuesday.
- (112) It is very windy.
- (113) The lousy weather is very windy.
- (114) They are forecasting snow.
- (115) The latest reports are forecasting snow.

We might want to consider *today*, *it*, and *they* as defacto nouns, but notice the adjectival constructions do not carry over: we can't say "big today", "lousy it", or "latest they".

In other words, some restriction on the "adjective" and "noun" types must be identified which blocks constructions like "big today" being parsed as valid examples of *big* as an adjective type-instance. One option might be to define the adjective and noun *types* more narrowly, which is more in the spirit of type-theoretic semantics. In that case, we don't take adjectives, say, as "functions" which input and output *any* noun, but rather model a suite of adjectival types operating on different noun types. For example, the adjectives *salaried* and *elected* in

- (116) She is a salaried employee.
- (117) He is an elected official.

can only be attributed to persons, so qua functions these adjectives only "input" persons, as a subtype of nouns in general. Via Link Grammmar, on the other hand, the basic theory involves adding extra conditions on the adjectives and nouns involved, which are required (along with the underlying type-compatibility) to permit the function (the adjective) to input the argument (the noun). Then *today*, *it*, and *they* cannot take adjectivs because they do not have the proper "connectors". Of course, both ideas can be combined, so we can define nouns and adjectives restricted to narrower subtypes (like person, living thing, physical object, etc.) and also marked with connectors, so adjective-noun pairings depend on compatibility both at the subtype level and the connector level.

The important point for the current context is that connectors essentially extend any type system compatible with Link Grammar, so we need to imagine an extra kind of input and output channel representing *connectors* as orthogonal to underlying Part of Speech or lexical types. In *big departmental meeting* we have to treat *departmental* as a kind of cognitive procedure modifying the concept *meeting*, and then *big* as a procedure modifying the "output" of the first procedure. Then we *also* have to represent a *connector* on *meeting* establishing that this conecpt/lexeme can be modified by an adjective, and similarly a related connector inheres to the *output* of the "departmental" procedure. So there is a kind of output-channel establishing which connectors are available on procedural outputs (connectors of the same varieties as would be available on individual words), and special input-channels which similarly model connectors which must be available on procedural inputs. I'll call these input-connector and output-connector channels. Type-thoretic semanticists like Luo and Pustejovsky might prefer to model connectors as aspects of types themselves, but we come closer to capturing the Link Grammar model if we represent the connector channels as distinct from the regular input and output channels, whose parameter-types are orthogonal to the language's connector-system.

I have, in any case, hereby presented eight different kinds of channels applicable to different programming- or natural-language constructions: *lambda*, *sigma*, *capture*, and *input-connector* on the input side; *return*, *error*, *control*, and *output-connector* on the output side (later I will introduce a few other channels). Notice that the range of different channels, each with distinct semantics and theoretical roles, extends far beyond the basic intuition that every procesure has some inputs and some outputs. Instead, type theories can evolve to capture theoretical structures in diverse domains, because many theoretical concepts can be systematically represented by describing special kinds of channels applicable to certain procedures. One way to capture data models and theoretical commitments is to envision scientific models as organized — implicitly or explicitly — around some sort of "procedures" and then analyze the various protocols by which information is mapped into and out of procedures, with the *semantics* of these protocols described by stating requirements on specialized "channels".

The notion of *channel* is therefore closely tied to the notion of *procedure*, and *types* are similarly specified via both procedures and channels. That is, most of the complex types in a type system are functional types, which in turn are characterized in part by the kind of channels used by instantiating procedures. In principle, function-types are differentiated by the *kinds* of channels they use as well as the *types* of their arguments. For example, in Object-Oriented programming, a *method* in a string class might take a string *object* (representing a string of textual characters) as the nethod "receiver", aside from *arguments*: e.g., a "substring" method would take a pair of intgers. This procedure would be considered to have a different type than an equivalent non-method function taking *three* arguments (one string and two integers) — even if both versions had the same number and types of input parameters. In C++, "pointer-to-member-function" types are never equated to function-pointer types.[4] The explanation for such distinctions in Channel Algebra is that a procedure which takes all inputs from a lambda channel has a different type than an (even if otherwise identical) procedure which takes one input from a *sigma* channel (equivalnt to the C++ *this* keyword).

In Object-Oriented environments, non-static member-functions (aka "methods") are distinguished from non-methods in part because there are different rules for resolving method-calls when a given function name refers to several different procedural implementations (such as a base-class function and a derived-class function which overrides it). This is one example of how "sigma" and "lambda" channels have different semantics: the types carried within sigma channels are more consequential for overload-resolution than those in lambda channels. Conversely, sometimes channels are not semantically significant enough to decisively differentiate types. In C++, a function which *does* throw an exception cannot be overloaded with a function which *does not* throw an exception (assuming the rest of the functions' signatures are identical). This means that — if we model type systems like that of C++ via Channel Algebra — procedurs with and without error channels can gbe the same type. But it is always possible *in principle* to differentiate function-types based on the kinds of channels their associated procedures use; just that somethimes this results in fine-grained distinctions not recognized by a particular type system.

The larger point is that function-types are specified via channels ("modulo" potential coarsening that equates types that could potentially be distinguished). Therefore, the fundamental fabric of the type system is dependent on modeling channels, because this determines how function-types themselves are miodeled; and, as I will now explicate, function-types are the logical core of almost any practical type system

6.2 *Channels and Carriers*

Most type systems take it as self-evident that any type is associated with *values* of that type, and usually *sets* of values. That is, intuitively, for any type (say, 16-bit signed integers) there is a set of values which are the "inhabitants" of that type. One weakness of this picture is that many types vary in terms of *what* set of values is actually representable in a given computational context. The case of 16-bit signed integers carries no such ambiguity; this type always has an extension equivalent to the interval -32768 to 32767 in $\mathbb{Z}$. However, consider the type of *lists* of 16-bit signed integers; depending on a program's available memory, some relatively long lists which can be represented on one computer will exceed the capacity of a different computer. Since computer code in general is not tied to a specific environment, we have to accept that for many types we do not know *a priori* what set of values conformant to that type can actually be used.

In addition to this practical problem, it is also difficult to describe exatly what a value *is*. Any instance of any type (at least in the software ecosystem) does have a numeric manifestation in computer memory — essentially an encoding as a sequence of bytes, that is, 8-bit unsigned integers — but it is not obvious that such encodings (sometimes called a "bit pattern") actually are "values" of types. In reality, computer code almost never deals with "values" per se, but rather deals with types represented symbolically in function signatures: passing "values" around from procedure to procdure. One exception to this rule is that some values are written directly into computer code — the numeric literal "10" represents a specific value (usually in some intger type). However, even here some procedure is needed to interpret the character strings in source code to the actual typed value.

Given these considerations, while I will informally talk about "values" I try to minimize the use of "value" as a technical construct in Channel Algbra. With this foundation we can consider a kind of "value free" type theory by rough analogy to "point-free" topology (and therefore distantly to mereotopology). More central than the notion of *value* is the idea of a *carrier*. A carrier is a computational construct — symbolically represented by a source-code token — which represents an instance of a type. Each carrier is associated with one canonical type (though carriers may "hold values" associated with supertypes of its canonical type). When we talk about procedures calling other procedures, we really mean that the value of symbols in one body of code (where the call-

[4]Note that C++ terminology is confusing in that pointer-to-member-functions can never point at *static* member functions (i.e., the fact that such functions are members has no bearing on their pointer-types), even though member functions themselves *can* be static.

ing procedure is implemented) is sychronized with the value of symbols in another stretch of code (where the callee is implemented). In short, at any stage of program execution, we can form groups of source-code symbols across the code base unified by the guarantee that these symbols carry “the same” value. But rather than talking of values directly we can take this syncronization between symbols as the deeper notion: the notion *value* is itself defined as the correlation exhibited by synchronized “symbols”. The notion of “carrier” is then a more rigorous extension of the notion of source-code symbols or tokens.

The difference between a *carrier* and a *type* is that carriers have aditional states. Some carriers are defind in function signatures, but others are introduced as lexical symbols in a procedure implementation. In many programming languags, lexical symbols can be *declared* before being *defined*. We can represent this scenario via a *carrier* which is in a particular *state* (I’ll call it *preinitialized*). When a carrier is initialized, it takes on a state of holding a specific typed value — *values* are defined indirectly as characteristics of carriers in initialized states. At some point (consider a pointer to deleted memory) carriers no long hold meaningful values, and they enter a state I’ll call *retired*. Introducing *preinitialized* and *retired* as carrier-states allows these to be separated from the type-system: we do not have to assume a “preinitialized” *value* which can be an *instance* of some types. In some cases, type systems *will* reognize values which play similar semantic roles to these carrier-states: for example, Haskell’s “bottom” value is an instance of every type and represents a “null” or “missing” value. However, using semenatics of carrier-states rather than type-instancs means that we do not have to introduce extra structure to type systems which we may want to model via Channel Algebra.

Carriers which can be in preinitialized, retired, or initialized states I call *tropes* (there may be only one, or multiple, initialized states for tropes). A different class of carriers are called *emblems*, and represent abstract (“emblematic”) specfications on carriers rather than carriers which hold concrete values: in effect, emblems are carriers present in function signatures. One or more carriers in an ordered list then form *channels* (though a channel can also be *empty*, with no carriers). I distinguish an *empty* channel, which exists but has no carriers, from a *vacant* channel which does not exist at all. For instance, a function that *can* throw exceptions but, at some point, has returned a normal value instead, has an *empty* error channel; a function which can *never* throw an exception (e.g. the C++ *nothrow* keyword) has a *vacant* error channel. Channels cannot include both tropes and emblems; those taking tropes are called *staged* channels, and those taking emblems are called *abstract* channels.

Carriers and channels interoperate according to several operators, which give Channel Algebra its “algebraic” character. To present these oprators I’ll also intoduce the notion of *stages*. Briefly, any procedure is broken down into a sequence of stages, each of which involves constructing some aggregate of chanels. The basic outline is as follows:

Carrier Append Any staged channel can append a trope, and any abstract channel can append an emblem (represented as $\mathcal{C}\oplus\mathfrak{c}$).

Channel Product Any collection of abstract channels can combine to a “product”, called a *channel complex*. Similarly, any collection of staged channels can become a channel *package*. A channel complex or package is generically called a channel *product*. A channel product is considered “complex” if any of its chanels are abstract. The basic channel-to-channel operator $\mathcal{C}_1\otimes\mathcal{C}_2$ represents a channel product formed by combining $\mathcal{C}_1$ and $\mathcal{C}_2$.

Carrier Handoff Given carriers $\mathfrak{c}_1$ and $\mathfrak{c}_2$, a *carrier handoff* $\mathfrak{c}_1 \looparrowright \mathfrak{c}_2$ means that the value carried by $\mathfrak{c}_1$ is (at last temporarily) carried to $\mathfrak{c}_2$. This means that there is some phase of program execution when $\mathfrak{c}_1$ and $\mathfrak{c}_2$ are synchronized, or “aligned”; exhibiting the same state (or sufficiently related) states. Alignment allows for imperfect handoffs, like coercing a floating-point number to an integer.

Digamma Reduction A channel *package* can be *allied with* a channel *complex* (written $\mathcal{C}_p\circledcirc\mathcal{C}_x$) if carriers in $\mathcal{C}_p$ and $\mathcal{C}_x$ are “alignable”. The actual description of such alignment is non-trivial; in [20] I address this in terms of hypergraph models of computer code. But in general alignment means that handoffs are possible between tropes and emblems, and if there is enough alignment the chanel *package* $\mathcal{C}_p$ can be interpreted as a call to a *procedure*, whose *signature* is modeled by the channel *complex* $\mathcal{C}_x$. In this case we have a "Digamma Reduction" operator $\varsigma\Psi\mathcal{L}$, meaning that the package $\mathcal{C}_p$ is "evaluated" and then control passes to the stage labeled $\mathcal{L}$.[5]

Each of these operators represent a step in a computational process whereby channel packages are constructed and then evaluated, which over the course of several stages (in general) provides implementation of procedures. A single operator is associated with a *microstage*, for example, appending one carrier to one channel. A sequence of microstages is than an *intermediate representation* used to translate high-level source code to data structures that can be executed direcly (or more or less directly, by interfacing to "ambient procedures", e.g. via C++ reflection). This strategy is concretely put into practice in the sample code distributed with this paper. In effect, high-level source code is "compiled" into an intermediate representation, and this IR is a more or less direct translation of Channel Algebra oprations.

One of the technical challenges of using this strategy for practical software developments involves mapping sophisticated Channel semantics to ordinary type systems. Since a language like C++ does not support the full range of channels I have presented here, the more detailed channel-complees have to be mapped to function-call semantics which C++ will actually recognize. In practice, a lot of this work involves manipulating function pointers and casting carriers to generic binary representations, like arrays of void*-pointers. These techniques are not especially relevant to the philosophical issues I am focused on in this paper, so I'll leave them to the published data set (interested readers will find a relatively complete C++ development environment, intended to be used with the Qt platform, that operationalizes the theory I am developing in this section).

At this point however I *will* comment on the overall architecture of building and then evaluating channel packages. Supporting "Digamma Reduction" in a runtime encironment requires reasonably complex C++ libraries (assuming C++ is the language of the runtime itself); but most of the Intermediate Representation is concerned with asserting carrier properties and then adding carriers to channels. Channels themselves act as stack machines, in that they can be built up like machine stacks and then cleared in the passage from one stage to the next. This is an example of a point I made much earlier, in the introduction, that computing environments ultimately involve stack machines at their most primitive level.

We are, in any case, operating here on several different semantic levels. The Channel Algebra operators define one, intermediate level whose main theme is building channel packages. At a "lower" level each package must be evaluated at runtime, for instance by converting it to a C++ function-call, so the semantic issues there are identifying the proper C++ function (or function-pointer) and marshaling the channels to mimic the C++ ABI (Application Binary Interface). Conversely, at a higher level, source-code formations are interpreted in terms of the channel products they imply: so in code like $x = y\!-\!>\!f(z)$ the implicit channels are likely populated as follows: z goes into f's *lambda* channel, y into its *sigma*, and x becomes bound to its *return* (of course whether this is the actual meaning of the code depends on the high-level language's formal grammar). This implies that grammars can be organized around the channel structures indicated by conformant code. To the degree that grammar engines adopt this paradigm they can be called *Channel Algebraic Grammars*.

This paper's data set includes one example of an implmented Channel Algebraic Grammar insofar as code written in a special high-level language is translated to a Channel Algebraic Intermediate Representation (and then evaluated). The syntax and semantics of this spcial-purpose language is, of course, only distantly related to *natural* language; I won't address whether a comparable architecture could yield a workable Natural Language Processing engine. However, the design and role of this Channel Algebraic Grammar in the *Software Language Engineering* problem-space can perhaps serve as at least an analogy for how *natural* language orchstrates the "flow" of information, and the ordering of operations, across the cognitive proceures which underly linguistic understanding. I will return to this possibility at the end of the section.

6.3 *Channels and Constructors*

As I indicated, Channel Algebra downplays the notion of typed *values* except in a derivative sense (e.g. a

[5] The motivation for the term "digamma" is first that the "sigma" in ς Calculus looksblike a smaller version of the Greek letter Digamma, and second that "gamma" is often used to represent graphs, and "digamma reduction" can be sen as a relationship between two different source-code graphs.

"handoff" means an alignment between carriers which we can picture as a value being copied). However, carriers do become initialized, and even if this initialization results from a handoff originating with another carrier, that carrier in turn had to be initialized. At some point these chains of initialization have to be grounded on some underlying data. This data may come from outside the software itself: for example, a program emulating a calculator relies on human users to type numbers on a kyboard or by pushing buttons on a User Interface. Other times values are literally written in computer code, or obtained from files, databases, or over a network.

For sake of discussion, we can limit attention to values read literally from source code. Even external data tends to depend on some numeric or string literal: reading data from a file requires specifying a file name, and obtaining data from a network location requires a URL. So computer code itself provides the primordial values from which other values circulating through the software are derived.

In a typical type system, then, at least some types should have procdures which construct values directly from source code literals. I'll call these *literal-constructors*.[6] In addition to literal-constructors, there are some procedures to create type values from other values (or from no values at all); I will call these *co-constructors*.[7]

There is no strict rule separating constructors for a type $\mathfrak{t}$ from other procedures that may return values of $\mathfrak{t}$. Intuitively, they play different roles: constructors are about creating new values, while other functions analyze or modify existing valus. The canonical examples are so-called *trivial* constructors, which take no arguments — for instance, the constructor for a list of numbers returns an empty list. Such a function surely qualifies as a constructor. On the other hand, consider a function which takes a list of numbers and returns a new list with duplicate numbers removed — such a procedure acts more as a utility function and probably would not be classified as a constructor.

The constructor/non-constructor distinction is anyhow typically left open by the programming language environment, so coders have to signal their intention to treat a given function as a constructor by some extra syntax.[8] In Channel Algebra, one option is to define a special "*construct*" channel for values output from constructors.[9] Consider the case of appending values to a list of numbers: should a function which maps $\mathcal{L}{\ll}\mathcal{X}$ to $\mathcal{L}'$ — where $\mathcal{L}'$ is the same as $\mathcal{L}$ except it has x at the end — be considered a constructor? In most functional programming languages this is actually a classical case (along with trivial ones) of constructors, because they provide the basic mechanism wherein instances of list types are defined. In other words, this *append* function seems logically anterior to other functions which may create a list — for instance, by *removing* the last element from a (non-empty) list.

Such a notion of "anteriority" can sometimes be made rigorous. If we build up a list of numbers by appending values to smaller lists, we can eventually construct any list whatsoever. We can also run this process in reverse: for non-empty $\mathcal{L}'$ there is only one way to construct $\mathcal{L}'$ from a pair $\mathcal{L}{\ll}\mathcal{X}$. In other words, an *append* constructor is "reversible". Moreover, we can repeatedly reverse constructors like thse to get shorter and shorter (and eventually empty) lists. This means that algorithms can traverse a chain of constructors "backward" and will be guaranteed to terminate. For example, to determine if a list of numbers contains the number n, it is easy to check if it *ends* with n. If not, "reverse" the construction, and see if each smaller list ends with n. Eventually we would reach the empty list, meaning that the original list did *not* have n.

The possibility of "reversing" constructors is a familiar pattern in functional programming, where it is often

[6] In C++, similar constructor-functions are called *literal operators*. This terminology only applies to "user-defined" constructors; the compiler itself handles initialization for built-in typs like integer and floats. However the overarching term "literal-constructors" is helpful for theory-focused languag-agnostic discussion about types and constructors.

[7] This terminology has the benefit of distinguishing the property of functions I call *co-constructors* from what existing programming languages call "constructors", which itself has different meanings for different languages. For example, in C++ one cannot take the address of a constructor function; however, co-constructors are implemented such that you *can* have co-constructor pointers, which is essential to the idea of "preconstructors" that I will address below.

[8] E.g. in C++ a constructor is given the same name as the type it constructs for. One consequence is that two different constructors cannot be declared without overload-resolution: each constructor has to have a different signature than any other constructor of the same type. However, the rationale for this restriction seems to be syntactic more than semantic.

[9] It is useful to pair this channel with a semantically similar channel I'll call *placement* (after "placment new" in C++) for scenarios where the constructed result should be written to a buffer provided by the calling procedure rather than returned.

called "pattern matching". It allows algorithms to be implemented in a functional style, with heavy use of recursive functions and sparing use of side-effects and mutable state. On the other hand, pattern matching relies on some simplifying assumptions that may not be consistent with all type systems. For example, C++ is laxer about how values are constructed; I can obtain a list of numbers by dereferencing a pointer to a list, with no information about the provenance of the referenced data. Data types in C++ do not usually carry around details about their "history", and it is not always easy to reconstruct that history the way we can "obviously" reverse the construction of a list.

In any case, these variations present some potentially informative characteristics about individual types. Given type $\mathfrak{t}$, we can ask questions like:

1. Which instances of $\mathfrak{t}$, if any, can be the result of a trivial constructor?
2. Does $\mathfrak{t}$ have a *default value* whish is the result of a trivial constructor?
3. Which instances of $\mathfrak{t}$ can be the result of a literal constructor?
4. Which instances of $\mathfrak{t}$, if any, can be the result of a reversible constructor?
5. If we have values which *are* the result of a reversible constructor, is there an efficient way to "un-construct" the value to support pattern matching?
6. Does $\mathfrak{t}$ have co-constructors (i.e., they are not literal) which also are neither trivial nor reversible?

Notice that a trivial constructor does not necessarily produce a default value. For example, a type meant to represent days of the week could default to whichever day is current when a constructor is called: if an application is run on Tuesday, the day-of-week trivial constructor would return the value for Tuesday. So a type may have *more than one* trivial-constructed values. But if a type has *exactly one* trivial-constructed value, this is *usually* a "default" value.

However, a type can have a default value without a trivial constructor. A defalt value plays the conceptusl role of a "fallback": 0 is a reasonable default for most numeric types. However, some numeric types don't have trivial constructors at all. Meanwhile, types representing calendar dates sometimes default to a standardized "day zero", like January 1, 1970. But a trivial constructor for such a type may instead return today's date (when the function is called). When a type has a default value, a (co-)constructor which returns that value can be called a *default* constructor.[10] As the Calendar Date example shows, types can have default and trivial constructors that return different values.

Sometimes (co-)constructors are significant even if they are not actually used. To demonstrate how this may occur, consider the problem of enforcing dependent-type constraints without using dependent types explicitly. A canonical example is a function which must take a (maybe monotone) increasing or decreasing pair of numbes (I used the monotone-decreasing example for systolic and diastolic blood pressure). Suppose we implement a procedure to highlight a selection of characters in a screen display, whose inputs are the start and end character indices in some displayed text. We want to indicate that the second number (call it y) must be greater than the first (x). Via unrestricted dependent types, we could just define the type of y as "numbers greater than x"). The problem with this type-declaration is that we therefore do not know what type y has until the function is called (and x has a value). This could violate the principle that every argument to a function must have a type which is known in advance. Alternatively, we can say that y's type "provisionally" is, say, a 32-bit integer the same as x, but it's "real" type once x is known is a dependent type that depends on x's value. Not every type system however allows for this kind of distinction between "real" and "provisional" types.

One way to assert the dependent-type restriction while avoiding these problems is to note that x and y must form a monotone-increasing pair. That is, the procedure mandates the *possibility* to create the monotone-increasing pair xy from x and y, even though the procedure does not use this pair-value directly. As a construct in Channel Algebra, we can introduce the idea of a *rider* channel which asserts the *possibility* of creating certain values without actually creating them The simplest case is suggested by this number-pair example. Let's assume we

[10] For an example of a non-trivial default constructor, consider a literal constructor for a ratio type that returns 0/1 given a malformed character string.

have an implemented type modeling monotone-increasing pairs, with a co-constructor that creates such a pair from two numbers (verifying that the two numbers are indeed monotone-increasing). We can then form a pointer to this co-constructor function, or obtain some other unique identifier for it. I call a function-pointer or similar value a *preconstructor* if it references a co-constructor. In addition to being an indirect way of calling the co-constructor, a preconstructor serves as a *certification* that the co-constructor *could* be called. For example, one way to indicate that y has been checked and is indeed greater that x is to use the monotone-increasing pair preconstructor as a kind of signal value: test for $y > x$, but if so, instead of using boolean *true* for an affirmative, use the preconstructor.

The key point here is that many conceptual details or programming requirements that concern interrelationships between values can be modeled within a type system — even without full-fledged dependent types — via preconstructros used as signal values. For a given requirement, such as "is y greater than x?", we can identify a type that *could* be constructed if (and only if) the requirement is satisfied. For instance, y *is greater than* x is true iff we can form an instance of a monotone-increasing pair type out of x and y — and so, the preconstructor for this type becomes a convnient signaling value for the affirmation of $y > x$. Conceptual requirements can be defined by modeling types whose values necessarily exhibit some significant property, and then using preconstructors to those types as certificates that the property is true (in some context). A "*rider*" channel can then be populated with one (or possibly several) preconstructors affirming facts about the values carried in other channels. For instance, a *lambda* channel holding x and y can be paired with a *rider* channel holding a monotone-increasing-pair preconstructor, certifying that y has been checked to be greater than x.

The larger point of this whole subsection is that details about the nature and existence of types' constructors can provide useful conceptual information about types themselves. Often this information dovetails with the metadata pertinent to Conceptual Space Theory and CSML. Consider a simple but representative example of an object exhibiting core Conceptual Space "quality dimensions": a colored rectangle in a computer graphics environment. This object could have some 13 dimensions: colors for the shape's interior and border (including 3-dimensional color vectors plus transparency factors); the top-left position, width, and height of the rectangle; and the width of the border. A software engineer has numerous constructor options for this type of object: should there be one "pod-tuple" constructor that takes all 13 values in a flat list?[11] Should there be distinct data types for 3-vector colors or 4-vector colors (including transparency)? Should the top-left point be merged into one 2-vector point type? The rectangle-constructor could potentially have its 13 fields folded into 5: two color 4-vectors; one top-left point; width; height; and border-width. Or border width and color can be merged into one "border" type. On top of that there is the question of default values: should pure black, or maybe pure white, be a default color for the interior? Should the border default to width-one black, or width-zero (i.e., no border), or something else? However the types are designed, there is a mutual dependency between simpler types like colors and points and the constructors for complex objects like rectangles: since complex objects are built from simpler ones, a type interface should be designed with consideration of how to assemble the whole from the parts, or retrieve the parts from the whole.

Some compound objects are conceptually analogous to basic pairs or tuples of values: 2D graphics points are 2-vectors, say, and solid colors are RGB 3-vectors. One way to signal that a compound type is like a tuple "product" of its component fields is to allow instancs of that type to be constructed just by listing each field separately. In C++, this is often implemented by defining a constructor which takes an "initializer list". Analogously, in Channel Algebra we can define a *pod-tuple* channel that serves as the *lambda* channel for pod-tuple co-constructors. A *pod-tuple* channel indicates that a given type behaves essentially like a tuple, with a sequence of values that, in most cases, vary independently of one another. These kinds of types hew closely to the Conceptual Space idea of multi-dimensional quality spacs. However, other kinds of types have more complex, interdependent internal structuration. I think Channel Algebra is a way to make Conceptual Space theory relevant for these more complex types also, using different Channel Semantics and the modeling roles of different forms of types' constructors; how these rooes reveal types' conceptual foundations.

[11] "POD" is a common coder's parlance for "plain old data", and it generally describes data structures conformant to *structs* in the C language, rather than C++ classes. A typical feature of *structs* is that they are initialized by listing all of their fields in one tuple.

Having argued for Channel Algebra as a formalization potentially relevant to Conceptual Space models, I want to conclude this section by considering how Channel Algebra msy be intuitively applicable to Cognitive Grammar.

6.4 Rider Channels and Deferred Coercions

Earlier in this section I described how Channel Algebra can represent dependent types and coercions, both of which are essential ingredients in type-theoretic semantics. I am not proposing Channel Algebra as a *literal* theory for natural language, particularly in its implemented form as a runtime and parsing environment for programming languages. However, some of its formal details for processing programming languages could be at last suggestive of procedural patterns factoring in to natural-language understanding.

Before going into detail, I think it's worth distinguishing different aspects of natural language where type theory may play a role. On one level, very general Part of Speech classifications can be approached type-theoretically. This helps reinforce the intuitive idea that syntactic categories like verbs, adjectives, and adverbs corresponds to conceptual, cognitive processes which effectuat changes in beliefs, conceptualizations, or situational records. A noun by itself is an abstract concept; during the course of a sentence, it is subject to concretization and preicatization, ending up in an idea that has some degree of concrete propositional content.

For example, we might go from *dog* to *dogs* to *those dogs* to the sentence *Those dogs are barking*. Logically we can see this as building up a propositional structure from sub-propositional parts. But cognitively the process is more like migrating from a cognitive register dealing in conceptual abstractions (like "dog") to a register for propositional attitudes and situational understanding. Logical constituents are more like stages in a concept-to-belief evolution than mereological units. That is, the relation between the signifying whole and its semantic or morphosyntactic parts is more the relationship between a process's ending to its intermediaries than a mereological hierarhy. If this picture seems compelling it can be conveyed by figuring the majority of Part of Spech types as function-like: the nature of verbs, for example, is to functionally transform (in our cognitive frames) nouns to propositions. Analogously, adjectives transform nouns to other nouns — in the sense that "red apples", say, can substitute as a noun-concept in most places that "apples" alone can; *red* being like a procedure that produces a modified *apples* concept which substitute for just *apples* in subsequent processes. Likewise, adverbs produce new verbs from other verbs; subordinators like *that* transform propositions back to nouns (as I argued in the last section), and so forth. So Parts of Speech can be usefully analyzed as "function-like" types (I will discuss specific language examples arguing for this prespective in the next section). These are, however, very general types, which would be the "uppermost" types in a natural language semantcs; I will call these *macrotypes*.

On the other hand, at a much finer level, individual lexical "cliques"[12] — the concept or extension or intensional property-set associatd with particular word-meanings — often seem to behave as *types* as well. In "Formal Concept Analysis", *concepts* are (statistically) defined as a combination of extensional and intensional criteria: neither extension nor attributes alone fully characterizes a concept, either cognitively or extra-mentally. In particular, practical fluency in a concept involves knowing canonical examples (like having seen many of the medium-size, traditionally architected dwellings that would be prototypical *houses*) and also the prototypical features that characterize the concept (houses are three-dimensional, enclosed, divided into rooms, function as a place of residence, etc.). A combination of exemplars and attribute-prototypes define the "core" or "center" of a concept: insofar as some example is "peripheral", an outlier which is somehow not representative of the concept (but still can be classified to it), it must have some *featural* difference from examplars; but we can also compare it as an individual to more exemplary individuals. That is, we understand outliers both intensionally — we can articulate the features which make both a log cabin and a gated mansion atypical as houses — and extensionally: we can mentally juxtapose cabins and mansions with ordinary houses.

If this gloss on the nature of concepts is accurate, it helps explain why the lexical entrenchment of concepts often has a type-theoretic feel. In the more logical aspects of semantics, lexicalized concepts do present

[12] Borrowing this term from [31] though I'm not using it exactly the same way

operationally as types:

- (118) A penguin is a flightless bird.
- (119) Rhinos in that park are threatened by poachers.
- (120) Baby elephants don't have tusks.

The point of these examples is that their signifying structures involve operations that can be explaind type-theoretically. In (118), a concept is charactrized via a subtype/supertype relation. In (119), a concept is being "extensionally filtered": we start with an expression that seems to designate the extension of some concept (*rhinos*) and then narrow it based on extensional criteria (*in that park*). This suggests a type/set interface similar to my analysis earlier of "students polled" (**??**). And (120) suggests an *intensional* filter, narrowing a type for contxtual purposes into a subtype that is conceptually meaningful but not entrenched: there is no common word (peer to "kitten" or "puppy") for *baby elephant*.

All of these operations — fine-tuning concepts to the specific ideas salient in a specific signifying act — have plausible representations based on a concepts-as-types analogy, and suggest another level where type theory could be an effective formalizing tool. But in this case, we are discussing the almost minimal groupings of a linguistic hierarchy, individual word-senses — I'll call these *microtypes*.

Meanwhile, in between coarse Part of Speech types and fine lexical "cliques" are the kinds of Ontologically-characterized categories or "lexical sorts" [58] associated with linguists working in a formal type-thoretic vein, like Zhaohui Luo and Bruno Mery. I will call types in this vein *mesotypes*, being intermediate in generality between individual lexemes and syntactic categoires (Parts of Speech and their refinements, like plural nouns). The broad philosophical implications of mesotypes is that they give some formal traction to what happens cognitive-procedurally when we negotiate between different word senses and/or use language in seemingly metaphoric (but not unrestricted) ways.

Consider these exmples:

- (121) My favorite Korean restaurant is adjacent to the bookstore.
- (122) My favorite Korean restaurant is closed today.
- (123) My favorite Korean restaurant is decorated with posters from the 2002 World Cup.
- (124) My favorite Korean restaurant started out in a food court.
- (125) My favorite Korean restaurant said I'm their most loyal customer.
- (126) She's constantly barking at her employees.
- (127) He's not playing well because his back is barking at him.
- (128) He's not playing well because his sore back is acting up.
- (129) The kitten barked at the dog.

The first three profile (using Langacker's term) a restaurant as a location, a building (with commercial and architectural properties), or an institution/organization. Note that we can distinguish the commercial/architectural sense from the institutional sense: to *close* can be temporary (as in 122), which we hear in conjunction with the former sense, or more permanent as in "cease operations", i.e., close "qua institution". The former sense seems to mix the institutional and location sense: while location is not explicit as in (121), an asserion that some *chain* restaurant is closed today would usually be heard as referring to one location, not the entire chain. In (126) through (129), a common idiom applies "bark" to things that are not dogs; but this is not just a matter of metaphor, blending different "spaces" with no conventionalizing pressues. The (126) and (127) senses are rather entrenched, using *bark* to suggest something a little obnoxious or mean. But (129) does not sound right, even though it is no more of a strecth to imagine a kitten's hissing as argry bark-like than a boss's orders. Perhaps the *literal* similarity between cats and dogs maks the figurative usage harder to accept as a purported abstraction from literal situations.

The conventional type-semantic picture is that language has a collection of (what I am calling) "mesotypes" and we modulate word-uses by switching between this medium-grain types, sometimes in unexpected ways. An effective way to develop such an analysis is to identify one or two senses as the most prototypical for some concept/lexeme, and read other senses as transforms involving other types. So the commercial/architectural mesotype may be canonical for *restaurant*, and then we branch out to a more geo-spatial sense (*where* the building is located), or institutional (the food-court incarnation may have been in a different place with diffrent staff and business classification). Hence a *commercial* *building* type is "cast" to a geosptial point or to a social institution. Thse "casts" are not really metaphors; they have conventions, limitations, and rules.

The mainstream theory is simplest when analyzing casts between mesotypes of similar gnerality, like plant-to-sentient in "flowers like water" or cerebral-to-physical in "heavy thoughts". But not all casts follow this recipe: (126) and (127) seems to cast from a *microtype* to a *mesotype*. The construction in (128) is a common "personifacation" of medical/anatomical concepts — a similarly scalar idiom is cases like *my arthritis is acting up*, or *flaring up* to render figure ailment as physical rather than personalistic — but here we care operating between typs of comparable Ontological granularity (anatomical part/medical ailment to person/physical thing) But semantically and syntactically (128) seems a lot like (126), even though the ploy in that case is to compare things to a lexical "clique" (dogs). And in (125) we infer that some *person* complimented the speaker, but this is more of a synecdoche than a cross-type cast like (124)-(124): the point is not that a restaurant has a personhood "aspect" that can be highlighted (the way it *does* have an architectural or geo-spatial aspect) but that reference to the restaurant can be proxy for people closely associated with it.

Another complication for type-cast theories is potential ambiguity between word-senses and coercing "usages", as in:

- (130) Tea-smoked duck is a Sichuan delicacy.
- (131) The baby's favorite toy is a rubber duck.
- (132) Wedding ducks are traditional Korean gifts.

If the prototypical duck sense is an animal, these cases disrupt the basic type hierarchy: Wedding ducks are made of wood; tea-smoked duck is a kind of food; rubber ducks are toys (is the phrase descriptive — ducks which happen to be rubber — or a distinct noun-concept, like *decoy duck*?). This translation from one branch of sub/supertype relations to another is what we would expect of type-cases, but we can also see these cases as distinct lexemes, or word-senses, or entrenched phrases with *de facto* lexical status. The overall picture which seems to emerge is that type-coercions remain relatively metaphorical or metonymic in cases like (126) or (125); become idiomatically entrenched in cases like (121) and (124) — especially where there is a similar scale of granularity btween mesotypes in a coercion — and can become *lexically* entrenched in cases like (131)-(132).

Let's assume in any case that we can give a thorough analysis of type-coercions as semantic devices. This is still working on the level of generalized lexical use-patterns; we are not studying the *cognitive* steps involved in actuallly making whatever imagistic, situational, or conceptual modifications are directed by a type-cast. In other words, there is a cognitive process of thinking of a restaurant (say) and then revising this framing to accommoate senses like spatial points or social institutions. We can weave different senses and coercions into one sentence:

- (133) This book, which costs $40, has some crazy ideas inside.
- (134) This book, which the library classifies as young adult nonfiction, has some dude's phone number scrawled inside.
- (135) My boss barks louder than his dog does.

In short, we can't assume that type-coercions simply replace an image forged according to one micro- or mesotype with one shaped by an alternative type. Instead, signifying elements seem to carry a package of type attributions around, and different types are "activated" to different extents, and in different ways, at different stages of linguistic processing.

Another complication is that types of different scales seem to coexist and yet in other respects macrotypes, mesotypes, and microtypes seem to be distinct hierarchies. A microtype like *dog* acts sometimes as a subtype for a mesotype like *animal*, but also mesotype concepts like *animal* and *person* are sometimes microtypes themselves: after all, these are lexical entries as well as Ontological categories. So on the one hand we may say that words have three different types — even excluding cross-mesotype or cross-microtype ("bosses barking" cases) casts — and that macro-, meso-, and microtypes are distinct thoretical posits with different analytic mthodology; but sometimes the boundaries between micro- and meso, and thir analyses, seem to blur. Analogous comments can apply to the meso/macro boundary as evinced by issues like classifying forms of pluarality, as in [57]'s analysis of noun plurals.

This metathoretic hemming and hawing may be acceptable — even desirable — at the philosophical level. But it causes problems if we want to see type theory as a formalizing (albeit simplifying) window onto cognitive-linguistic processes. In a computational context values have one canonical type; they can be cast to other types but do not maintain a kind of superposition "history" over multiple types. These kinds of phenomena can be technically modeld in various ways (e.g. Luo's "dot-product" types), but in that case we want a formalization that seems appropriate for how the corresponding cognitive procedures might unfold.

In the case of Channel Algebra, I mentioned the idea of "rider" channels which supplement the type information contained in other channels, adding more information without actually introducing new parameters into a proceure. So a rider asserting that y can be made into an xy pair is semantically analogous to giving y the type *integer greater than* x, but y itself is not presented as having a dependent type. In short, *greater than* x is not presented as an *alternative* type for y, nor is $y > x$ presented as an alternative *value* as if we are "casting" y from a wider to narrower type. However, we are asserting properties of y by certifying that such casts *would* be possible.

I think this may be a useful analogy to how type-casts work in practice in Natural Languages, especially in complex cases where multiple word-senses are involved. Not every type associated with a word makes sense in every conceptualization. When, for instance, we attend to the conceptual properties of a book as an intellectual object, there may be physical details which are conceptually incompatible with this attitude. It would be simpler if there were a neat partition among senses, and some overarching cognitive order — Ok, now we're figuring the book as physical; now it's an intellectual artifact; now it's a commodity — supervises the coercions back and forth. Neither semantic nor syntactic evidence warrants this simpler picture: it seems more as if conceptualization across types is a matter of networked cognitive procedures taking turns operating on one conceptual package, where latent type atttributions are available to each procedure whether or not they are "usable" in the sense of involving type structures that logically fit each procedure's purpose.

I will give concrete cases of word-senses that I think substantiate this picture in the next section. Here, though, I'll conclude as follows: Channel Algebra can perhaps model what is going on insofar as procedures can take "rider" channels that can add detail to procedural inputs. In a cognitive-linguistic setting, we can imagine these riders as multifaceted and complex. Because riders are not part of procedures' actual inputs, they do not necessarily need to use types that the procedure recognizes or knows about; the riders may only come into play as values are passed among procedures. The analogous computational case would be some extra data associated with a value that is only relevant for certain security-oriented validations; i.e., permissions to modify a file. Functions can pass around such values without considering the security-related data, except for a few procedures where security-sensitive operations are attempted. So the security details are "part" of the data carried by a value, but only become semantically salient parts in certain procedural contexts. Rider channels are a way to represent this kind of extra information within a type system directly. I think they are a plausible analogy for cognitive re-inscriptions that occur in the evolving significations in a sentence, according to analyses like I will entertain in the next section.

7 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 [46], [73], [56], [28]; [14]; [21]. 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 SOV 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 (propositional) 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 [55], [70], [57]. 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, however, 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.

7.1 *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" [15] (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 types 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 latter 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".[13] 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.

Moreover, expectations 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 by documentation and unit testing). So state-space in a given context may 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.[14]

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.[15] 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

[13] 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.

[14] 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 [2], and it is very interesting to juztapose scientific and mathematical treatments of Conceptual Spaces (as in [90] or [32]) with mathematical (e.g., topological) thoeries of data types [27], [74].

[15] 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 [40] (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).

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 ([49, p. 18]; [41, p. 171, or p. *xi*]) and embodied/enactive patterns of interaction ([49, p. 90]; [41, 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 sets 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 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 [106], [10], [104]. 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 (136 repeats 119):

- (136) Rhinos in that park are threatened by poachers.
- (137) Young rhinos are threatened by poachers.

Both sentences focus a conceptual lens in greater detail than *rhino* 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 rhinos", in the sense of *existing* rhinos, 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 $\mathfrak{t}$ there is a corresponding "higher-order" type of *sets* whose members are $\mathfrak{t}$.[16] If we take this (higher-order) type gloss seriously, the extension of a concept is not its *meaning*,

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

but a different, albeit interrelated concept. Extension is not definition. *Rhino* does not mean *all rhinos* (or *all possible rhinos*) — though arguably there are concepts *all rhinos* and *all restaurants* (etc.) along with the concepts *rhino* 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 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.[17] 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" [86]; cognitions allow it to be latent against the disclosures of material consciousness [84], [85], [107], [42]. So the contrast between singular, mass-multiples, and count-multiples, among nouns, depends on cognitive construal of the behavior of

[17] 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 all over the driveway" from Pinker [69] on page 119 and Langacker's "Nouns and Verbs" [50] on page 67.

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).[18] 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 multidimensional 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 "rhino" means the concept *rhino* ("type" in the sense that type-theoretic semantics would model lexical data according to type-theoretic rules, such as *rhino* 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 schemata 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.

[18] 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 know about the cake ahead of time, apparently uses "bake" in the broader sense of "made", not just "cooked in an oven". Words' senses mutate in relation to the kinds of situations where they are used — why else would *bake* mean "make"/"prepare" in the past or future tense but "cook"/"heat" in the present?

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, 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 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:

- (138) I got glue for your daughter.
- (139) 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

- (140) We’re going to Grandma!
- (141) Let’s go to him right now.
- (142) Let’s go to the lawyers.
- (143) 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 $\mathfrak{t}$ there are mass-plural and count-plural collections of $\mathfrak{t}$, ordered and unordered $\mathfrak{t}$ 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 *rhino*, *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 nonspatial (/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 which have their own types. This introduces one form of head/dependent relation, where a head word instances a function-like type and is applied to one or more "dependents".

- 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 of links mandate particular type interpretations of the links elements: TS links,[19] to cite a narrow example, would only be formed 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.[20]

- 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.[21] 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

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

[20] 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".

[21] Monoids: [25]; Tensors: [55]; Continuations: [9]; Combinators: [98]; Side Effects: [77]; Monads: [33], [76], [46]; Topology: [68], [18].

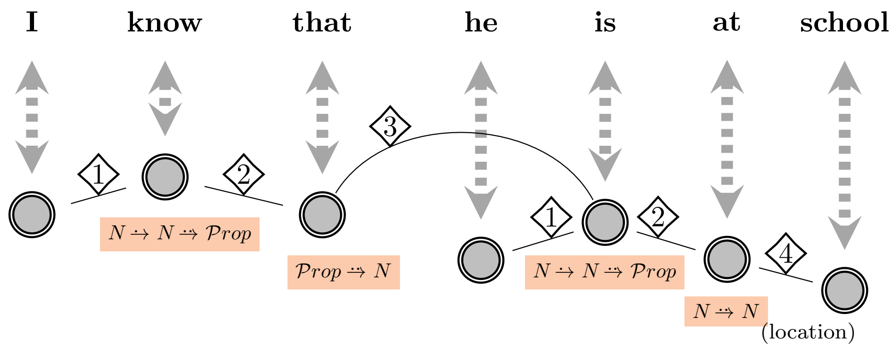
as a presumed fact designated as one idea, for the sake of making further comments, as if "making a noun" out of it: $\mathcal{P}rop \dashrightarrow N$. Perhaps our intuitions are more as if *that he is at school* is also a proposition, maybe a subtly different kind, by analogy to how questions and commands 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 $V :: N \dashrightarrow N \dashrightarrow \mathcal{P}rop$ 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 1 shows one potential, rather simplified 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 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. Perhaps cognitive schema occupy an intermediary role: progressing from basic recognition of grammaticality, 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 $V :: N \dashrightarrow N \dashrightarrow$

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)

$\mathcal{P}rop$ signature). Cognitive ascriptions fill this out by adding detail to the broader-hewed typing, associating 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 inanimate things 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.

8 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; [59]), and Anglo-American writers in the "Naturalizing Phenomenology" tradition, there is evident interest in mathematics *apart from* logic: topology, differential geometry, mereotopology, multi-granularity.[22] Phenomenology therefore un-

[22] 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 philo-

covers 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 **??**): our environing world mostly discloses itself through 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 [90]). This kind of transformation, described (say) via differential geometry, is *qua* theoretical device an example of semiotic morphism, a mapping between representation disciplines [35], [34]. 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.[23] 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, interword 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

sophical 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.

[23] 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.

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 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.

The Cognitive-phenomenological project is very different, I believe, than the AI or Atificial General Intelligence projects. Nevertheless, as I noted to conclude Section 5, AI — for all its reductive ideology — does show the benefits of an intellectual framework where researchers can experiment, try things out, and write code. We should not underestimate the power of technology and experimentation to ground and engage the scholarly process:

it allows the scholar to program her own research environment, autonomous as necessary from academic and institutional paradigms — which, notwithstanding a general acaemic commitment to innovation, can get mired in inertia: particularly when it comes to interdisciplinary methodology and particularly when it comes to reengineering the publishing process and the dissemination of scholarship. There is a lot of technical and technological potential which in the acaemic and publishing communities is not being realized.

This is not just a procedural claim tangential to actual scholarly argumentation: we need new generations of publishing tools to properly syntheize computational technology with nonreductive, humanities-based philosophies of mind and consciousness. We need to properly implement the technological tools that empowe individual scholars, without buying uncritically into academic and corporate appropriations of technology for regressive ends.

At the risk of seming to conclude with an infomercial, I'll cite as an example the Conceptual Space Type Theory and Type Expression Language (CSTX), which is currently used in the context of scientific data publication (see my forthcoming chapter in [20]). CSTX presents a flexible type theory that can model both natural-langauge phenomena (such as Link Grammar, the internal parsing formalism in OpenCog, and the type-theoretic semantics favored by linguists such as Zhaohuu Luo or James Pustejovsky) as well as formal-language specifications for Software Language Engineering and Requirements Engineering. CSTX allows linguists to consider a type-theoretic representation of linguistic data, or language-as-interface "intermediate structures", *without* presuming that automated (AI/machine-learning) systems could necessarily generate Intermeiate Representations without human intervention. It is not a "practical" software system in the AI sense of enabling useful human-like behavior.

On the other hand, since CSTX *also* provides concrete software-development tools, it does have practical uses outside the AI paradigm. In this sense it perhaps serves as a case-study in concrete software whose practical dimension spurs hands-on experimentation and decentralized, extra-institutional open-source collaboration, but whose theoretical commitments gravitate to cognitive linguistics and phenomenology — while bypassing an AI paradigm that underestimates the cognitive importance but complexity of social-situational awareness and of sensate consciousness. AI is not a canonical arbiter of software practicality (our contemporary instinct toward measuring all software around AI-driven analytics and "Big Data" reflects a clever marketing campaign by companies with financial incentives to prioritize AI research over other disciplines). Nor is AI a value-neutral or politically progressive vision of what human mind and society are like.

Perhaps this is part of what it means to be a phenomenologist in the 21st century: not to reject technology or computational models or to believe in a mode of phenomenological research carried by pure thought, but to embrace — as part of the research infrastructure, of our own respective academic identities — practical software that suggests interesting cognitive-humanistic paradigms without endorsing reductive AI hypotheses. Insofar as scholarship is a social phenomenon, the metaphilosophy of "pure thought" is an illusion anyhow: theory is inevitably mediated by the disciplinary expectations of its audience. Given this reality, software offers a renewed agency and autonomy to the researcher: computer code does not intrinsically know from disciplinary norms, and the code-writer is programming a medium where disciplinary boundaries can fade out — if the program compiles. The programmer does not *argue* for interdisciplinarity; she *implements* it.

Technology, in conclusion, can liberate scholarship from disciplinary inertia in the same gesture as open-source software liberates technology itself from commercial oligarchizing. Good open-source software programs monetary inequalities out of existence; as humanities scholars we have an analogous duty to program disparaties in intellectual capital and influence out of existence. Open-source software is the fiat currency of the digital commons; by analogy, phenomenology is the liberation theology of the intellectual commons. We don't argue for a just and existential foundation of the humanities and the natural/social science interface: we implement it.

Sophisticated but philosophically and morally responsible cognitive-computational paradigms are probably more likely to arise from adding formal methodology and open-sourc experimentalism to a fundamentally humanities foundation, rather than bringing sensitivity to human nuance to a natural-science academic tradition. The reasons for this are institutional as well as intellectual: insofar as formal-computational models are still rather unfamiliar in humanities contexts, practitioners in a hybrid cognitive-computational-humanities orientation can have a level of autonomy that helps us distinguish sophisticated computational models from simplistic philosophical (and commercial) paradigms. And the affordances of open-source code and digital publishing supports a robust but low-cost technological environment, tangential to academic laboratories and hierarchies.

Perhaps this open-source ecosystem is a worthy 21st-century field wherein to continue 20th-century phenomenology. Let's not forget that phenomenology began as a philosophy of mathematics but evolved into a moral, political, and Existential system. Honoring the subtelty of human consciousness is a way to respect the technical priorities of phenomenological philosophy but also the political activism that — certainly often rendered into praxis by the intersectionality of lived experience with race, class, and gender — follows from phenomenological ethics.

Kant's critical philosophy did not only inspire generations of abstract Idealism; it spurred the cosmopolitan ideal of a Community of Nations and the municipalist axiology of, in particular, Kant's 19th century French translator, Jules Barni. Our communal existence is not intrinsically, cognitively, tribal or chauvinistic: the basic adaptation of human minds to ecologies transcends race, class, and culture. Cultural differences are real, but extrnal: enculturation is minds being shaped by the natural and civil infrastructure around us. While preserving nation and comunity as a practical medium, Kantianism unmasks nationalism as a metaphysical gambit. This is perhaps how, for Barni, Critical Philosophy flows organically into municipalist activism: to understand the mind we have to embed ourselves into the cognitive patterning of mind, which means the environs where cognition is honed, which means our urban and neighborhood ecologies. The architecture of cognition lies not only in the cultures we receive via transmission — religion, education, inter-generational ideologies — but in the grid of the streets outside our front door.

The axis from Kant to Barni has 21st century analogs: Husserl as our Kant, and progressive ethical frameworks like Murray Bookshin's libertarian municipalism taking the mantle from Barni's post-1848 variety. But one key difference is that communities are now partly (though of course not entirely) digital, virtual, and technological. So, I believe, part of being a phenomenologist in the 21st century is to — as much as we can, and virtually if need be — implement a municipalism in our time that metastatizes Husserl in a recapitulation of how, for example, Barni metastatized Kant. This is not just an abstract exercise, because intellectuals are performing their commitment to humanities scholarship, to the progressive and cosmopolitan spirit of humanitis discourse, in environments far mor challenging than we associated with Western academia — Budapest; Rojava. This is part of what I had in mind referring to "phenomenological ethics".

Wes Enzinna, a New York Times reporter who taught a journalism class at the Mesopotamian Social Sciences Academy in Qamishli, told a story (in the Times Sunday Magazine, November 29 2015) about his reconciliation with students after a brief culture-shock-like falling out:

> "We reject the master-and-slave relationship as a model for the teacher-and-student relationship," Ali said. "But we've decided that you're welcome to continue teaching us." Ramah, the atheist, stood up and said, "I'm so happy you're here." They all approached my desk and turned in their assignments.

Sherhad Naaima, another Kurdish activist a few months earlier, put it this way (in an interview with Eleanor Finley from the Institute for Social Ecology in Vermont):

> History is a river, it cannot be cut. We have no West or East, but rather one history which is moving and retaining all human culture ... [T]he Left needs to dive deeper into hidden history and revive their own traditions of freedom and the idea of a utopia of freedom. They then must build a holistic theory provided by the unity of natural sciences and social sciences. That new theory can be called "the epistemology of freedom".

These testimonies are what "to the things themselves" means today.

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