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Challenges to the What, When, and Why?

Berwick, Robert C. & Noam Chomsky. 2016. *Why Only Us: Language and Evolution*. Cambridge, MA: MIT Press.

by Marc D. Hauser

Why Only Us (WOU) is a wonderful, slim, engaging, and clearly written book by Robert C. Berwick and Noam Chomsky (B&C). From the authors' perspective, it is a book about language and evolution. And of course it is. However, I think it is actually *about* something much bigger. It is an argument about the evolution of thought itself, with language being not only one form of thought, but a domain that can impact thought itself, in ways that are truly unique in the animal kingdom. Seen in this light, *WOU* provides a framework for thinking about the evolution of thought and a challenge to Darwin's claim that the human mind is only quantitatively different from other animals. Since this is an idea that I have championed (Hauser 2009), I am of course a bit partial. Let me unpack all of this by working through B&C's arguments, especially those where we don't quite agree.

One caveat up front: As I have written before, including with B&C (Hauser et al. 2014), I am not convinced that the ideas put forward here or in *WOU* are testable: Animal capacities are far too impoverished to shed any comparative light on the evolution of human language, and the hominid fossil record is either silent or too recent to be of interest. My goal here, therefore, is to focus on the fascinating ideas raised in *WOU*, leaving to the side how or whether such ideas might be confronted by significant empirical tests.

One of the essential moves in *WOU* is to argue that Merge—the simplest recursive operation—is the bedrock of our capacity for infinite expression by finite means, one that generates hierarchical structure. Because no other animal has Merge, and because Merge is simple and the essence of language, the evolutionary process may well have occurred rapidly, appearing suddenly in only one species: modern humans or *Homo sapiens sapiens (Hss)*. To accept this argument, you have to accept at least five premises:

- (1) Merge is the essence of language.
- (2) No other animal has Merge.
- (3) No other hominid has Merge.
- (4) Due to the simplicity of Merge, it could evolve quickly, perhaps due to mutation.
- (5) Because you either have or don't have Merge (there is no demi-Merge), there is no option for proto-language.

This piece originally appeared as a post on the *Faculty of Language* blog on 29 February 2016 (http://facultyoflanguage.blogspot.com.cy/2016/02/hauser-reviews-why-only-us.html).



I accept (2) because the comparative literature shows nothing remotely like Merge. Whether one looks at data from natural communication, artificial language learning experiments, or animal training studies with human language or language-like tokens, there is simply no evidence of anything remotely recursive. As B&C note, the closest one gets is the combinatoric gymnastics observed in birdsong, but these are neither recursive nor do they generate hierarchical structures that shape or generate the variety of meaningful expressions observed in all human languages.

I also accept (3), though here we don't really have the evidence to say one way or the other, and even if we did, and it turned out that say Neanderthals had Merge, it wouldn't really make much of a difference to the argument. That is, the fossil record for Neanderthal, though richer than we once thought, says nothing about recursive operations, and nor for that matter does the fossil record for *Hss*. Both records show interesting signs of creative thought—a topic to which I return —but nothing that would indicate recursive thought or expression. If evidence emerges that Neanderthals had Merge, that would simply push back the date of origin for B&C's evolutionary account, without changing the core details.

Let's turn to (1), (4), and (5) then. What is interesting about the core argument in *WOU* is that, although B&C place significant emphasis on Merge, they fully acknowledge that the recursive machinery must interface with the Conceptual-Intentional system (CI) on the one hand, and with the Sensory-Motor system (SM) on the other. However, once one acknowledges the non-trivial roles of CI, SM, and the interfaces, while also recognizing the unique properties of each of these systems, it is no longer possible to accept premise (4), and challenges arise for premise (5). This analysis lays open the door to some fascinating possibilities, many of which might be explored empirically. I consider a few next.

B&C devote some of the early material of WOU to review work on vocal imitation in songbirds, including comparative genetic and neurobiological data. In some ways, the songbird system is a lovely example because the work is exquisitely detailed and shows some nice parallels with our own. In particular, songbirds learn their song in some of the same ways as young children learn language, including evidence of an innate system that constrains both the timing and material acquired. However, there are elements of the songbird system that are strikingly different from our own, not mentioned in WOU, but when acknowledged, tell an even more interesting tale about the evolution of *Hss*—one that is at the same time supportive of the uniqueness claims in WOU while also raising questions about the nature of the uniqueness claim. Specifically, the songbird system is a striking example of extreme modularity. The capacity of a songbird to imitate or learn its species-specific song is not a capacity that extends to other calls in its vocal repertoire, nor to any visual display. That is, a songbird can imitate the song material it hears, but nothing else. Not so for our species, where the capacity to imitate is amodal, or at least bimodal, with sounds and actions copied readily, and from birth. This disconnect from sensory modality is a trademark of human thought, and of course, is a critical feature of our language faculty: At virtually all levels of detail, including syntax, semantics, phonology, and pragmatics as well as acquisition, there are no differences between signed and spoken languages. No other animal is like this. Whether we observe

songbirds, dolphins, or non-human primates, an individual born deaf does not emerge with a comparably expressive visual system of communication. The systems of communicative expression are intimately tied to the modality, such that if one modality is damaged, other modalities are incapable of picking up the tab. The fact that our language, and even more broadly, our thoughts, are detached from modality, suggests a fundamental reorganization in our representations and computations. This takes us to CI, SM, and the interfaces—and Merge.

Given the modularity of the songbird system, and the lack of imitative capacities in non-human primates, we also need an account of how a motor system capable of imitating sounds and actions evolved. This is an account of how SM evolved, but also about how and when SM interfaced with CI and Merge. There is virtually no evidence on offer, and it is hard to imagine what kind of evidence could emerge. For example, the suggestion that Neanderthals had a hyoid bone like *Hss* is interesting, but doesn't tell us what they were doing with it, whether it was capable of being deployed in vocal imitation, and thus, of building up the lexicon. And of course, we don't know whether or how it was connected to CI or Merge. But whatever we discover about this account, it showcases the importance of understanding the evolution of at least one unique property of SM.

When we turn to CI, and in particular, lexical or conceptual atoms, we know extremely little about them, even in fully linguistics human adults. Needless to say, this makes comparative and developmental work difficult. But one observation seems fairly uncontroversial: Many of our concepts are completely detached from sensory experiences, and thus can't be defined by them. If we take this as a starting point, we can ask: Do animals have anything remotely like this? On one reading of Randy Gallistel's elegant work, the answer is "Yes" (e.g., Gallistel 1990). All of the empirical work on number, time, and space in animals suggests that such concepts are either not linked to or defined by a particular modality, or minimally, can be expressed in multiple modalities. Similarly, there is evidence that animals are capable of representing some sense of identity or sameness that is not tied to a modality. If this is right, and even if these concepts are not as abstract as ours, they suggest a potential comparative approach that at this point, seems closed off for our recursive capacity. Having a comparative evolutionary landscape of inquiry not only aids in our analyses, it also raises a challenge to premises (4) and (5), as well as to Richard Lewontin's comment (supported by B&C) that we can't study or understand the evolution of cognition (Lewontin 1990). Let me take a small detour to describe a gorgeous series of studies on the evolution of cognition to show what can and has been done, and then return to premises (4) and (5).

In most monogamous species, the male and female share the same home range or territory. In polygynous species, in contrast, there are several females associated with one male, and thus, the male's home range area encompasses all of the smaller female home ranges. Based on this observation, Steve Gaulin and his colleagues (e.g., Gaulin & Wartell 1990; Jacobs et al. 1990; Puts et al. 2007) predicted that the spatial abilities of a monogamous vole would show no sex differences, whereas males would show greater abilities than females in a closely related polygynous vole species. Using a maze running task to test for spatial capacity, results provided strong support for the prediction. Further, the size of the hippocampus—an area of the brain known to play an important role in spatial navigation—was significantly larger in males of the polygynous species when contrasted with females, whereas no sex differences were found for the monogamous species. This, and several other examples, reveal how one can in fact study the evolution of cognition. Lewontin is, I believe, flatly wrong.

Back to premises (4) and (5). If nonhuman animals have abstract, amodal concepts—as some authors suggest—then we have a significant line of empirical inquiry into the evolution of this system. If our concepts are unique—as authors such as B&C believe-then there may not be that many empirical options. Perhaps Neanderthals have such concepts, perhaps not. Either way, the evolutionary timescale is short, and the evidence thus far, relatively thin. On either account, however, there is the pressing need to understand the nature of such concepts as they bear on what I believe is the most interesting side effect of this discussion, and the issues raised in WOU. In brief, if one concedes that what is unique about language, and thus, its evolutionary history, is Merge, CI, SM, and the interfaces, then a different issue emerges: Are these four ingredients unique to language or part of all aspects of human thought? Said differently, perhaps WOU is really an account of how our uniquely human system of thought evolved, with language being only one domain in terms of its internal and external systems of expression. B&C often refer to our Language of Thought, as the core of language, and what is our most dominant use of language: internal thought. On this view, externalization of this system in expressed language is not at the core of the evolutionary account. On the one hand, I agree. On the other hand, I think the use of the term of 'Language of Thought' or LOT has confused the issue because of the multiple uses of the word 'language'. If the essence of the argument in WOU is about the computations and representations of thought, with linguistic thought being one flavor, then I would suggest we call this system the Logic of Thought. I suggest this substitution of L-words for two reasons. Language of Thought implies that the system is explicitly linguistic, and I don't believe it is. Further, I think Logic of Thought better captures the abstract nature of the ingredients, including both the recursive operations, concepts, motor routines, and interfaces.

The Logic of Thought, I would argue, is uniquely human, and underpins not only language, but many other domains as well. It explains, I believe, why actions that appear similar in other animals are actually not similar at all. It also provides the ultimate challenge to Darwin's argument that there is continuity in mental thought between humans and other animals, with differences attributable to quantity as opposed to quality. In contrast, if the ideas discussed here, and ultimately raised by B&C are right, then it is the Logic of Thought that is unique to humans. The Logic of Thought includes all four ingredients: Merge, CI, SM, and the interfaces. How these components are articulated in different domains is fascinating in its own right, and raises several additional puzzles. For example, if Merge is the simplest recursive operation, is it one neural mechanism that interfaces with different, domain-specific concepts and actions, or were merge like circuits effectively cloned repeatedly, each subserving a different domain? The first possibility suggests that damage to this singular Merge circuit would reveal deficits in multiple domains. The second option suggests that damage to the Merge circuit in one domain would only reveal deficits in this domain. To my knowledge, there is no evidence of neuropsychological deficits or imaging studies that point to the nature or distribution of such recursive circuitry.

In sum, *WOU* is really a terrific book. It is thought provoking and clear. What more could you want? My central challenge is that it paints an evolutionary account that can only work if the essence of language is simple, restricted to Merge. But language is much more than this. As such, there has to be more to the evolutionary process. By raising these issues, I believe B&C have challenged us to think about another option, one that preserves their title, but focuses on the logic of thought. Why only us? Much to think about.

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★ FORUM ★

The Human Oscillome and Its Explanatory Potential

Elliot Murphy

My intention in this piece is to briefly outline a novel hypothesis regarding the neurobiological implementation of feature-set binding, the labeling of feature-sets, and the resolution of linguistic dependencies arising from the cyclic combination of these labeled objects. One of the numerous motivations for this was reading Robert C. Berwick & Noam Chomsky's (B&C) recent book *Why Only Us: Language and Evolution* (Berwick & Chomsky 2016; henceforth *WOU*), which struck me as moderately comprehensive in its interdisciplinary scope (including good critical commentary on recent work in comparative neuroprimatology and theoretical biology) but severely impoverished in its range of linking hypotheses between these disciplines.

While the authors are correct to point out that the Strong Minimalist Thesis follows the 'divide-and-conquer' approach which helps narrow the gap between disciplines, their actual implementation of this approach is fairly mild and uninstructive. There is lots of talk about how language is "an 'organ of the body', more or less on a par with the visual or digestive or immune system" and how it is "a subcomponent of a complex organism" (p. 56), accompanied by the usual discussion of the Newtonian dispelling of the mind-body problem—all of which is true, unequivocal, undeniable, but directionless and intensely vague. B&C discuss Lenneberg's early work on language evolution, deeming it "a model of nuanced evolutionary thinking" (p. 5), but as Lenneberg (1964: 76) himself noted, "[n]othing is gained by labeling the propensity for language as biological unless we can use this insight for new research directions-unless more specific correlates can be uncovered". The absence of concrete linking hypotheses between the domains of the life, cognitive, and biological sciences in WOU, and its concern with isolated and disparate sources of evidence which lend support to an emergentist model of language evolution, whatever its merits, does not promote this kind of cross-disciplinary collaboration. I think that from the perspective of brain dynamics, what the authors call the "Basic Property" (Merge) can be explored in a number of interesting and fruitful ways, promoting further interdisciplinary work and relying on a neurolinguistic perspective which, unlike WOU, goes beyond the cortex and examines the important role of subcortical structures like the thalamus and basal ganglia.

To set the scene for what follows, it is useful to consider the framework in Boeckx & Theofanopolou (2015), which highlights the inadequacy of standard

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cladistic thinking so prevalent in much of contemporary biolinguistics (most notably in the FLN–FLB distinction, under which the 'Basic Property' was simply added 'on top' of faculties shared with other species, as if no reciprocal causation had occurred). Boeckx & Theofanopoulou "very much doubt that cognition can be studied independently of the basic neurophysiological principles that produce it", going against the many 'Marr Misreaders', as I term them in Murphy (forthcoming), who claim that the three Marrian levels need to be studied in a segregated fashion, privileging the computational level.¹ For instance, while computationally distinct, music and language share a number of important algorithmic properties such as prediction, synchronization, turn-taking, and oscillatory entrainment (Doelling & Poeppel 2015). This seems to emerge from cell assembly specializations and distinct rhythmic profiles; language and music have different hierarchical processing networks but shared working memory and cognitive control systems (Rogalsky et al. 2011).

Much work in contemporary neurolinguistics appears instead to be effectively crypto-creationist in its monolithic approach to language implementation and evolution, discussing it in terms of 'syntax', 'phonology', and other complex categories—similar to an ophthalmologist speculating about the evolution of 'red' and 'green'. Top-down perspectives, of the kind proposed in *WOU*, are useful up until the point that sufficiently decomposed and generic sub-operations and processes have been discovered. But insisting on a top-down perspective 'all the way down' is inconsistent with both Darwinian and Thompsonian thinking. Indeed, the importance of domestication and cultural evolution for language is also often overlooked, despite it being known that domestication can directly impact computational competence and trigger previously dormant operations (Okanoya 2012; Murphy 2015a).

The lexicalist framework of *WOU*, and much recent work in linguistics (see Boeckx 2014 and Murphy 2015c for critiques), presents a number of obstacles for evolutionary theses. Most notably, contemporary neurobiology is far from achieving an understanding of *representations*, and I think focus should instead be placed on investigating *operations*, with set-formation and labeling (a composite of object permanence and property attribution) having a much greater potential to be grounded in (oscillatory) processes than roots and intransitive verbs. Studies of particular oscillations are increasingly being linked to gene sets via their neurochemical implementation, and if cognitive capacities like language can be causally derived from oscillatory factors then this would serve as an important step in narrowing the bridge between cognition and neurobiology.

It's possible to detect a peculiar kind of dualism in the work of Marr Misreaders. To take one of numerous examples, Gazzaniga (1995: xiii) argues that algorithms "drive structural neural elements into physiological activity", suggesting that higher-order entities have causal force over neural assemblies. Moreover, in conceptual terms computational investigations boil down to input-output schemas, by definition insufficient to understand the biological basis of language, despite the common generativist claim that theoretical syntax amounts to biology "at a higher level of abstraction", whatever that means. This argument has always felt to me like a totally needy cop-out, similar to someone ditching their A Level physics class and, when challenged by their teacher about their absence, replying: "But I've chosen to write some poetry about gravity while jumping and rolling down the hill in the park, because I thought that was a good way of studying physics at a higher level of abstraction."

The neurolinguistic approach in WOU relies on outdated assumptions, sticking purely to localization issues and answering the 'How' question of language evolution by just pointing to good old BA44 and 45. "Our general problem", B&C write, "is that we understand very little about how even the most basic computational operations might be carried out in the neural 'wetware'" (p. 50); however, a number of recent proposals have attempted to establish intriguing relations between brain function and language comprehension (Lewis et al. 2015; Lewis & Bastiaansen 2015, among many others). These considerations embrace how the brain actually operates (via oscillations and their various coupling operations). B&C additionally "(speculatively) posit that the word-like elements, or at least their features as used by Merge, are somehow stored in the middle temporal cortex as the 'lexicon'" (p. 159). This ignores well-accepted findings that conceptual representations are widely distributed across several regions, even if the middle temporal cortex acts as a store for many core representations and a crucial memory buffer in phrase structure building (just as how Broca's area is most likely a similar kind of buffer in syntactic computation, and not the "seat of syntax" as Angela Friederici has often claimed; see Blank et al. 2016 for evidence of distributed syntactic processing).

B&C's middle temporal cortex hypothesis relies solely on imaging studies which point to regional specialization for particular language tasks, but this methodological cut-off point, while typically acknowledged by fMRI experimentalists (who can now achieve voxels of 0.8mm³), is side-stepped by B&C, who ignore the important language-related activation in non-specialized voxels. Noone would claim that the responses to tactile sensation in non-selective regions are somehow not part of the story of how we become acquainted with surfaces, and so a laser-like focus on middle temporal cortex amounts to a severely rundown neurolinguistic model. When limited to such a narrow view of functional (not to mention dynamic) brain activity, it is almost inevitable that one would be forced to arrive at bizarre and outmoded models of language localization.

It is widely assumed that human and animal concepts are composed of necessary and sufficient features surrounded by a periphery of ancillary but related features used to 'point' the comprehender in the right conceptual direction (grey feathers may be suggestive of a bird, for instance, but are not necessarily part of one), and any neurolinguistic models informed purely by imaging studies will likely reflect only the implementational regions (and not the neurobiological mechanisms) responsible for these peripheral features. I think this point is crucial and to my knowledge has not been recognized by the neurolinguistics community.

Relatedly, localization studies impose no constraints on the theory of linguistic or cognitive structure they are putatively attempting to explore. This point is somewhat more obvious, but also seems to me unappreciated in the literature. A given brain region (say, BA45) cannot 'do' anything to shape or directly inform a higher-level computational theory, and it can potentially be involved in any number of mental functions. Brain dynamics, on the other hand, are by definition far more constrained: A single γ cycle, for instance, cannot be claimed to be responsible for processing a verb phrase purely because of its narrow temporal window. In addition, claiming that a given portion of Broca's area is "responsible for interpreting word movement" (as is often done) is hellaciously bad biology, and only serves to give credit to a syntactic/processing theory rather than contribute to an understanding of brain and language function.² We spend our time well when we reconsider the conclusions of Ojemann (1990), who showed that while distinct features of language propagation are strictly localized, such loci are *temporary* and display great individual variability, with the neuronal functions changing over time, and so we can only ever conclude from neuroimaging experiments that cell assemblies are active in particular tasks *at time T, under condition P*, and can at best be specified for particular functions.

The most advanced experimental evidence B&C put forth is Musso et al.'s (2003) seminal work on nonsense languages obeying UG principles, which they say "elicit normal activation in the language areas of the brain" (p. 106). The misleading term "language areas of the brain" reflects the general level of disengagement the authors adopt towards all the "important biological questions" (p. 1) which "arise" from an exploration of the Basic Principle's implementation in the brain. It is certainly odd that B&C can write that "some small rewiring of the brain provided the core element of the Basic Property" (p. 107)-without even attempting in chapter 4 (putatively focused on brain structure) to cash this out in implementational terms. Pointing to a relatively dense, large regional structure like the middle temporal cortex and stating that it is where "the lexicon" is housed is similar to if Stephen Hawking sat under a dark star-filled night sky, pointed very roughly somewhere up at space, and claimed, "There's a black hole over there somewhere"-a statement which tells us nothing about black holes nor anything about space. In fact, Hawking would be on much firmer ground than B&C, since at least he can provide a theory of his object of study which can be embedded within a larger framework of quantum effects.

The strikingly basic neurobiology and cortico-centrism presented in much neurolinguistic work is incompatible with what is known about the brain and its principal dynamics. As a novel approach, from the perspective of brain dynamics what B&C call "some algorithm" responsible for labeling becomes capable of being explored in a number of interesting ways. Neural oscillations might be a suitable way of exploring mesoscopic computations across a number of cognitive faculties, as is already being done in domains outside of language like working memory. Consider a relatively simple example. The model of linguistic computation in Murphy (2015d) invokes a number of cross-frequency coupling operations, and in Benítez-Burraco & Murphy (2016) current knowledge of the linguistic and 'oscillopathic' profile of individuals with autism was used to empirically test it. It is additionally of interest, for instance, that schizophrenic

² We might conclude from this that there are really only two types of people in the world: neurolinguists and *neuro*linguists. Too often is the brain used to 'back up' a given linguistic theory by the former, while general theories of language are sometimes used by the latter to support a particular neuroscientific model. Meanwhile, both brain structure and linguistic computational competence remain locked in different cells on different floors of different prisons, unable to communicate or help each other escape. These approaches seem to confirm the beliefs of some medieval philosophers who thought that the insufficiency of human logic would result in barriers to naturalistic understanding (O'Meara 1982)—although it's not really human 'logic' which is causing the problems here, rather cross-disciplinary prejudices.

patients showed higher α - γ cross-frequency coupling in Popov & Popova's (2015) recent study of general cognitive performance, despite this co-varying with poorer attention and working memory capacities. This is surprising given that most studies show reduced left frontal γ in schizophrenia. The reason for this may be that the increased phase-amplitude-locking likely results in smaller 'gamma pockets' of working memory items (as Korotkova et al. 2010 argue on independent grounds) and hence low total γ power. In this instance, the size and order of working memory sequences outputted by the conceptual system is not optimally compatible with the oscillopathic profile, leading to greater rhythmic excitability and yet inhibited linguistic functionality. Global rhythmicity is consequently disrupted due to unusually strong fronto-parietal interconnectivity.

This may represent a genuine neural mechanism of an 'interface' between syntactically generated conceptual representations and external (memory) systems; a significant finding, if corroborated by further experimental work. Importing standard assumptions from syntax, we can think of the computational system as imposing its own conditions on the interfaces. The shift in perspective to oscillatory terms allows us to reformulate this such that the neural ensembles responsible for storing representations used to construct phrases require particular phase-amplitude-locking levels in order for the interconnected regions coupled with them to 'read off' their content. Studying what we could call the human 'oscillome' may provide an excellent way of experimentally investigating what kind of features can 'pass through' the interfaces, and because each rhythm plays numerous, non-overlapping roles, it is crucial for these oscillopathic studies to be accompanied by biophysical modeling and computationally explicit mesoscopic frameworks of regionally localized cross-frequency coupling functionality.

Over the past couple of years, the oscillation literature has shown great promise in exploring some major topics in linguistics (Ramírez 2015). Recent studies of α have shown that listeners who show better attention-to-memory capacities show more flexible α power allocation, leading to the suggestion that "selective attention to a specific object in auditory memory does benefit human performance not by simply reducing memory load, but by actively engaging complementary neural resources to sharpen the precision of the task-relevant object in memory" (Lim et al. 2015: 16094). Just as John O'Keefe and colleagues have shown that fast γ rhythms can compute vectors in the mouse hippocampus for spatial navigation (Chen et al. 2013), it may be that this generic oscillatory mechanism is employed in the service of constructing language-relevant featuresets. The absence of a complete dorsal-ventral stream 'loop' in the macaque brain (Frey et al. 2014) appears to be only the briefest sketch of the real underlying puzzle, and could be incorporated well into a larger oscillomic system invoking, among other things, human-specific myelination rates as a way of directly modulating the phase and power of oscillations (Pajevic et al. 2014).

Ding et al. (2016) showed that distinct rhythms entrain to distinct grammatical constructs, from words to phrases to sentences, with slow rhythms in the parietal lobe, superior temporal gyrus and inferior frontal cortex entraining only to phrasal and sentential structures, not syllabic ones. There have been many quibbles raised recently about the experimental materials, controls, number of participants and so forth, as indeed there should be. But there has been little discussion about the actual implications of this study for cognitive and linguistic architectures more generally. Following other seminal work by David Poeppel's group on the dynamics of phonological computation (e.g. Giraud & Poeppel 2012) and Lisman & Jensen's (2013) hypothesis that items from working memory are extracted via θ - γ embedding (which dates to the mid-1990s), we could draw up an 'oscillomic' hypothesis for the construction of linguistic feature-sets (Figure 1) which would directly enrich B&C's cartographic perspective.



Figure 1: An idealized model for feature-set retrieval. 'Q' denotes Q-feature, 'T' denotes Tense feature, 'C' denotes Case feature, and ' ϕ ' refers to ϕ -features (Person, Number, Gender).

In Figure 1, after inhibition reduces over the θ cycle, the most excitable representation would be itemized through low-middle γ , followed sequentially by the other, less excitable clusters. This would determine feature-set composition, completed after the θ phase resets. The 'lexicon' may amount to stored timefrequency profiles, with each item being composed of particular, sequentially excited and 'binded' feature-sets (although see below for a qualification of this term). Recent work (Chomsky 2015) has also argued that linguistic structures can be labeled not only by standard categorial labels, but also by ϕ -features, as in $[_{\varphi} ... \alpha ... [_{\gamma} ... \beta ...]]$, expanding the oscillomic search range. Derivational featurechecking (e.g. ϕ -feature agreement followed by Q-feature agreement within the same phase) may arise from the particular sequence of items extracted within a given oscillatory cycle. The set of feedforward γ rhythms employed in this model would be mostly generated in supragranular cortical layers (L2/3) (Maier et al. 2010), while hippocampal θ would be generated via slow pulses of GABAergic inhibition as a result of medial septum input, part of a brainstem-diencephaloseptohippocampal θ -generating system (Vertes & Kocsis 1997). The interactions between the hippocampus and medial prefrontal cortex necessary to focus attention on language-relevant features (considering the conclusions of Lara & Wallis 2015 on the role of prefrontal cortex in working memory, which stressed the centrality of attention rather than storage) may be mediated through an indirect pathway passing through midline thalamic nucleus reuniens (Jin & Maren 2016).

External constraints would also influence the temporal serialization of feature extraction: Ray & Maunsell (2015) note that the coordination of γ phases

across multiple, distant areas is difficult due to conduction delays, mediated by myelin thickness and nodal structure. For instance, a conduction delay of only 5ms could change the interactions of coupled γ oscillators from constructive to deconstructive interference (Pajevic et al. 2014); see also Nevins (2016) for related discussion of feature composition and motivations for assuming that Number and Person features do not combine via symmetric conjunction but rather through specific orders, possibly grounded in the above oscillomic mechanisms. Finally, while Ding et al. (2016) explored the rhythms responsible for 'packaging' particular constructions, their top-down experimental approach has its limitations, since the functional role of these rhythms in cognition more generally needs to be explored alongside broader research into the oscillatory nature of working memory, attention, and other domains necessary for language comprehension.

This idea could be developed through the construction of an 'oscillomic tree', in contrast to standard linguistic tree structures (Figure 2).



Figure 2: An oscillomic tree representing the putative rhythms responsible for particular lexical and phrasal structures according to Murphy (2015d). 'TP' denotes Tense Phrase, 'vP' denotes Verb Phrase (e.g. 'swam in the river'), 'NP' denotes Noun Phrase (e.g. 'The man', 'John'), and 'PP' denotes Preposition Phrase (e.g. 'in the river').

In Figure 2, at the point of *v*–PP concatenation generated by γ and coupled to θ , β maintains previous phrases in memory and embeds subsequent γ cycles, permitting the binding of phrasal constituents into a larger structure. As discussed in Murphy (2015d), α is likely involved in embedding cross-cortical γ , a form of set-formation, and is possibly generated in the thalamus (see Crandall et al. 2015 for evidence of neocortical control of thalamic gating, enhancing the role of the thalamus in higher cognitive functions). Spatio-temporal patterns of processing syntactically complex, memory-demanding sentences result in left parietal α increases, while higher β was found for long- relative to short-distance dependencies (β is more generally implicated in the maintenance of existing cognitive sets; Engel & Fries 2010). A possible reason for this is that the greater working memory load needed to resolve long-distance dependencies requires a higher frequency band to synchronize the cell assemblies implicated in the feature-sets of the filler and gap; certain assemblies would be pre-activated by the

filler (since dependents share a sub-set of their features). Because γ is modulated by cloze probability (Wang et al. 2012), β – γ synchronization may be the central mechanism of feature-set binding within phrase structures, with γ being responsible for semantic prediction and feature-binding (compositional meaning) and β being responsible for syntactic feature-binding and object maintenance (monotonic labeling).

Human-specific diverse phase relations (Maris et al. 2016) would also permit a greater degree of featural 'size' via the range of cross-coupling information gating, and may also permit different ϕ -features to 'probe' in unison (van Urk 2015). Similar approaches (accompanied by hodological research into the pathways responsible for a given cross-frequency coupling relation) could be taken to the various monkey oscillomes, attributing distinct rhythms and phaselocking patterns to particular call sequences (Murphy forthcoming). B&C's observation that syntax appears to operate via structural and not linear distance when constructing dependencies may also emerge from temporally distant crossfrequency couplings, such that an ensemble storing a given representation may be more closely coupled (via 'cycle skipping', controlling the activation of particular cell assemblies; Brandon et al. 2013) to a rhythm activating temporally distant ensemble X and not the rhythm responsible for the temporally closer ensemble Y.

In the above model, bottom-up γ would rapidly shift the ongoing set of featural representations through a standard feedforward mechanism, updating hippocampal θ and the widely distributed inter-areal β . The responsibility for linking distinct cortical areas into NeuroCognitive Networks (NCNs; Bressler & Richter 2015), or large-scale, self-organizing cortical networks, likely falls to β . Bressler & Richter claim that this rhythm plays dual roles, being implicated in NCN maintenance and transferring top-down signals to lower levels in the cortical hierarchy (e.g. the γ range). This model is compatible with the need for phrases to be labeled via two (domain-general) sub-processes: object maintenance (keeping the constructed set in memory) and property attribution (affording the set an independent computational identity), since β would be able to simultaneously maintain an object as a cognitive set (via its steady or increasing amplitude) and attribute a specific representational property to it (via top-down feedback and transferring prediction signals).

Similar studies of infant and child language processing will also be crucial, since the developmental characteristics of the oscillome are far from well understood. To take one of the very few current examples of this, Schneider et al. (2016) recently showed θ and β power decreases in adults at, respectively, left frontal and parietal sites and right parietal sites during the processing of ungrammatical sentences. These global(ur), dynamic concerns also speak to Gallistel & Matzel's (2013) assessment that, as a fundamental mechanism of synaptic transmission, the properties of long-term potentiation cannot explain the properties of associative learning and memory. As Fitch (2014: 392) writes, we should be "under no illusions that the theory of computation, with its stacks and queues and rewrite rules, provides anything even close to a final model of biological computation". Along with being able to describe how the brain performs large-scale interregional computations (potentially moving towards alleviating Fitch's anxiety),

oscillomic phase hierarchies may support the extraction of morphological representations (see Leong & Goswami 2015 for related discussion).

In modern humans, there is increased fronto-cortical connectivity and a more developed role for the subplate in achieving this, which likely altered the structural and functional role of cortical γ oscillations. The evolution of the subplate additionally aids language network inter-connectedness, which relies not only on axon pathways but on the synchronous firing of cortical cell assemblies transmitting information between each other (although in what format this 'information' is stored remains unclear). This gives rise to γ , essential for higher cognition. Relatedly, fast-spiking interneurons such as chandelier cells play an enhanced role in humans relative to other species, aiding the cortex in transmitting longer sequences of information (Molnár et al. 2008). Different interneurons can compete to generate the same γ rhythm, as Clowry (2014: 227) summarizes:

The degree of involvement of each cell type dictates the frequency of the network rhythm within the gamma band. This ability to switch between frequencies opens up the possibility for a group of neurons to bind with different neuronal assemblies depending on which frequency channel was in operation. Potentially, the greater the repertoire of interneurons present, the greater is the potential number of channels of communication.

There is a dense literature, then, on the functional role of brain rhythms in a number of cognitive domains, and which could inform major debates in the field. For instance, Jensen et al.'s (2012) approach to the visual system's prioritization of salient unattended stimuli claims that γ rhythms phase-lock to posterior α and β-oscillating regions to form a clocking mechanism sequentially activating particular visual representations, such that object X in a given scene is interpreted before object Y, imposing general cognitive set-constructing rules of efficiency. If similar oscillomic mechanisms are responsible for linguistic feature-set composition, then this could potentially provide a way of neurobiologically grounding the principles of Relevance Theory, through which particular representations are claimed to be triggered before others due to their 'cognitive relevance'. Crossfrequency coupling may consequently be able to connect segmentation/parsing with representation decoding/interpretation, with oscillations (implementation) being the mechanism to address segmentation (computation) via a phase-resetting (algorithm).³ Instead of coming up with new names for the 'Language/ Logic of Thought' (à la Hauser 2016) or tweaking and re-re-revising the odd model of the Italian left periphery and addressing other computational concerns, it may be more beneficial (both to linguistics and the brain sciences) if efforts were instead made to discard as much of the "attendant logico-philosophicomathematical baggage" (Tomalin 2006: 188) carried by modern linguistics and retranslating or re-embedding only the bare minimum required for hierarchical phrase structure building into the rest of the biological and neurophysiological sciences.

³ This type of multi-dimensional perspective on language can already be found in Bechtel's (1994) model of 'mechanistic explanation', in which different levels of description are composed of discrete entities with causal-explanatory force between each level.

This will also undoubtedly 'free' linguists from investigating the computational system from such a narrow perspective. For instance, given the minimalist framework provided to him, van Urk (2015) sensibly eliminates the A/A' position distinction and replaces it with obligatory A-features (ϕ -features) and optional A'-features (*Wh*, Top, Rel, and so forth). But where does this A/A'feature distinction come from (a question which seems to me just as problematic as how A/A'-positions emerge)? Examining the oscillomic nature of these features would deliver a 'bottom-up' account of how they emerge and what their limits of interaction and generation are. Computational studies can undoubtedly (though only partly) direct oscillomic hypothesis formation, but I hope by now it should be clear that sticking purely to recycling and refining feature-based models of Merge-based grammars will not result in an adequate theory of linguistic competence: Syntacticians will simply never be able to know whether a given input-output derivational system properly characterizes the human language faculty until they explore its hardware.

Oscillation-based linking hypotheses might also provide a substantive response to Revonsuo's (2001: 51) comment that in contemporary neuroscience, "the main efforts are concentrated on the description and systemization of data and the utilization of the data for clinical purposes. No radically new theoretical purposes, comparable to the neuron doctrine, have emerged from this enterprise as yet". As Snyder (2015) reviews, oscillations are increasingly being shown to play a causal, and not correlational role in the perceptual segregation of sound patterns (though it should be stressed, as Snyder does not, that numerous other oscillatory mechanisms likely do not play a causal-functional role in cognition).

The unfortunate influence of Marr Misreaders has discouraged linguists from engaging with this literature, with cognitive neuroscience oscillation research perhaps being initiated properly over a quarter of a century ago by Gray & Singer (1989), who discovered that, when multiple features of a visual scene were interpreted by an individual as belonging to the same object, the neuronal temporal impulses were synchronized in the regions assumed to subserve each featural component. I think the potential for these mechanisms to explore, and perhaps even constitute part of, the language faculty is substantial; indeed, Gray & Singer were surprised by oscillatory coupling at neuronal groups 7mm apart, but by now it has been well established that coupling can occur at much greater distances, and so the potential explanatory scope of the oscillome has dramatically increased over recent years.

Crucially, the information synchronized by the striate cortex is discrete, and so it makes little sense to talk (as is very often done) of features 'combining' in the brain to form a coherent representation. Similar things presumably apply to the present model of linguistic computation: To understand a word is simply to comprehend a given set of features, and it is superfluous to invoke an additional 'binding' mechanism on top of rhythmic synchronization. Cross-frequency coupling simply *is* the binding mechanism. The mind is sensitive to whichever features cross-frequency coupling operations can excite. Neither seeing a table nor interpreting the word *table* require a further procedure to 'construct the image of a table' or 'construct the meaning of *table*'. To see a table is not to 'bind' its legs and arm rests and color and size and edges—it is rather to

see/excite these features in synchrony. Similarly, to know a language is not to 'combine' language-relevant features triggered by some modality, it is rather to sequentially excite them, yielding a conscious representation which we may, for convenience, term a 'binded' one.

Finally, studies of the human oscillome could provide an elegant way of grounding some recent proposals about 'third factors' in language design. Using Laplacian Eingenmodes to analyze MRI and DTI data, Atasoy et al. (2016) demonstrate that resting brain function is related to brain shape. They argue that "the critical relation between the neural field patterns and the delicate excitationinhibition balance fits the neurophysiological changes observed during the loss and recovery of consciousness". The eigendecomposition of the Laplace operator may provide fundamental principles permitting a direct macroscopic description of collective cortico-cortical and thalamo-cortical dynamics. The spatial harmonic waves they observed seem to predict resting state networks and obey the same physical principles as other self-organizing phenomena (such as tiger and zebra stripes or the patterns of vibrating sand), lending support to Descartes's original intuition that the brain is organized through principles of "efficient causation", and not being incompatible with recent work in generative grammar suggesting that syntactic computation operates via principles of efficient computation (Narita 2014).

While most of the topics of language evolution (like language use) do indeed remain in the dark, I hope to have shown that some-given the right multidisciplinary perspective-are becoming increasingly tractable. If feature-set binding, object maintenance, property attribution, featural comparisons, and cross-modular searches are experimentally found to be implemented via generic oscillomic sub-routines and various cross-frequency coupling relations, this would be a substantial step towards understanding the biological basis of language. Research into the human oscillome's neurochemical and genetic basis is rapidly expanding, widening the scope for interdisciplinary investigations into its lower-level implementation and origins. Although this work is not formally described as 'language evolution' literature, given the promising directions open to oscillomic experimental and theoretical work it may not be all that long until studies of thalamic α and frontal γ are considered contributions to the implementational basis of phrase structure building. An underlying impetus for this burgeoning language evolution literature was touched on by Gérard Wajcman, who as a Lacanian scholar and a figure far from evolutionary biology consequently serves as an appropriately disconnected departure from an analysis of a (currently) disconnected oscillome:

We are animals sick with language. And how sometimes we long for a cure. But just shutting up won't do it. You can't just wish your way into animality. So it is then, as a matter of consolation, that we watch the animal channels and marvel at a world untamed by language. The animals get us to hear a voice of pure silence. Nostalgia for the fish life [...] We record whales singing their whale songs capable of transmitting messages to other whales thousands of kilometers away, but in truth, brandishing our microphones, we only aspire to one thing—that those whales would sing us a song.

(Wajcman 2009: 131)

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Phasal Eliminativism, Anti-Lexicalism, and the Status of the Unarticulated

Elliot Murphy

This paper explores the prospect that grammatical expressions are propositionally whole and psychologically plausible, leading to the explanatory burden being placed on syntax rather than pragmatic processes, with the latter crucially bearing the feature of optionality. When supposedly unarticulated constituents are added, expressions which are propositionally distinct, and not simply more specific, arise. The ad hoc nature of a number of pragmatic processes carry with them the additional problem of effectively acting as barriers to implementing language in the brain. The advantages of an anti-lexicalist biolinguistic methodology are discussed, and a bi-phasal model of linguistic interpretation is proposed, Phasal Eliminativism, carved by syntactic phases and (optionally) enriched by a restricted number of pragmatic processes. In addition, it is shown that the syntactic operation of labeling (departing from standard Merge-centric evolutionary hypotheses) is responsible for a range of semantic and pragmatic phenomena, rendering core aspects of syntax and lexical pragmatics commensurable.

Keywords: concepts; contextualism; labeling effects; phasal eliminativism

1. Introduction

The distinction between the uttered and the meant dates back at least to the 4th century rhetoricians Servius and Donatus (Horn 2004: 3). More recently, divisions between linguistic form and semantic content have been proposed from a number of perspectives, invoking unarticulated constituents and 'completion processes' such as free enrichment to derive and fully specify the supposedly underdetermined conceptual representations delivered by syntax (Carston 2007, 2009, 2012; Fodor 2008). In this paper, the status of unarticulated constituents in pragmatics is claimed to have a more much limited role in linguistic interpretation than standardly assumed, and what the computational system delivers is shown to be propositionally sufficient and psychologically plausible enough to eliminate certain pragmatic operations from the Conceptual-Intentional (CI) system (Chomsky 1995, 2014). The problem of biological adequacy is also addres-

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sed in relation to the syntax-pragmatics division of labour, and new directions are suggested for how the study of the computational system and pragmatic competence can embrace the plurality characteristic of the life sciences.

2. Lexicocentrism and the Structure of CI

This first section will present a basic overview of some standard cases discussed in the pragmatics literature, setting up the main focus of the paper in section 3, which explores how syntax delivers propositionally whole structures and that pragmatics can only enrich, and not alter, such structures. It is shown that in cases of complex polysemy, nominal reference, and even Case assignment, meaning is determined grammatically, not pragmatically.

2.1. Polysemy

To begin, I will assume that questions of meaning and reference should be explored at the grammatical, and not purely lexical, level. This 'internalist' (Hinzen 2006, 2007) perspective can be explored through classic pragmatic thought experiments. For instance, if we take Travis's (1997: 90) sentence "The leaf is green" when spoken by either a child or a botanist, the former would be accessing a representation from the INTUITIVE BIOLOGY core knowledge system (CKS for short; Spelke 2010), while the latter would be using the "science forming faculty" (Chomsky 1975).¹ We could notate these meanings as LEAF_i and LEAF_s for *intuitive concept* and (*natural*) *science concept*. The meaning of *leaf* would still be atomic, but speakers could employ the respective representations based on appropriateness (Ludlow 2014: 132).

Is there a need, then, to appeal to pragmatic processes in this case? I think not. As with complex nominals like *book*, *city*, *person*, *appointment*, or *construction*, the word *leaf* can bear the above multiple senses not because it is an indexical (shifting its meaning based on context) or because its meanings are coerced or because of pragmatic processes, but simply because it is polysemous.² As Frisson (2009) and Vicente (2015) demonstrate, variations in the truth conditions of a number of standardly explored utterances like "The leaf is green" or "The book was brilliant but weighed a ton" can be systematically explained if we assume the existence of semantic operations forming complex types like *book*(INFOR-MATION•PHYSICAL_OBJECT) and *school*(BUILDING•INSTITUTION).³ A similar situ-

Perhaps a clearer example would be a generic statement like "A leaf is green", since Travis's case refers to a token leaf (at least, on the most natural reading).

² As Vicente (2015: 54) points out, "[p]olysemy seems to be a relatively neglected phenomenon within philosophy of language as well as in many quarters in linguistic semantics. Part of this neglect is due to the fact that philosophical and a good part of linguistics semantics have been focused on sentential, truth-conditional, meaning, instead of on lexical meaning for a long time. But another part has to do with [...] the idea that, barring homonymy, each word-type has a unique simple denotation".

³ In this case, we need not invoke the observation that *green* appears to be scalar, being licensed if "some contextually specifiable" part of an object is green (Szabó 2001: 137). Note that this approach does not exclude the possibility that pragmatic processes can derive certain of these stored senses.

ation arises in *blue ink* due to the polysemous status of the noun: When we apply the concept BLUE to INK we can do so either by modifying what Pustejovsky (1995) terms its 'formal' aspect (which defines the ink as a liquid) or its 'telic' aspect (which defines the ink as a device for writing). This yields the apparent flexibility in describing *ink* as either appearing blue or being able to write in blue.

The topic of co-predication is particularly relevant here. This is the phenomenon of two apparently incompatible properties being attributed to a single object (Murphy 2015b). In (1a), informational and physical predicates apply to *book*, while in (1b) the *bill* is simultaneously an abstract monetary amount and a slip of paper:

- (1) a. The book was brilliant but weighed a ton.
 - b. He paid the bill and threw it away.

Philosophers of language and pragmaticists have typically sidelined the importance and intricacy of complex dotted types (Pustejovsky 1995) of the kind found in co-predication (see Carston 2012: 616, 2002: 362f., 374f.). Following proposals from Gotham (2012, 2015) and Bosch (2007), treating the meaning of nominals like book and city as reflections of conceptual, and not lexical semantic, complexity, allows us to deal with apparent paradoxes which force the multiplication of semantic senses. Consequently, novel simultaneously possesses abstract and concrete conceptual features, a form of productivity which allows it to extend its meaning from a material text to a piece of electronic information on a memory stick, and beyond, licensing different CI representations: (i) $\forall x$ (BOOK₁(x) \rightarrow PRINTED TEXT(x)...), (ii) $\forall x$ (BOOK₂(x) \rightarrow INFORMATION(x)...).⁴ It follows that our knowledge of novels being prose "is not lexical knowledge, but literary theory" (Bosch 2014: 45, emphasis his). The NOVEL concepts seen in co-predication are what Bosch terms "contextual" / unsaturated concepts which are enriched by subcategorization and predication information, along with discourse data. This allows us to relocate polysemy-including the verbal-nominal cases of *cut* and stop discussed by Searle (1980) and Rayo (2013)-to the CI-system.⁵ These results

- (i) The translation that lies on the table was difficult.
- (ii) ?The translation was difficult and lies on the table.
- (iii) John held the reactionary and large newspaper.
- (iv) *That newspaper is owned by a trust and is covered with coffee.
- (v) The most provocative newspaper of the year has been sued by the government.
- (vi) The well-written newspaper that I held this morning has been sued by the government.
- ⁵ Lexical ambiguity and polysemy may partly result from the fact that "the human brain is limited in the number of signs that it can store and quickly retrieve. This number is

⁴ Co-predication appears to have a number of grammatical and semantic constraints which have not been noticed in the literature (including Gotham 2015 and Chomsky 2000), which remain to be accounted for in model-theoretic or syntactic terms and which suggest that the qualia and argument structure relations of words like *book* and *newspaper* are much more intricate than Pustejovsky originally assumed. Dot-type nominals like *translation* can refer to a process or a physical text, but while (i) is well-formed, (ii), which reverses the sense order, is not. While the physical and informational senses of *newspaper* can appear together, as in (iii), adding the institutional sense leads to a licensing failure in (iv)—but not when placed in a modificational structure, as in (v), and (vi) even points to the existence of three-way copredication (see Murphy 2015b for discussion):

also depart from Fodor's (2008) view that words express Fregean 'senses', or modes of presentation (MOPs), being representations of some mind-external entity 'out there', invoking an indefensible mind-world dualism (see Collins 2015 for related discussion).⁶

There have been attempts, however, to explain co-predication on pragmatic grounds, which I think can be shown to be empirically inadequate. For instance, Brandtner (2009) proposes that the co-predication yielded by German deverbal *–ung* nominalization cannot be addressed by compositional operations alone, but additionally require pragmatic processes. In the case of *Übersetzung* 'translation', the selectional restrictions of two conflicting interpretations simultaneously apply to one token of the nominal, where 'tedious' and 'easy' refer both to the act of translation and more difficult translations are assumed to have a higher 'pay-off' (an event, EV, and result, RE):

(2) *German*

Die [langwierige]EV Übersetzung [verkaufte sich millionenfach]RE. *the tedious translation sold itself million-fold* 'The tedious translation sold million-fold.'

Certain cases bar co-predication licensing, as in (3):

(3) *German*

?Die [einfache]EV Übersetzung [verkaufte sich millionenfach]RE. *the easy translation sold itself million-fold* 'The easy translation sold million-fold.'

If co-predication with event and result readings is only possible if there is a salient relation between the two, then co-predication, Brandtner argues, cannot be reduced to semantic principles. He points to 'general ontological constraints' on type combinations, such that we cannot conceive of a firm's management as being simultaneously an event (an act of managing) and an agent (a manager), even though *management* can independently be either an individual (or individuals) and an event (where AG denotes AGENT):

(4) German

??Die Leitung der Anwaltskanzlei ist [schwierig]EV und hat [angerufen]AG. the management the.GEN law-firm is difficult and has called 'The management of the law firm is difficult and has called.'

relatively small compared to the extremely vast number of situations we may encounter and ideas we can entertain about them" (Bouchard 2013: 49).

Contrary to Russell, Kripke, and Putnam's semantic externalism, Franz Brentano thought that the default mode of human cognition centered on thoughts about non-existent things, and that thoughts about existent things are 'secondary'. Co-predication and related studies in semantic internalism (Pietroski 2012, forthcoming) appear to support this (admittedly vague) position that we initially think about non-existent things as if they existed; *books* and *cities* are thought about 'as if' they were existent entities, but in fact are not.

With derived nominals, event and object readings can be licensed if a causal or salient reading obtains, as in (2), with the difficult translation paying off with higher sales. But in 'The easy translation sold million-fold', Brandtner claims that since expectations (of easy translations selling poorly) have not been, the unexpected reading must be licensed by local discourse markers, as in the case in which an easy translation is made known to nevertheless sell well:

(5) *German*

Die einfache Übersetzung verkaufte sich **dennoch** millionenfach. *the easy translation sold itself still million-fold* 'The easy translation still sold million fold.'

But we do not need to say that pragmatic processes 'save' the co-predication interpretation from crashing, since 'The easy translation sold million fold' is semantically unexpected but still able to constitute a complex type. Co-predication is licensed in the same way it is in unexpected cases like 'The brilliant newspaper I held this morning has been sued'. Even if Brandtner's pragmatics-based theory was accurate, we would only need to invoke world knowledge to yield the supposedly poor judgment in (3), and the processes of pragmatics and dot-type generation need not interact or influence each other.⁷

2.2. The Philosophy of Case

While the word-world relation is gradually being severed through the work of such semantic internalism, or 'I-Semantics' (Pietroski 2005, Hinzen 2007), the word-concept relation, used to defend the existence of pragmatic unarticulated constituents, remains strong and well accepted-for dubious reasons. Nouns, for instance, "need not denote objects either when they are used as predicates or parts of predicates" (Hinzen & Sheehan 2013: 73). For instance, 'This is the building' is referential when asserted, but when functioning as an argument ('believed [this is the building]') it is a predicate to a mental event. It may be possible to go so far as to argue that propositional forms of reference are not 'semantic' or 'pragmatic' but are rather grammar-dependent, relying on relations typically designated as structural cases (nominative and accusative). For instance, by showing that such Case cannot be reduced to thematic structure, Person, Tense, or Agreement, Hinzen (2014) argues that Case can receive a rationalization through its role of marking cross-phasal word movement, rather than simply reflecting formal licensing constraints on nominal arguments. Case has also been assigned no philosophical significance (troubling no theorists of denotation or reference), and is seen as a peculiar, even quirky 'syntactic' feature of grammatical structure. Since language is often thought of as merely a mode of expressing thought, and not organizing it, Case has unsurprisingly been sidelined. But if it

⁷ The complex polysemy seen in co-predication also seems to explain why Chomsky's (2000) *London* can be demolished and rebuilt elsewhere, and why Pietroski's (2005) *France* can simultaneously be both hexagonal and a republic. Additionally, I think much of the 'lexical underdeterminacy' discussed in Ludlow (2014) can be accounted for when explored through accounts of polysemy.

can be shown that Case licenses referential arguments and that no other grammatical device can do this, Case would be given a meaningful role in linguistic cognition, sidelining the need for extra-syntactic pragmatic accounts.⁸

As a way of approaching this possibility, we can begin by noting that lexically organized meaning is distinct from syntactically configured meaning: Despite its internal featural complex, lacking any subjects, predicates, modifiers, definiteness, or assertions, an individual word like *lion* can never refer to a particular lion, some lions, lion-meat, lion-like characteristics, or lions more generally. Since *lion* is a lexical item and *the lion* is not, and only the latter can refer to a lion, then reference consequently lies on the side of grammatical organization. Since *the* carries no substantive lexical content, it also cannot be maintained that reference arises from a somewhat more complex lexical level; even *the lion* will only become referential when occuring in a suitable grammatical structure. *The lion ran* is referential, for instance, but *I wish to be the lion*, in the case of a stage production, is not. In addition, referentiality can arise from other structures like *Gold is yellow*, in which a common noun becomes referential, possible through N-to-D movement (see Longobardi 2005; Murphy 2014a).

Further, the KP/nominal 'phase' (Chomsky 2008, Gallego 2012) appears to be mapped to *objects*, the *v*P/verbal phase to *events*, and the CP/clausal phase to *propositions*, with a containment relation existing from the highest to the lowest phase (hence events necessarily contain objects):

(6) *Phasal Hierarchy* [CP ... [vP ... [KP ...]]]

These formal distinctions (objects, events, propositions) co-vary with grammar, not other systems like beliefs or intentions. There are no clauses that are object-referential in the way proper names are, verb phrases or non-finite clauses can denote events but not full propositions with truth-values, and nominals cannot do so either. Referential objects are consequently ordered in a hierarchical fashion, in part–whole terms (events include states, which in turn include objects and their substances), with a core function of grammar appearing to be the regulation of reference.⁹

A notion of referential *strength* also seems to mirror this hierarchy. The KP argument [$_{KP}$ K [$_{NP}$ lions]] in *I like lions* is an argument, but the phase edge is empty, lacking a determiner. As a result, reference is only to lions in general, and not to any particular lion(s). Reference to an amount of *lion* (as a substance) requires reducing this structure even more, removing Number marking: *I had lion*

⁸ As Hinzen (2014: 138) puts it: "If grammar is meaningful, and in a different sense of 'meaning' than we find in the lexicon, then grammatical relations matter as an independent input to semantic interpretation, in a way that Agree or Merge, as abstractions from such meaningful relations, do not."

⁹ This mereological, hierarchical organization lends support to the characterization of the CP, vP, and KP phases in Murphy (2014a) as, respectively, the Russellian phase (co-varying with propositions), the Davidsonian phase (co-varying with events, defined as such regardless of physical or temporal features—*atomic decay* qualifies as an event just as much as *cosmic expansion* or *football game*), and the Fregean phase (co-varying with objects and their substances).

(i.e. I ate lion). When a determiner appears, individual reference is licensed: *I had a lion*. Definiteness is also licensed in this configuration, but only when the determiner is strong, e.g. *the* (as in *I had the lion*). Individual deictic reference requires a deictic morpheme (*I had that lion*), and the NP itself is no longer required (*I had that/this*). Finally, with the presence of singular personal deictics, this restriction on NP dropping is no longer optional, but obligatory (**I man*).¹⁰ This leads to a hierarchy ranging from predicative to non-specific to indefinite-specific to definite-specific to-specific to-specifi

(7) Nominal Phase Referential Hierarchy
*(NP) < *(the) *(NP) < *(this) (NP) < *I/you (*NP)

Grammatical hierarchies also arise with events (which progress from states to full events) and propositions (progressing from non-finite to finite CPs). Only syntactic theory, and not model-theoretic semantics, can offer an explanation for the *emergence* of such ontologies, and not just a formal characterization of them. The generation of these hierarchies crucially relies on relations morphologically interpreted as Cases: "In the absence of argument-positions, which do not exist in Minimalist grammar, Case is the only thing that yields argument relations: thematic roles, in particular, exist in the adjunct system, and require no arguments" (Hinzen 2014: 140).¹²

Assuming that all arguments are introduced by functional heads (indirect objects via an applicative head, agentive or active subjects via a Voice head, and direct objects in the edge of v), this leads to the following schema, which can reveal how particular argument relations are morphologically realized: [Voice ... NP₃ ... [Appl ... NP₂ ... [v–V ... NP₁]]] (see Kratzer 1996). As noted in Hinzen & Sheehan (2013) and Hinzen (2014), a formal ontology is produced alongside this licensing, with NP₁ being licensed in relation to v yielding an event or state, Voice yielding more complex events containing the previous event/state, and all of which is morphologically interpreted in terms of Case-marking. Different Voice-v heads generate distinct Case-marking patterns, something which covaries with the hierarchy of meaning:

¹⁰ These observations suggest that the term 'definite description' is misleading, since whether or not a phrase like *the lion* is used as a definite description is determined by its syntactic context.

Similar considerations lead Martin & Hinzen (2014: 102) to propose a Grammar-Reference Link Hypothesis: "Referential strength (from predicativity to deixis) is not an intrinsic property of lexical items, but rather of certain grammatical configurations."

¹² It remains to be stressed that, contrary to the statements in Hinzen & Sheehan (2013) and Hinzen (2014), *grammar* itself does not refer, but rather *people* use grammar to refer in a given circumstance. Words like *chair* and *table* do not 'refer' to anything, but when used by a speaker (with intentions) they can potentially refer, given the phasal configurations provided by grammar. Syntax itself is not enough for reference to be established, any more than a functioning olfactory system is enough for someone to smell (the notion of *will* needs to enter, too). The referential capacities of non-human primates should also not be underestimated (see Murphy 2015c), with Hinzen & Sheehan summarily dismissing primate cognition for supposedly not rising to the level of 'thought' (a term they mystically associate only with grammatical cognition, misleadingly and unhelpfully). Reference cannot be solely reduced to grammatical factors, then, and questions remain about how speaker intention interfaces with syntax, to be explored in section 3.

- (8) a. We [Voice_{ACT}-v killed him_{ACC}]
 - b. **He**nom [Voice_{pas}-*v* was killed]
 - c. **He**nom [Voice_{unacc}-*v* died]

Case morphology consequently appears to track cross-phasal relations; when a nominal crosses a phase boundary, its Case marking changes, despite the fact that, for instance, in (8a) and (8b) *him* and *he* have identical thematic roles. In (8a), ACC expresses a relation between the verb and internal argument, yielding a predicate with no truth-value (*killed him* cannot be assessed for truth). But in (8b), NOM expresses a relation between the finite verb and external argument, corresponding to a proposition.¹³ Movement for reasons of Case is therefore interpretable, contrary to standard minimalist assumptions (Chomsky 2001).¹⁴

There is also no need to invoke *deflationary* theories of truth (Horwich 1998) according to which to assert that a statement is true is just to assert the statement itself, since grammar delivers the structure which the interpretive systems proceed to substantiate (see Martin & Hinzen 2014 and section 3 for examples). Moreover, the criterion of individuation is heavily influenced by grammar, and is not just an amorphous series of 'sortal concepts' as invoked by Galery (2009). This phasal theory of reference also resolves certain debates in contemporary Millianism (Mousavian 2015), since the strength with which it is possible to refer using some nominal expression is modulated by how 'high' up the phasal hierarchy an object moves, while *existence* is shown not to be encoded in the grammar (unlike features such as Tense). While we cannot explore the *formal* ontological structure of the world through physical experimentation or perceptual analysis, linguistic theory provides a way (indeed, perhaps the only way) of doing so.

With a phasal syntax, then, concepts like *proposition* and *event* co-vary with the grammatical architecture itself (de Villiers 2014)—that is, its computational and its base of declarative knowledge as opposed to the system processing speech acts—and it is needless to postulate Mentalese or a language of thought (\hat{a} *la* Fodor 1998) or pragmatic processes, even if mediation of such syntactic and semantic structures is not identical to reduction, since an understanding of CI bare output conditions and of conceptual representations (through developmental psychology, philosophy of language, and other domains) is, under core minimalist assumptions, all that is needed. The importance of developing syntactic analyses becomes clearer when we acknowledge with Narita (2014: 10) that there is no direct evidence for the nature of CI, and we can access its effects only via "speculations, introspections or theory-internal considerations".¹⁵

¹³ This leads to a possible solution to the perennial problem surrounding why Case is category-sensitive, being primarily assigned to nominals, since it may be that Case is rather sensitive to referentiality, which happens to be related to nominals (but which cannot be reduced to the category Noun).

¹⁴ Knott's (2014) model of Case also attributes a semantic role to it, but from the perspective of a particular hypothesis concerning the sensorimotor–LF interface.

¹⁵ More worryingly, since the human scientific faculty is, like all organic faculties, limited and constrained—being composed of concepts such as probability, determinacy, and input–output schemas—the conceptual tools available to linguists may be insufficient to explain core (and very simple) aspects of CI.

2.2. Lexical Semantics

Since I have argued against any substantial role for pragmatic processes in complex polysemy and nominal reference, I would like to propose two phases of linguistic interpretation: *syntactic computation* and *pragmatic computation*. In order to properly address the debates surrounding unarticulated constituents, I will situate the discussion in section 3 within a clear architectural framework, which requires elaboration.

I will assume that the inputs to syntax are flat or atomic 'lexical precursor cells' (LPCs; Boeckx 2014: 27) which acquire their lexical features as the derivation proceeds and phases are transferred to the interfaces (Munakata 2009). Call the set of LPCs the Precursor Lexicon, *p*LEX for short (as in Murphy 2015a). What lexical features contribute is a unique configuring of other mental systems, providing instructions to them (Chomsky 2012: 191). This idea seems to be supported by the finding that verbal labels influence categorization in infants (Plunkett et al. 2008). Questions remain over how the nature of lexical items came about, but, as argued below, a significant step in the right direction is made when we detach syntactic computation from lexical influence.¹⁶ The work of Borer (2005), Boeckx (2014), and others suggests that forms of grammatical order arise not from the lexicon but from the dynamics of the derivation.¹⁷ In sharp contrast to this, it is possible to detect notable similarities between lexicocentrism, genocentrism, and neo-phrenology, all of which seek explanations based on elementary components rather than deriving structure from processes or forms. But unlike lexicocentrism, the latter two have been surpassed over the last half century by evo-devo agendas, systems neuroscience, and other 'formalist' (Amundson 1998; Hinzen 2006) and dynamic approaches.

In addition to the above model of reference, I think there are other reasons not to rely on pragmatic accounts of natural language meaning. For instance, there is a near-optimal match between phasal derivations and Neo-Davidsonian event representations (Kratzer 2003), with Boeckx (2014: 103) arguing for a causality between the emergence of phases and the evolution of complex event concepts. C maps to the point of existential closure, v to internal/external thematic role assignment, and n to type-lifting turning a predicate into an argument, and p

¹⁶ This is a change which is already steadily developing in labeling theory and recent discussions centered on how Merge is no longer seen to be 'driven' by, for instance, feature valuation and θ -role assignment; see Epstein et al. (2015), but also Wurmbrand's (2014) valuation-based Merge Condition and Bošković's (2008) observation that feature checking has a freezing effect on movement, which would be difficult to capture in a 'free Merge' architecture.

¹⁷ In this sense, but not others (for instance, see Boeckx 2015), this anti-lexicalist stance is compatible with the present reference-centered rationality of Case, in which it is grammatical organization which gives rise to propositional reference, and not Case-features rendering Goals active to Agree with Probes—a move which reduces grammatical relations to features; an example of what Boeckx would term 'featuritis', with features in contemporary minimalism often being deployed simply to 'capture the facts', being all-powerful in a similar way transformations and parameters were in the 1960s and 1980s. The explanatory power of feature-driven theories is far from awe-inspiring: Nouns are defined as belonging to the category [+Noun], and so on; similar to how Fodor "often seems satisfied to explain a concept by typing the word for it in different cases and fonts" (Pinker 2008: 97), with *dog* denoting the concept DOG and *subprime mortgage* denoting the concept MORTGAGE(SUB-PRIME).

to adjunct introduction. Although these correspondences are admittedly cursory, it nevertheless appears that Collins and many others are likely incorrect in claiming that "syntax fails to match up with content in a principled way" (Collins 2007: 806).

These observations support Borer's (2005) exoskeletal morphological model which views open-class words as hidden 'conceptual packages' that are purely embedded in the syntactic structure, causing no alteration to it or itself. Only when the structure is built by phase is the package 'opened' (interpreted). This is one of many reasons why syntax appears to be entirely free of lexical influence, operating independently of the needs of feature matrices (see Epstein et al. 2014 on 'free' Simplest Merge). As discussed in Murphy (2015d), many linguistic modules constructed during the Government and Binding era live on re-cast as features, yielding a form of massive modularity as a historical residue.¹⁸ Invoking Merge and roots (Marantz 1997; Borer 2014), though necessary, also fails to illuminate the structure of the objects Merge ultimately operates on, leaving unaddressed the question of how feature-bundles are constructed to begin with (for a proposed mechanism of feature-set binding based on neural oscillations, see Murphy 2015e, forthcoming; Murphy & Benítez-Burraco 2016).19 This kind of lexicocentrism is simultaneously a barrier to developing linking hypotheses between linguistics and neuroscience, since it presupposes that syntax only operates on something as narrowly domain-specific as a lexicon. Instead, we can assume that LPCs are enriched by a small set of featural representations as the derivation proceeds, such as obligatory A-features (ϕ -features) and optional A'-features (*Wh*, Top, Rel, and so forth), as they are termed in van Urk (2015).

This modular perspective opens up new avenues for interpretation. The concept BOTTLE, for instance, relies on visual cognition through its shape and colour features, with language contributing its functional properties (container, used to move material masses, and so forth; McGilvray 2005: 308). Similarly, a pile of leaves in a forest becomes a *thing* if it is put there intentionally, perhaps to act as a signal, where thinghood should be distinguished from the objecthood of visual perception (the point being that the functional criteria of language is not strictly aligned with the structural criteria of the visual system: Language seems to deliver to objects a functional role). If the mind is composed of CKSs (Spelke 2010), then language may allow a child to use pre-lexical concepts, which may not be systematically combinable, 'to introduce Lexical Concepts', which-via setformation/Conjoin-can be combined (Pietroski 2014a). Exploring these issues further, Pietroski (2012) has claimed that the lexicalization of concepts is a necessarily creative process which cannot be reduced to instances of words 'labeling' or 'standing for' particular concepts, with his theory of semantic computation reducing to Conjoin and a limited form of existential closure.²⁰ This seems to sup-

¹⁸ Thus Lakoff (1972: ii): "So linguists fudge, just as has been done in the reflexive rule, by sticking on the arbitrary feature +REFL. Such a feature is a fudge. It might as well be called +CHOCOLATE, which would in fact be a better name, since it would clearly reveal the nature of the fudge."

¹⁹ See Svenonius (2012) for a proposed 'Bundle' operation, and Murphy (2015a) for an alternative based on set-formation/Simplest Merge.

²⁰ When the brain acquired the ability to lexicalize concepts (see Murphy 2015e for a neurobiological proposal for how this was achieved), it created "items that could be freely called up,

port the notion that words are not concepts but rather *instructions to build concepts* (*from their semantic features*) (Pietroski 2014a, forthcoming). Given this background, it remains to be seen how the syntactic and pragmatic components operate to derive conceptual structures. This topic will be the concern of section 3.

3. Unarticulated Constituents and the Syntax-Semantics Interface

While much is known about the computational operations of syntax (Adger 2003; Narita 2014), the computations of the pragmatics module(s) stand on less firm ground. One such proposed computation is *saturation*, a 'completion process' (Bach 1994: 133; Carston 2009: 15) operating on constructions like "Paracetamol is better [than x]".²¹ Saturation has been argued by Stanley & Szabó (2000), in their syntactically-motivated rejection of much of the pragmatics architecture, to be the only active pragmatic computation. For others, such as Hall (2008), there are processes such as *free enrichment*, a lexical process modifying subparts of CI representations: "It's snowing [in location x]" (Sperber & Wilson 1995; Recanati 2004). These are cases of 'unarticulated constituents' (Recanati 2002), differing from those proposed in theories of syntactic ellipsis in that they are motivated on pragmatic grounds. Finally, computations involving *lexical pragmatics* (Wilson & Carston 2007, Sperber & Wilson 2015) adjust or modulate existing elements of linguistic meaning, as in the case where "David is a man" is interpreted as meaning David is an ideal man.

3.1. Phasal Eliminativism

This section will argue that most of these operations can be eliminated in favor of more principled grammatical accounts. As an alternative, the following model will be defended:

(9) Phasal Eliminativism

Syntax supplies instructions to CI to construct conceptual representations which can optionally be pragmatically enriched.

Phasal Eliminativism is a form of eliminativism not because it denies word meanings, but rather because it denies the existence of core components of the

partially independent of perception" (Hinzen & Sheehan 2013: 38). Boeckx (2014: 109) speculates that it may turn out that "some of the properties of human concepts can be derived from the fact that they have been lexicalized".

²¹ Saturation is seen as a central pragmatic process under Wrong Format (WF) theories. Recanati (2004) defines this as the view that linguistic semantics does not yield a truthconditional component, but there is nonetheless context-independent meaning associated with a word. WF holds that words have meanings, albeit ones which are too semantically rich to be employed in utterance interpretation. On the more extreme end of the spectrum, Meaning Eliminativism (ME) is the most radical form of contextualism (Bezuidenhout 2002), or the view that sentences express content only given a particular speech act context, which triggers relevant memory traces (Hintzman 1986) from a 'grab bag' of maps and images (Rayo 2013), along with other top-down processes (Rumelhart 1993: 78). ME is WF "pushed to the extremes" (Recanati 2004: 141), denying word meaning at the type level and embracing only contextual tokens.

pragmatics system. It should be stressed, however, that while pragmatic processes *can* enrich syntactic structures (hence the 'optional' status), such structures are not as radically underspecified for conceptual content as is typically claimed in the pragmatics literature. As a way of explanation, unarticulated constituents are usually deemed part of presupposed discourse knowledge. They are taken to be propositional elements which do not arise at the sensorimotor interface (SM) but are necessary for a sentence to become truth-evaluable, occuring as part of the top-down free enrichment process.²² The status of such constituents remains a major topic of research. To take a few simple examples, McIntosh (2014) claims that "It is raining in London" really expresses the proposition "It is raining in London now", while Fodor (2001: 12) argues that "It's three o'clock" really represents "It's three o'clock here and now, in the afternoon" (or whenever the sentence is spoken). These cases suggest a degree of misalignment between externalization and thought. Debates in lexical pragmatics often then center on the question of whether one should expand the influence of Logical Form (Chomsky 1995) or pragmatic processes of free enrichment to account for such misalignment. Departing from this focus and putting the explanatory burden on syntax, Hinzen (2015) argues that there is nothing 'missing' in grammatical constructions for them to encode propositionality. When the supposed unarticulated expressions are inserted, completely different propositions result, rather than a simply more 'overt' or 'specific' form of the underlying proposition usually posited. The only hidden constituents are the ones syntactically motivated in theories of movement, control, and so on, which are interpreted at CI but not externalized at SM.²³ Focusing on free enrichment, a cross-linguistic exploration of pragmatic processes led Martí (2015) to suggest that most cases typically used to defend free enrichment processes can be explained through the involvement of grammatical processes. In addition, the present section will show that only lexically and not grammatically specified aspects of meaning are altered by context: The principles of theta-role assignment and agreement relations are unswayed by how much rain is pouring in London. There may consequently exist cases of what could be called 'lexical underdeterminacy', but not at the level of phrase structure building. I will also argue, following numerous others, that Logical Form can be dispensed with, and that syntactic structures are mediated purely through pragmatic processes (extra-grammatical in nature, such as world knowledge), as Phasal Eliminativism suggests.

The cases typically explored in defence of pragmatic unarticulated constituents crucially involve a level of optionality; that is, the enriched meaning is not necessarily tied to the expression, as in "Every time John lights a cigarette, it rains" (Stanley 2000), which *can* introduce a location variable ("…rains in the place he lights the cigarette"), but does not *have* to.²⁴ Confusing optional for obli-

²² For the seminal proposal, see Perry's 'Thought without Representation' (1993: 206).

²³ The centrality of CI in linguistic structure, a core minimalist assumption, was arguably appreciated by 'Counter-Enlightenment' philosopher Johann Hamann: "To speak is to translate—from a language of angels into a language of men" (Rudd 1994: 197). See Strawson (2008) and Murphy (2014b) for related classical references.

²⁴ This perspective aligns with Chomsky's claim that pragmatics, although being the "wastebin" (2006: 98) of linguistics into which inexplicable puzzles are cast, equates to "principles of action" and comprehension, not structure-building (Andor 2015: 148).

gatory processes, perhaps the defining characteristics of contemporary pragmatics, would be deemed a thorough methodological catastrophe in any other scientific domain. It can further be shown that grammar systematically determines, and not merely constrains, the proposition expressed in cases of supposed misalignment between meaning and syntax. For instance, all too often are possible logical deductions about expressions taken to be 'implicatures', when in fact the content of implicatures derived from a single expression are not only propositionally distinct, but contextually distinct, encoding dissimilar thoughts and being appropriate under different circumstances. To illustrate, the implicature standardly derived from "John has four cars" is "John has exactly four cars," despite the latter construction being propositionally and circumstantially distinct from the former. Following Phasal Eliminativism, assume that semantic interpretations are built via cyclically transferred labeled structures and the operations of the pragmatic/interpretative faculties. Pragmatics can enrich but not conflict with the output of the grammatical Merge-Agree-Label-Transfer process. What's more, to revert the standard metaphysical assumptions of lexical pragmatics, phases also determine what constitutes a *context* by constraining how a situation can impact the referential uses of expressions. Contexts are not preexisting, mind-independent states of affairs in the world, but rather amount to different ways in which grammar can orient its delivery of conceptual content around experience, which determines (at most) perceptual schemas and preferences for particular representational retrievals. In short, contexts are nothing more than mental states, and syntactic structures denote updates of these states. There is no a priori reason why some independently defined 'context' should influence the operations of syntax and CI. The present proposal consequently departs from Wilson's (2014: 144) belief that a "linguistic expression" is interpreted by being "put in systematic correspondence with states of the world." The pragmatics literature rarely unpacks what is meant by "linguistic expression" or "states of the world", and with words like book and city being shown to have no mind-independent referent (Murphy 2015b), the referentialist perspective Wilson adopts becomes unmotivated.

With syntax ultimately being responsible for numerous interpretive phenomena, this leads to a similar situation that Strawson (2015) is left in after discussing the philosophical distinction between internal and external content:

The domain of external content has traditionally been taken to be the external world of tables and chairs. It's a vast domain, even when we restrict ourselves to concrete reality and put aside things like numbers and concepts. I've argued that the domain of external content is larger still. It extends further into the mind than is sometimes supposed. It's only at a very late stage, as we travel into the mind from its traditional heartland—the 'external environment' as it is usually understood—that we reach its true border. And the metaphor of the border is misleading. The internal content-external content boundary isn't a straightforward ontological line, because we can think about can be external content, and is external content when we think about it.

While it is true that lexical features determine conceptual content, what has not been acknowledged by the pragmatics literature is that *reference* is determined by the grammar, not the lexicon, as noted in section 2. Lexical specifications are thoroughly context-sensitive, but grammar is not. Both the $_p$ LEX and the computational system contribute to meaning, but meaning of a different sort. Consider the examples below:

- (10) a. The colonel wanted to be [a man].
 - b. [A man] was seen by the butcher.

In (10a), 'a man' is used predicatively to denote a property the colonel wishes to satisfy, whereas in (10b) the phrase is used referentially. It can also be used generically, as in 'A man would be wise to avoid that river', and the uses of the phrase 'a man' are purely determined by the grammar, not lexical content. That is, it is determined by the phasal position, with movement to the phase edge -such as in N-to-D movement-yielding stronger referentiality.²⁵ The crucial factor in determining referentiality is not lexical category (N or D), but rather phasal position, so a more adequate term for this would be Interior-to-Edge movement, where [edge[interior]] is the phasal template, and under which descriptive content is found in the Interior (e.g. predicative interpretations like 'I saw $[E_{I} \text{ [amb]}]$ ' describing the kind of meat witnessed) and referentiality is established at the Edge (e.g. referential interpretations like 'I saw $[_{E}$ the $[_{I}$ man])' or rigid 3^{rd} Person interpretations like 'I saw [E Mary [I t]]', where Interior-to-Edge movement has taken place). A given name's semantic type reflects its phasal position, then, and so claiming (and is standardly done) that names enter the derivation as type <e> is an inaccurate generalization.

These observations are compatible with the ethological literature (Murphy 2015a, 2015c), which reveals that non-human forms of externalization are most likely limited to 'functional reference', and not the elaborate forms of reference made available through the labeling-driven syntactic component. The lexicon (however one formulates it) and syntax play entirely different roles in the construction of interpretations, as cases of specific language impairments and forms of mental disorders appear to illustrate (Hinzen & Sheehan 2013). The computational system therefore allows for a systematic and well-grounded investigation into the nature of meaning, escaping the kind of ad hoc adventurism of many philosophical and semantic theories parodied by Lycan (1984: 272) in his Double Indexical Theory of Meaning:

(11) MEANING=_{def} Whatever aspect of linguistic activity happens to interest *me now*.

Another major issue I would like to raise with the lexical pragmaticist's reliance on enrichment is that it dodges the more fundamental problem of accounting for the internal complexities of individual lexical items and phrases.

²⁵ In a related discussion, Hinzen (2014: 140-141) writes: "We only know whether a given lexical item functions referentially or predicatively by looking at its grammaticalization, and the question of whether proper names are predicates or referential is ill formed. It wouldn't make sense to class a word like 'Mary' lexically through a feature like REF (for 'referential'); or to specify a given nominal as 'ARG' (for 'argument'); or to class it as 'ACC' and define a derivation through the need to 'check' such a feature." Again, the prospects for feature-driven theories of meaning are bleak.
The logic appears to be as follows: Explain the mysteries of lexical items and their complex conceptual interface properties by invoking further lexical items with their complex conceptual interface properties.

Going somewhat beyond Hinzen's (2015) and Hinzen & Sheehan's (2013) analysis, I would like to propose that it is not just grammar that mediates conceptual content like propositionality and objecthood, but more specifically grammatical sub-operations.²⁶ Set-formation (in its various guises in the literature) is responsible for forming adjuncts, which crucially do not influence the grammaticality (i.e. phrasal/labeled/headed status) or truth-values of the construction they adjoin to. The truth of "It is 6 o'clock" is not affected by adding the PP 'in the afternoon'. The common claim in lexical pragmatics and lexical semantics that the PP is somehow 'hidden'—indeed, 'obligatorily hidden'—does not square with the well-established influences of the computational system on sentence meaning (Pietroski forthcoming; Hornstein & Pietroski 2009). To illustrate further, consider the following:

- (12) a. It's three o'clock.
 - b. It's three o'clock now.

Even though (12a) means, in virtue of its fully specified tense, "It is three o'clock now", we cannot suitably answer the question "When is it three o'clock?" by saying "It's three o'clock"; instead, we have to say "It's three o'clock now". Again, the adjunct is not 'hidden', and a different CI representation arises in the absence and presence of the adjunct (contra McIntosh 2014: 97 and his focus on Dummettian 'ingredient senses' and statements being true "just in case" certain conditions obtain). Adding *now* only serves to distort the meaning of the sentence in particular circumstances: (12b) can be corrected with (13), but (12a) cannot (in a case in which it's three o'clock when (13) is being spoken):

(13) No, it's three o'clock then.

The supposedly hidden constituents posited by Fodor (2001) and others do not in fact yield a 'more accurate' structure, but simply a propositionally and psychologically distinct representation.²⁷ Among other theories, this weighs against McIntosh's (2014) revival of Evans's (1985) proposal that the truth-value of propositions can vary over time. The grammar of a proposition is an object independent of its truth-value, though one which crucially directs its construction. Syntax builds sentences through procedures which are unrelated to truth, contrary to a number of claims in the philosophical literature (see Pietroski 2014b for discussion). Truth is an epiphenomenon of syntax requiring various kinds of

²⁶ This proposal should be understood in the context of the Decompositionalist Project outlined in Murphy (2015c), which seeks to achieve a finer-grained level of understanding of syntactic computations in an effort to make the theories of linguists relatable to (and perhaps commensurable with) domains outside of the language sciences.

²⁷ Belleri (2016: 29) presents different, complimentary arguments that "it is not the case that sentences even generally fail to fully express our thoughts", given "minimal contextual information," countering the claims of Recanati (2004), Carston (1999), Travis (1996), and countless others.

cognitive processes, and to say that a particular expression can vary in its truthvalue is, on the one hand, to utter a platitude, but on the other it is to imply that constructs like *time* and *personal taste* somehow impinge upon the operations of syntax.²⁸ Evans's use of tense logic, for instance, reveals its shortcomings in representing (let alone explaining) the semantics of (12a), which it would incorrectly notate as (14) (similar to how the decompositional approaches to open class words like *open* noted in section 2 are inadequate):

(14) $(\forall t)$ ('It is three o'clock' is true_t = it is three o'clock at t)

Further, by placing *time* on an independent metaphysical plane from all other forms of context (while also exclusively discussing the concerns of 'modal logicians' and 'tense logicians', and not linguists), McIntosh (2014) is indirectly sidelining the importance of other contextual variables, which, as we have seen, are much closer to the content of a given linguistic construction than has typically been appreciated. Quite apart from these empirical considerations, from a purely naturalistic perspective the motivation behind invoking pragmatic operations and unarticulated constituents is a relatively peculiar one, failing to meet universally accepted standards of theoretical simplicity and empirical adequacy taken for granted in other domains of the cognitive and natural sciences. If an investigator of a higher-level science can explain some phenomenon by way of a lower-level account (a systems neuroscientist invoking neurochemical processes, for instance), then the need to construct further higher-level objects or processes becomes redundant.

Relatedly, while philosophers of physics and philosophers of biology need to be well versed in physics and biology, it is somewhat peculiar that philosophy of language textbooks are remarkably light on linguistics. Discussions of syntax typically reduce to bullet points about how syntax is the study of 'word order' and the like. Empirical claims about language should be accompanied by a scientific understanding of linguistic structure, just as debates about physicalism and Hox genes need to be supported by an understanding of the relevant area of knowledge. More generally, there is a tendency in philosophical and pragmatic circles to ignore the fact that language has grammatical organization, and to sideline the implications of this for topics ranging from meaning to vagueness to intentionality. The ideological and structural barriers to innovation in this domain are substantial, and often overlooked.

The pragmaticist's desire to appeal to, for instance, essentialism and Atlas (1989, 2005) and Carston's (2002) 'underdeterminacy thesis' may stem from a more general cognitive tendency to complete missing details, such as in the case of Kanizsa's 'incomplete' triangle, which is not too distant from saying that "Mary has arrived" is really a particular manifestation of "Mary has arrived in London". The evidence used to defend, for instance, the silent subject-argument of 'win' in control structures like "Mary wants to win the game", with the argument co-referring with 'Mary', are entirely different from the justifications given

²⁸ This perspective is in fact similar to J.L. Austin's intuition that questions of truth arise at a different level from natural language expressions.

in the pragmatics literature for silent elements. The principles of syntactic computation explain the semantic phenomena, and the hidden constituents (e.g. PRO) are not only defended on such grounds, but also crucially interact with other grammatical constructs like Case and c-command. The kind of rationale seen in discussions of pragmatic underdetermination, saturation and free enrichment is similar to the one seen in the case of someone explaining that the reason why "John arrived at the park" really expresses the meaning "John arrived at the nice, sunny, green park" is because they happen to know (via a close friend) how much John loves parks which are nice, sunny, and green. Missing elements need to be independently grammatically licensed, not stipulated as a 'general pragmatic process'. Pragmaticists also often 'over-generate' hidden elements (Sennet 2011), as in the case of the common claim that "Everyone went to London" or "Everyone screamed" really express the propositions that everyone in a given context went to London or screamed (Carston 2009: 7). But to claim that everyone went to London is certainly not to claim that "Everyone alive went to London", and so there is no need to invoke ancillary pragmatic operations, since there is in fact no semantic mismatch between content and linguistic form to begin with. More generally, a tendency to interpret a given utterance in a particular way (e.g. interpreting "It's three o'clock" as "It's three o'clock at the time of utterance") says nothing about the intrinsic content of that utterance. Likewise, a given speaker's communicative intention to express "It's three o'clock now" when uttering "It's three o'clock" does not provide a basis from which to posit obligatorily present silent elements (contra Fodor & Lepore 2004: 10), any more than my communicative intention to express "I don't know" when shrugging my right shoulder in a given context implies that there is some inherent, obligatory semantic content to the act of shrugging one's shoulder, which could mean any number of things.

These observations also apply to supposedly unarticulated instruments. "He took the gun out and shot John" is often taken to include a hidden constituent 'with the gun' after 'John' (Korta & Perry 2008). But not only is it otiose to add the PP 'with the gun' when answering the question "What did he do with the gun?" by saying "He took the gun out and shot John with the gun", but this statement is also false in situations in which John was shot with another instrument, unlike the original utterance in which 'with the gun' is absent. The two constructions yield different truth-values with distinct propositional force.It is also worth noting that many of the justifications for underarticulation and underdeterminacy, such as Neale's (2007) Underarticulation Thesis, rest on an implicit adoption of semantic externalism, through which linguistic meaning is somehow 'tied' and 'connected' to mind-external physicalist objects and processes, often discussed within the context of Twin Earth and Dry Earth scenarios, and driven and reproduced by an unspoken but powerful allegiance to what Sellars (1963: 6) called "the manifest image" of ordinary perceptual content, rather than the underlying conceptual representations and system of computations which sustain it (see Chomsky 2000, 2013; Lau & Deutsch 2014).²⁹ Defend-

²⁹ A similar suspicion of externalism can be detected in many literary works, for instance in John Cowper Powys's 1934 novel *Weymouth Sands*, in which the philosopher Richard Gaul

ing the existence of hidden location variables in utterances like "It's raining", Perry (1998: 9) reasons that the location "is a constituent, because, since rain occurs at a time in a place, there is no truth-evaluable proposition unless a place is supplied." But this argument stands only if syntax (and presumably lexical content, too) is structured and directed by necessarily syntax-external processes. Rain is not the same thing as the complex concept RAIN, any more than a child's (or, for that matter, an adult's) conception of water the same thing as H₂O (contra Belleri 2016: 36). Syntax supplies temporal and spatial associations in the structure "It's raining" through tense and nominal reference, while what Hinzen (2015) calls the Here and Now of a speech act (its given time and location, which necessarily accompany any utterance) also saturate it, and so nothing is underarticulated, and grammar requires no assistance from exotic pragmatic operations.

As noted in section 1, grammar and content align in ways largely unrecognized in the literature on pragmatics and human cognition more generally. Grammar-meaning alignment should be seen as the null hypothesis, with empirical work required to justify deviation from it. Assuming this, we can propose the following guideline:

(15) Syntax-Internal Precedence (SIP)

Invoke syntax-external processes, such as pragmatic procedures, only when the explanatory power of syntax-internal operations reaches its limit.

To push the above argument further, the present evaluation of (12)–(14) leads to a rejection of pragmatic unarticulated constituents of the kind which can also be produced by merely observing the adicity of particular concepts, without even resorting to the level of analysis Phasal Eliminativism operates at. Indeed, instead of invoking unarticulated elements, an urgent and more difficult task faces the linguist and philosopher concerned with why (16) is a full sentence, if stabbed is a concept with a variable corresponding to the stabber:

(16) Caesar was stabbed.

Understanding the valences/adicities of lexicalized concepts requires no 'silent' elements constructed by human pragmatic competence (e.g. "Caesar was stabbed [Op]", with a silent operator standing for the stabber) or even individual differences amongst people of different tongues, but can be achieved through a deeper understanding of the individual set-theoretic operations and representations which host such properties, without the need to bring the grim human being into things. In a similar way that *truth* cannot purely be reduced to syntactic propositional structures (CPs), and can only be said to operate within

walks among the "glaucous-leaved, crimson-stalked marsh-plants" in Lodmoor country park's "dark stretches of gloomy peat-sold" with a young companion, Perdita Wane, and the "vague warmth of diffused well-being that it cast over him seemed to reveal with a culminating vividness that all material objects were unreal compared with the mental activity in which they floated, like rocking driftwood on an intangible tide" (1999: 155; see Murphy 2014b).

these constraints, so too can the differing number of arguments a verb takes (compare the dyadic *slept* to the highly polyadic—that is, ranging from dyadic to triadic to tetradic—*put*) be attributed to multiple factors. The adicities of lexical items is plainly one factor in the construction of their meaning. Another appears to be the effects of lexical items being instructions to build monadic concepts which may in turn have been introduced by other concepts with varied adicities. Since non-humans are capable of combining two distinct concepts (Murphy 2015a), the term *concept*, when used within linguistics and philosophy, should therefore be understood as *concepts which display a (yet to be fully determined) level of inter-modular assimilation*.

Given that thematic concepts are yielded by labeling, and the possibly human-unique nature of this operation, I would correspondingly like to shift the explanatory burden in accounts of linguistic interpretation not just to syntax, but to labeling. While there are a number of reasons to be suspicious of their lexicalist, word-internal definition of 'label' (according to which individual lexical items have a 'relabeling' capacity under certain conditions of movement), Cecchetto & Donati (2015: 31) are nevertheless right to note that "labels belong to the core part of grammar that cannot be dispensed with and cannot be relegated to the interface". The above division in the role of the computational system and the interpretive systems also reflects the *blind* and *free* nature of Merge on the one hand (documented by Epstein et al. 2014), and the necessary *optionality* of the interpretive operations of pragmatics, such as lexical narrowing (where *drink* is interpreted as *alcoholic drink*), on the other.

Syntax can also explain a number of entailment phenomena, if we assume, as noted above, that adjuncts are simply concatenated to a structure and do not reconfigure (i.e. re-label) the clause to which they are adjoined. "It's three o'clock in London" entails "It's three o'clock", but "Every man in the building is tall" does not entail "Every man is tall". This is due to the fact that in the former case the PP 'in London' is adjoined to the full structure, whereas in the latter case the PP 'in the building' is adjoined to the NP 'man' before quantification is fixed. Lexically, [NP man [PP in the building]] entails 'man', since a man who is in the building is still a man, but it does not entail that every man is tall since the PP is not adjoined to the QP 'every man'. The reason why an utterance of "Every man is tall" in a given context can entail that every man in the building is tall is because, as discussed, lexical but not syntactic representations are sensitive to context. In addition, meaning has always been justifiably understood as a relation between concepts and one, not two, linguistic structures.³⁰ Those claiming that hidden adjuncts and other material simply constitute the same meaning as the surface utterance therefore have to also provide reasons for abandoning this assumption; no such contemporary argument has been presented. When Recanati (2004: 58) moves beyond lexical underdeterminacy and argues for the existence of 'constructional' (grammatical) underdeterminacy in the case of 'red pen', we can simply point to the trusty computational system and invoke labeling as the operation which ensures that this phrase can never denote a red object which

³⁰ See also the contrast principle put forward in Clark (1988), under which speakers assume that two forms always differ in meaning.

happens to function as a pen (in which the adjective would label the phrase an AP), and can only denote a pen with the property of being red (an NP). Syntax consequently determines meaning, carving the path pragmatics must blindly follow.³¹

Let us assume further that nouns, verbs and modifiers are instructions to build monadic concepts, a process achieved via set-formation/Conjoin. In contrast, labeling permits the creation of thematic concepts (Murphy 2015c), and can be appealed to in order to reduce the need for extra pragmatic processes. Labels can introduce dyadic concepts like INTERNAL(E,X), with the necessary information being filled by the monadic concepts fetched by lexical items. Adding to Pietroski's (2012) argument that "lexicalization is a tool for creating concepts that abstract from certain formal distinctions exhibited by prior concepts", the combinability of human concepts may be generated by labeling, amounting to the kind of type-lifting operation proposed by numerous figures (Montague 1974; Kamp 1975) yielding higher-order concepts (than purely monadic ones) able to be saturated, e.g. $\lambda Y.\lambda X.RED(X)$ & Y(X) can be saturated by CHAIR(X) to form RED(X) & CHAIR(X).

Given this, the implications for the language sciences are clear. The linguist concerned with exploring topics ranging from ellipsis to co-predication should attempt to construct hypotheses based on SIP, invoking pragmatic processes only in an effort to explain how syntactically determined representations are ultimately enriched. A principled account of syntactic computation can derive many of the truth-conditional effects discussed by pragmaticists, and there is no need to couch a description of such phenomena within theories of 'free enrichment' or 'underarticulation', which are, ultimately, nothing more than elaborate methods of data coding, not explanation.

3.2. Labeling Theory

Before concluding, I would like to briefly discuss the actual labeling architecture invoked above, since instead of exclusively seeking semantic or pragmatic accounts of linguistic content, an understanding of syntax, following SIP, can also reveal the structure (or at least the legibility conditions) of CI.

Though phrase structure building has traditionally been seen as being categorially anchored, Chomsky (2015) proposes that labeling can also be achieved through less obvious methods. He explores so-called $\langle \phi, \phi \rangle$ agreement, through which an {XP, YP} structure is labeled by symmetric ϕ -features. For instance, ϕ features shared by K/D and T can label a phrase in which KP has undergone movement due to Q-feature agreement with T:

(17) {{ $K_{[\circ]}, NP$ }, { $T_{[\circ]}$ {... t_{KP} ...}}}

As Epstein et al. (2015: 109) point out, structures like (18) also cannot be labeled and crash at CI, since XP and YP have no intersecting features, and what

³¹ Questions of semantic content hover in the background, and are related to and constrained by labeling, but naturally do not reduce to it. Epstein et al. (2014: 465) stress that labeling theory is silent about "how the conceptual-intentional systems use the information that, say, {H, XP} is an H-type thing" (where 'H' denotes the phrasal head/label).

would otherwise be the embedded TP remains unlabeled:

(18) *There is likely $[X_P a man] [Y_P to arrive]]$.

But the agreement features (uninterpretable features, *u*Fs, valued by Agree) on T in (17) would have to be visible at CI for the derivation to converge and satisfy Full Interpretation, which seemingly contradicts the uninterpretable (i.e. undetectable at CI) status of *u*Fs in the context of T, since there can be no meaningful Person, Gender, and Number specifications with regards to Tense. As a way of remedying this, suppose that Transfer to CI (either as a property of Transfer or an interpretive condition) can select which copied feature-bundles are interpreted in the case of featurally symmetric {XP, YP} structures, perhaps through a form of semantically driven minimal head detection, as in Narita (2014), or a modification to the labeling algorithm, as in Adger (2013), allowing the copied (via Agree) ϕ -features on T to remain invisible and K's feature-bundle to be assigned interpretation. This would effectively turn the above structure into a $\langle \phi, \phi \rangle$ object at CI, with the strikethrough denoting selective uninterpretability, and we can assume that agreement features are visible for labeling. This symmetrybreaking perspective on labeling, yielded by cyclic transfer, also speaks to the present anti-lexicalism, since labeling is shown to be independent of the influence of lexical categories.32

Relatedly, it is worth briefly returning to the similarity discussed above between certain syntactic and semantic operations, since this might shed further light on syntax–CI interactions and disparities. Consider Function Application and theories of type-shifting, which appear (broadly) syntactic since they concern forms of mental computation. Though many other semantic operations (such as Pietroski's Conjoin) may simply be syntax 'in disguise', these operations notably violate principles of minimal computation like the No-Tampering Condition (NTC) and Inclusiveness Condition (IC), and so may have been the result of the kind of Darwinian modification by descent impacting conceptual representations (Hurford 2007; Carey 2009), unlike the 'perfect' system of narrow syntax with its operations of cyclic transfer and labeling by minimal search, which likely arose through a less gradual evolutionary process, perhaps of the Thompsonian kind as discussed in the evo-devo literature (see Hinzen 2006; Murphy 2015a).³³ Such

³² It also seems to me incorrect to claim, as is standardly done (e.g. in Epstein et al. 2014, 2015), that Collins (2002) attempted to eliminate labels from the grammar. Despite the title of his article, Collins rather worked towards changing traditionally labeled nodes to a lexically defined set of prominence relations.

³³ Concerns over simplicity and elegance in the study of language trace back at least to Leonard & Goodman's (1940: 51) 'considerations of economy' in their logical-epistemic work, and to Quine & Goodman's (1940: 109) distinction between 'real and apparent economy', i.e. theory-internal elegance vs. notational simplicity. It was understood that simplicity of theory is tantamount to explanatory depth. See Larson (2015) and Narita (2014) for discussions of computational efficiency and attempts to refine this amorphous notion, and Boeckx (2014: 87) for a critical examination of the standard claim that an increase in phase boundaries necessarily leads to greater computational complexity, which is rejected in favor of a novel phase model which suggests that if the phase head α labels the singleton set β it is an 'intransitive' phase, and if δ labels the two-member set { γ, α } it is a 'transitive' phase; see Murphy (2015d) for discussion and also Boeckx (2012) for the original proposal.

'semantic' CI operations involve mapping from hierarchical sentential structures to truth-values and sets of functions, violating IC and NTC. This topic has not been addressed to my knowledge in the semantics or wider cognitive science literature, but further interdisciplinary collaboration would achieve a richer analysis of both the core computational system and more peripheral semantic conditions and pragmatic operations, perhaps alleviating Tomalin's (2006: 3) concern, in his history of generative grammar and its relation to the formal sciences, that there exist "many areas of research that are not understood with sufficient precision to permit an axiomatic-deductive analysis".³⁴ The mode of grammar which characterizes certain aspects of human thought, based on a phasal architecture, has the potential to reveal the structure, relations, and development of semantic representations; one of the motivations behind the following claim from Ott (2009: 360): "The particular phases we find in human syntax are thus not a matter of necessity; if the C-I system were structured differently, different structures would be 'picked out'."

Notice also that at this point the topics of anti-lexicalism, pragmatic competence and biolinguistics make a certain amount of hitherto unnoticed contact. If linguistic structures can amount to ϕ -labeled, propositionally complete, and cyclically transferred conceptual representations which are only optionally enriched through more general cognitive and pragmatic processes, then the task of achieving a suitable level of granularity from which to meet the demands of biological adequacy not only becomes much clearer, but it also carries with it a higher level of falsifiability, given a developing understanding of the neural dynamics of linguistic computation (Bastiaansen & Hagoort 2015; Murphy 2015e, 2016) and cartographic advances in mapping the brain regions implicated in particular semantic representations (Moseley & Pulvermüller 2014). This is a clear advantage over less specific biolinguistic hypotheses, as Lasnik & Kupin (1977) already noted in their discussion of reduced phrase markers and restrictive syntactic theories. In addition, Moseley & Pulvermüller's (2014) study found that topographical differences in brain activation in response to a variety of noun and verb types were modulated by semantics, and not lexical category. Combined with the insight that phrases can be labeled and stored in short-term memory (during online structure-building) as objects labeled by non-lexical features (e.g. $[_{0} \dots \alpha \dots$ $[\gamma \dots \beta \dots]$), this consequently broadens the available options for empirically studying language at the implementational level, with those concerned with, for instance, the neural correlates of phrasal comprehension no longer being limited to searching for signs of NP or VP interpretation.

As this section has demonstrated, there is no shortage of constructive ways to explore linguistic computation and the structure of conceptual representations; some well-established, others newly emerging. But the search for unarticulated

³⁴ Even in debates at the syntax-semantics interface, it is often left unaddressed which structures, operations and features qualify as being narrowly syntactic, and which are post-syntactic. This is indirectly intensified by much of the cartographic literature. *EvaluativeMoodP*, for instance, is likely not a syntactic primitive, rather arising as the output of syntax-CI Transfer operations. In addition, due to the 'syntacticocentric' (to use Jackendoff's term) perspective on CI interpretation adopted here, perhaps the 'interpretive' function of formal semantics, [[], should be re-analyzed as being concerned with labels.

constituents via pragmatic processes of free enrichment is not one of them. As the bridges between linguistic sub-disciplines become stronger, and the prospects for wider collaboration with the life sciences grow, it should by now be particularly clear that multidisciplinary perspectives, goals and agendas should be pursued. Syntax is not enough, semantics and pragmatics are not enough, mathematics and philosophy are not enough, anthropology and brain dynamics are not enough. Nothing short of everything will really suffice.

4. Conclusion

The ongoing search in the field of pragmatics for unarticulated, missing elements has derailed a generation of inquiry into the interpretive systems, even if certain properties of these systems, such as relevance-seeking, have been exposed. Following SIP, a return to the original concerns of generative grammar centered on the computational system and how it interfaces with the external systems is now needed. As I hope to have shown, reference is achieved through grammatical, not lexical, mechanisms, while syntactic structures are not underspecified for semantic content, as is often claimed by pragmaticists. An understanding of what syntax can and cannot do is required before post-syntactic CI structures and pragmatic mechanisms can be appealed to. By adopting Phasal Eliminativism and viewing word meanings as a combination of pragmatically enriched concepts and *p*LEX representations, there is consequently no underdeterminacy, no pragmatic compositionality, no signifier-signified semantics, no Twin Earth paradox, no productive polysemy, no essentialism, no problems of reference or eternal sentences. There is only the bi-phasal syntactic and pragmatic computational procedure and its various operations: set-formation, labeling, cyclic transfer, saturation, relevance-seeking, and so on. It remains to be seen how far the pragmatic systems and semantic content can be reduced either to operations of the computational system or the structure of CI.

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A Plea for *Why Only Us* (Berwick & Chomsky 2016)

Wolfgang Sperlich

In *Why Only Us* (Berwick & Chomsky 2016), Bob Berwick and Noam Chomsky (henceforth, B&C), as masters of the metaphor, hammer home three linguistic home truths: (1) language is hierarchical (not linear), (2) all we need is Merge, and (3) speech (and communication) is external to language. When this is set in the context of biological evolution, B&C do admit to some limitations like "biology is more like case law, not Newtonian physics" (p. 36). As such, they make a very good case that can stand up in any court of law, excepting of course in kangaroo courts that proliferate these days, online and offline. I shall address a few below but before I do, allow me a few general observations.

Attacking Noam Chomsky has long been an industry that is encouraged and sustained by political reactionaries *cum* pseudo-scientists, pretentiously disguised as scientific debate. If one could only discredit him as a scientist, he would suffer as a political animal —only neo-fascists will attack blindly, as they always have done. So let us find a few linguists *cum* biologists who can prove that Chomsky's views on language evolution are a load of rubbish. QED. Chomsky at a ripe old age is, of course, becoming vulnerable to attacks by younger wannabes snapping at his heels. One simply has to disagree with at least some points that B&C raise and one has established oneself has a potential successor, paying heed to the Popperian obsession that science is all about falsifying existing theories. Like there is a science fringe that is always attempting to falsify Einstein, however benign he was politically. Generally, however, sensible scientists do attempt to prove Einstein's theories-witness the recent discovery and measurement of gravitational waves that were predicted by Einstein. Now, I am not saying that Chomsky is on par with Einstein, but wouldn't it be nice if linguists, biologists, neuroscientists, and what have you would concentrate on proving Chomsky right-"for Chomsky is an honorable man", as a modern Shakespeare would have to say.

As such, it is quite sad to see that even formerly avowed collaborators with Chomsky, like the now somewhat damaged Marc Hauser, must write articles that disagree with a number of important points that B&C raise. I am not for one moment suggesting that B&C are beyond criticism—they are not, but let's not try to falsify their theories which they are the first ones to admit, are tinged with speculation that is inherent to the topic of language evolution. To go on the attack and discredit a speculative theory by pretending to advance facts of the matter – where there are none—is like taking the wind out of the opponents sails by shadowing the sailboat with an ocean liner (a metaphor Chomsky the sailor might appreciate). Let's keep the playing field level, as the English would say.



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Biolinguistics 10: 051–059, 2016 http://www.biolinguistics.eu Chomsky is a good sport and enjoys a good scrap, and he can give as much as he takes. When B&C go on the counterattack, they do so with good humor, on occasion pointing out some of the more bizarre critiques they have to endure. Witness Tomasello's 'UG is dead' moniker, which B&C counter as saying that:

If so, then there is of course no topic of the evolution of UG—that is, of the evolution of language in the only coherent sense. Rather, the emergence of language reduces to the evolution of cognitive processes—which cannot be seriously investigated for the reasons that Lewontin has explained. (Berwick & Chomsky 2016: 97)

I will return to the obsession by cognitivists to subsume language as a mere phenomenon of the cognitive apparatus, whatever that may be. Let us briefly consider another terrible sin perpetuated by B&C, namely that language has not evolved from communication. Vyvyan Evans reviews *WOU* and comes to the following conclusions (amongst others):

- "It's quite a stretch to suggest that language didn't evolve to enable communication."
- "Indeed, the book attempts to make a virtue of disagreeing with almost everyone on how language evolved."
- "The reader is asked to swallow the following unlikely implication of their logic: [L]anguage didn't evolve for communication, but rather for internal thought."

(Evans 2016, online)

These very blunt instruments used for critiquing a perfectly sensible theory should not be in the armory of sensible academics—or shall we call Evans an intellectual? Evans might be enamored by the proposal, but then let's shoot him down with Chomsky's dictum of many an intellectual being a 'commissar' to uphold the reactionary paradigm.

Next in line is the very curious case of Elliot Murphy, who on his blog starts his review as follows:

Bob Berwick and Noam Chomsky's new book Why Only Us: Language and Evolution has been making the rounds. I assumed this book would just be a re-hash of the fairly tiresome, hyper-sceptical 'mystery of language evolution' perspective the authors usually adopt. And it is in some respects. But it also includes a surprisingly decent discussion of recent literature on animal cognition. Berwick's ideas come through more clearly throughout the text, typically backed up with the usual selection of Chomsky's rhetoric, Martian analogies, irony and so forth. But both authors only brush over their core question of how hierarchy is actually established, pointing languidly to 'some algorithm' responsible for labeling (p. 10). It should be stressed I think that even Chomsky's more recent technical work doesn't go far beyond this 'some algorithm' attitude (2013, 2015). From the perspective of brain dynamics, 'some algorithm' becomes capable of being explored in a number of interesting ways, as I mention here and here and in upcoming papers (see also Boeckx and Theofanopo[u]lou's useful response to the latter paper).

(Murphy 2016a, online)

Wow! We are so grateful that the book in question slightly rises above the "fairly tiresome, hyper-sceptical 'mystery of language evolution' perspective the authors usually adopt". The rest of the article is merely a vehicle to launch his own theory which is interesting in some respects but even more tiresome in its relentless self-assertion and name dropping (note Boeckx being mentioned early on as the current guru of biolinguistics). One reader of Murphy's blog review is even embold-ened to praise his piece as "[a]t last a non genuflected description of a Chomsky's book!".

What comes next is an even greater surprise, namely that Murphy is elevated to double authorship in the current volume of *Biolinguistics* (Murphy 2016b, 2016c), introducing one of his articles thus:

My intention in this piece is to briefly outline a novel hypothesis regarding the neurobiological implementation of feature-set binding, the labeling of feature-sets, and the resolution of linguistic dependencies arising from the cyclic combination of these labeled objects. One of the numerous motivations for this was reading Robert C. Berwick & Noam Chomsky's (B&C) recent book *Why Only Us: Language and Evolution* (Berwick & Chomsky 2016; henceforth *WOU*), which struck me as moderately comprehensive in its interdisciplinary scope (including good critical commentary on recent work in comparative neuroprimatology and theoretical biology) but severely impoverished in its range of linking hypotheses between these disciplines. (Murphy 2016b: 6)

We are ever so grateful that he has slightly revised his opinion to "moderately comprehensive in its interdisciplinary scope"—maybe in an attempt to get his articles accepted by *Biolinguistics*, which has always acknowledged the debt (intellectual and scientific) of Noam Chomsky as the founding father of biolinguistics. I have commented before on this paradox inasmuch as *Biolinguistics* does publish true-blue biolinguistics papers, but on occasion gets it horribly wrong with articles that are anti-biolinguistics as much as anti-Chomsky. So let us hit back *ad hominem*, one more time, against one Edmund Blair Bolles, who writes a blog about 'the origins of speech' and reviews B&C as follows:

I love the fact that in the beginning, and before there was any language, and in some "completely unknown way" we got the computational atoms that Merge assembles. So we start with a miracle. Words get their meanings by invoking these concepts. Thus, when I speak of the Hudson, or the Seine, or the Nile I am getting my meaning, not by pointing to a specific geographical entity, but by invoking an innate concept of river that is older than language. This kind of raw Platonism has appealed to many thinkers over the centuries, but I confess to always being a bit repelled by the sterility of the realm of forms. (Bolles 2016, online)

No wonder Mr. Bolles has some difficulty in believing a word of B&C, if he is concerned with 'the origins of speech'. I suppose one must forgive the 'speech = language' enthusiasts for their simplistic reasoning, just like the flat-earthlings could not believe that the world is round. Actually, I am not sure why B&C traverse this issue in such detail, that is, making the point that sound production and voice—and its evolutionary sequences—are common to many species,

notably, of course, to songbirds, but no species apart from humans have developed anything like language. Songbirds sing beautifully, whales and dolphins create under-water symphonies, and our cat meows in a way that annoys my wife, just like the harsh voice of certain humans can be extremely off-putting (listen to Hitler's speeches and wonder how such a terrible voice could enthuse millions of Germans, lest they were hypnotized). The point I am trying to make is that common sense absolutely forbids any connection between producing sounds (including human speech sounds) and the potential for language. B&C argue convincingly that the human propensity for voice modulation was a pre-existing tool that was later used for externalizing language as an erstwhile mental product. Proverbial bird-brains, as those detractors named above, seem to waste a lot of valuable time of B&C, who somehow feel compelled to prove them wrong.

So let us return to one who at least believes in some of the 'basic properties' of language as advanced by B&C, namely Marc Hauser, whose review is also published in *Biolinguistics*. He starts with a rare compliment, namely that *WOU* "is a wonderful, slim, engaging, and clearly written book" (Hauser 2016: 1). He then goes on to claim that *WOU* is based on the following five premises:

- (1) Merge is the essence of language.
- (2) No other animal has Merge.
- (3) No other hominid has Merge.
- (4) Due to the simplicity of Merge, it could evolve quickly, perhaps due to mutation.
- (5) Because you either have or don't have Merge (there is no demi-Merge), there is no option for proto-language.

(Hauser 2016: 1)

Of these, Hauser can only accept 2 and 3. So what's wrong with 1? He doesn't really make a case apart from saying that there must be much more to language than Merge. Nevertheless, as Hauser does agree that Merge exists, what's wrong with 4 and 5? Here his main argument seems to be that since B&C also maintain that Merge must interface with CI and SM, Merge cannot emerge (so to speak) by itself without parallel evolution of CI and SM. Given that B&C move ever closer to the idea that 'language of thought' equals CI, Hauser baulks at the idea, saying that "Language of Thought implies that the system is explicitly linguistic, and I don't believe it is" (p. 4). As I argue (and have argued before) that $language = CI_{\ell}$ one can, of course, dismiss Hauser forthwith. Hauser is also a fan (as he has to be, as an animal cognitivist) that SM is intimately connected with language (and Merge), hence we cannot dismiss the evolution of SM as paralleling language. Since B&C make a case for dismissing at least the externalization effect of SM as being related to the language faculty, Hauser's songbird obsession shines through, making the startling claim that "in particular, songbirds learn their song in some of the same ways as young children learn language" (p. 2; see also my comments on 'learning' below).

Having surveyed a few reviews, allow me to now write my own, with my first admission being that I agree with everything that B&C have to say, with the exception of various sections I do not really understand due to lack of technical knowledge. For example, the section on computer modeling of language and cognition: I was naïve enough to assume that brain and language computations will perhaps never be replicated by a machine, but here B&C surprise me with "the well-known challenge is that there are many, many algorithms and implementations that can do the job" (p. 132). Nor am I *au-fait* with the current neurophysiology of the brain in humans and other species (such as songbirds). My real interest is in advancing B&C two steps further, namely, first, in equating human cognition with language (language equals thought) and, second, in pushing the anti-lexicalist ideas that minimize the problem of the 'lexicon'.

So what is my argument for the first assertion? The Cartesian proposition of *cogito, ergo sum* may be the best evidence for equating language with thought, for how else could you express this idea, if not by and through language. No language, no thought. Nobody has ever isolated a thought without language. Let us restrict the meaning of cognition to the ability to think. Learning to perform tasks without thinking is as such outside the realm of cognition. Practically all species are capable in some way of such learning but only humans can ask afterwards, "Now what do you think, did I learn it well?". Hence the proverbial 'teaching the monkey to perform tricks', or as B&C put it:

If we reflect on this for moment, it appears that chimpanzees are perfect examples of pure 'associationist learners'—what they seem to have are direct connections between particular external stimuli and their signs. They do not seem to regard the apple they see in some mind-dependent way, as discussed in chapter 3. Rather, they have stored a list of explicit, mindindependent associations between objects in the external world and the ASL signs for them. This is far from human-like language ability—the chimps lack both Merge and the word-like elements that people have. If so, chimps are also eliminated as suspects in our whodunit.

(Berwick & Chomsky 2016: 146)

Associated with this language = thought is, of course, the unpalatable consequence that language is not primarily a tool for communication. The famous witticism promulgated by Bronowski (1977, cited in Fujita 2009) is that were it true, then the first human uttering a word or phrase would not have a counterpart to understand anything (i.e. we have the first communication breakdown in human history). It makes sense to assume that the development of Merge established mental concepts that equated to language, allowing for initially simple abstractions leading to propositional thoughts. That such a development in a few individuals led to a selective advantage would equally make sense. The idea of externalizing such propositions to check if fellow individuals might have the same or similar thoughts would be a next step but fraught with many obstacles. To externalize mental language (= thought) into speech would have to be met with many frustrations along the way, like the communication breakdowns alluded to above. Exchanging thoughts via speech no doubt creates new feedback systems that give rise to new and possibly more interesting thoughts. A negative corollary might have been that such communication could be used for nefarious purposes. Animals are not known to communicate false warning signals but humans are. Communication, as a worst case scenario, developed into a narcissistic enterprise that is evident today as much as it has been throughout recorded history. The great communicators of our day, from Hitler to Reagan, used

speech-making as some sort of hypnotic mass medium, communicating precisely nothing but themselves. These people, as the proverb goes quite succinctly, do not think before they speak. They are like trained parrots who drill holes into the brains of their adoring fans, a feat otherwise known as brainwashing. Sure there is also the opposite effect; for example, communicating genuine feelings by saying so: "I love you!"

Let us also be clear what communication is not: the externalization of thoughts as self-reference, as typically achieved in the fields of science and literature. To externalize one's thoughts on how the universe works and how language might have evolved is to put on public record one's thoughts. Sure, scientists may talk to each other about research but the ultimate output is not to communicate to others what they found out-the output is a public statement of their thoughts. When B&C wrote WOU, they did not do so from a burning desire to communicate, they simply wanted to state the facts of the matter the way they see (=think) it. That their thoughts resonate with mine is not a matter of communication. I do not write this review in order to communicate with either A, B, or C. Externalizing one's thoughts in this way seems to be a good way to check the validity of one's thoughts for one has to translate one's language of thought into the product of writing. Writers who depend on their writing as a means to make a living will, of course, try to ensure that they have a wide readership—not to communicate with the readers but to entice them to part with their money to buy the book. Schrödinger famously dreamt his groundbreaking formula, and so do many other scientists and writers in terms of thinking for themselves-not to communicate with someone else. This whole issue about communication also harks back to the longstanding distinction between langue and parole, i.e. the latter being the use of language which in itself may be an interesting field of study but should not be confused with the study of language itself. As with Wittgenstein's game theory of what constitutes language, we all know the rules of the game but some players are better (or more devious) than others.

All in all, one cannot but vigorously defend B&C's following assertion:

Accordingly, any approach to the 'evolution of language' that focuses on communication, or the sensorimotor system, or statistical properties of spoken language and the like, may be seriously misguided.

(Berwick & Chomsky 2016: 84)

So what of the mysterious lexicon? B&C note:

We will (speculatively) posit that the word-like elements, or at least their features as used by Merge, are somehow stored in the middle temporal cortex as the 'lexicon'—though as we mentioned in chapter 1, it is not clear how anything in memory is stored or retrieved.

(Berwick & Chomsky 2016: 159)

This idea is reminiscent of the old idea that vocabulary items are endowed with mini-grammars, now called features or edge-features as used by Merge. The lexicon has always been a weak point in Chomskyan theory, so what about the simple (hence elegantly minimalist) solution to posit that there is no lexicon? This proposal seems to fly in the face of popular views on language, not to speak of the publishing industry that makes a good living out of selling all manner of dictionaries. Nevertheless, the so-called anti-lexicalist stance has made headway in recent discussions, including by the above much maligned Murphy, who takes a somewhat hesitant step towards the proposition:

These observations support Borer's (2005) exoskeletal morphological model which views open-class words as hidden 'conceptual packages' that are purely embedded in the syntactic structure, causing no alteration to it or itself. Only when the structure is built by phase is the package 'opened' (interpreted). This is one of many reasons why syntax appears to be entirely free of lexical influence, operating independently of the needs of feature matrices (see Epstein et al. 2014 on 'free' Simplest Merge). [...] [W]ords are not concepts but rather *instructions to build concepts (from their semantic features)* [references excluded]. (Murphy 2016c: 30–31)

So, we still have 'words' but they are stripped of all syntactic edge features, reduced to 'conceptual packages'. How do they arise and where are they stored, if stored at all? Enter Fujita (2009) who, as far as I know, makes the strongest anti-lexicalist claim to date:

Basic claims of anti-lexicalism

- a. Words are generated by syntax.
- b. The lexicon can be decomposed into FLN (Merge) and FLB (sound and meaning).
- c. Consequently, there is virtually no lexicon.

(Fujita 2009: 143)

How exactly words can be generated by syntax remains a bit of a mystery:

To a certain degree, it can be said that syntactic structure building by recursive Merge is at the same time a parallel hierarchical conceptual structure formation by Merging semantic atoms successively (say, conceptual Merge). This proposal, by no means, is intended to suggest that syntactic structure and semantic structure are the same, as was once claimed falsely by Generative Semantics. On the contrary, full semantic interpretation requires much more information than syntactic structure provides (in particular where the compositionality principle fails to capture the vastly multifaceted and flexible syntax-semantics relations), and syntax and semantics remain two autonomous modules as before. (Fujita 2009: 145)

So, what are these 'semantic atoms'? And why is it wrong to claim that "syntactic structure and semantic structure are the same"? Sure, Generative Semantics simply put the onus on semantics, but if you consider the proposition of language = thought, then why not claim that syntax = semantics? Fujita gives an example:

Notice finally that to the extent that simple words are syntactically complex objects, it follows that Sub-Merge (Subassembly-type Merge) is always involved even in the derivation of two word utterances. This is so since to Merge *milk* and *cup* to form *milk cup*, for example, each of the two nouns must first be formed by Merge. (Fujita 2009: 148)

Does this mean now that this 'Sub-Merge' (no pun intended?) equals semantics? Fujita, in the end, cannot do any better than Murphy (2016c), who evokes 'conceptual packages' (see above):

Needless to say, there has to be a universal pool of features in the human brain, different combinations of which will ultimately yield a different set of lexical items or words (sound-meaning pairings) available in particular Ilanguages. These are a residue of the lexicon that may safely be assumed to be part of FLB. (Fujita 2009: 143, fn. 11)

Are the sound-meaning pairings arbitrary? Why do the English say 'tree' and the Germans 'Baum'? Was there a proto-sound-meaning pairing? Let's say I am forming a thought in my head to the effect that as an externalization it reads 'This tree is beautiful'. Let's assume that this thought in my brain has no lexical equivalents. Only when I externalize this thought do I need lexical items which may well be inventions restricted only by the features of the system of externalization (some remnants like onomatopoeic words may well point to earlier vocalization features). Since externalization requires a raft of complex motor skills, one may then posit that such motor skills become part of the memory yielding a 'learnt' lexicon of a particular language. Even so, this learnt lexicon component is totally subject to syntax as proposed by Fujita and Murphy, one learns 'words' only in the context of syntax. It is well known that in the rare cases where children have no or only very limited lexical input for learning 'words', children will invent their own as required. I do realize that there is certain amount of circularity in this argument, since I cannot really make a case that this argument pre-existed as a mental construct totally devoid of lexical items. When I think, I do use ephemeral words-but note that babies born have language capacity but no lexicon in the sense used now. Since the language of thought may have a wider scope than the externalized language we use as active or passive comprehension, such a wider scope cannot, however, transcend the actual language we use (learnt lexicon included) every day, be it as linguists or tinkers, tailors, and candlestick makers for equal measure.

So, what could thoughts generated by Merge possibly be made ofbiologically speaking? Murphy invokes 'brain oscillations' which still sounds like Newtonian physics to me (as alluded to by B&C before) and so I am somewhat surprised that none of the protagonists reviewed here (B&C included) have delved into higher-level quantum biology which now can explain, amongst other complex biological systems, navigation in some migratory birds. Quantum mechanics even extends to the populist level what with the Canadian PM being lauded in a recent presentation in which he explained (very sort of) the mechanics of quantum computing (The Guardian, 16 April 2016). Indeed, if we take this a step further, since language = thought requires unheard amounts of computing power, quantum computing may well provide some models for language as well. Obviously, I lack the technical expertise in these matters, but even when reading a popular text on quantum biology (McFadden & Al-Khalili 2014; see also my review of the book in Sperlich 2015), one can make quite a few interesting suggestions for language. For example, the famous linguistic bugbears of 'displacement' and long-distance binding in anaphora can be envisaged

as quantum states, that is, as remaining connected or intertwined over long distances. The many 'spooky' phenomena of quantum mechanics may play major roles in the neurophysiology of the brain and should be of interest to biolinguists as well.

In any case, I do hope that my plea for B&C serves to convince the jury of learned biolinguists of the merits of B&C's arguments, thus being able to further investigate language on the basis of mental Merge, generating thoughts (and the lexicon when such thoughts are externalized).

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A Functional Role for Neural Columns: Resolving F2 Transition Variability in Stop Place Categorization

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Documented examples from neuroethology have revealed species-specific neural encoding mechanisms capable of mapping highly variable, but lawful, visual and auditory inputs within neural columns. By virtue of the entire column being the functional unit of both representation and processing, signal variation is collectively 'absorbed', and hence normalized, to help form natural categories possessing an underlying physically-based commonality. Stimulusspecific 'tolerance ranges' define the limits of signal variation, effectively shaping the functionality of the columnar-based processing. A conceptualization for an analogous human model utilizing this evolutionarily conserved neural encoding strategy for signal variability absorption is described for the noninvariance issue in stop place perception.

Keywords: columnar-absorption of variability; normalization; phonetic variability; stop place perception; tolerance limits

1. Introduction

The brain is a five-star generalizer. It simplifies and organizes, reducing a deluge of sensory information to a manageable sum. From that small sample, the brain produces an effigy of the world, whose features it monitors [...]. But individuals and events are never identical, only similar in vital ways. The brain doesn't have room to record the everythingness of everything, nor would that be a smart strategy. (Ackerman, 2004: 54)

The neural recognition of a spoken sound occurs over a temporal span best measured in milliseconds, and over a spatial extent best measured in microns. The only methodology that possesses the temporal and spatial resolution to capture this decoding event is microelectrode recording of single neuron activations. Unfortunately this glimpse into neural sensory processing can only be obtained from neural substrates in animals. Well documented neural algorithms emanating from neuroethology investigations studying both auditory and visual processing of complex input signals can provide a rich source of information that can be used as a theoretical springboard for analogous representational algorithms in human neural substrates tasked to process highly similar input signals. An additional benefit of using



biolinguistics © The Author (2016) data from neuroethology is to shift the level of scrutiny to the 'how' of speech processing, rather than the more commonly revealed 'where'. Brain imaging methodologies are more suited to revealing the locational organization of neural processing loci and interacting networks, rather than the operational principles underlying neural processing. The purpose of this paper is to provide a viable neural conceptualization of how the human brain might represent and process the fine-grained auditory detail of F2 transitions characterizing consonant + vowel utterances. The neural construct that emerges from animal studies investigating the resolution of signal variability/ambiquity in auditory and visual inputs is neural columns. This ubiquitous, vertically organized, laminated structure, comprising the entire cerebral cortex, as well as subcortical nuclei, is postulated to be the neural encoding structure capable of bringing about signal normalization. Two examples of columnar-based normalization, across two different sensory input signals, both characterized by lawfully generated variability, will be described. Following this, a well documented acousticphonetic metric, locus equations (Sussman et al., 1991), will be described. Locus equations empirically demonstrate a categorical-level orderliness in stop place acoustic representation that demystifies the neural encoding of stop place categories. Neural columns may very well map and process the array of F2 transitions lawfully reflecting the dynamically changing resonance properties of the human vocal tract during production of stop + vowel utterances.

2. Two Opposing Approaches to Processing Speech Signal Variation

Phonetic variability in speech is ubiquitous, as direct causation stems from widely divergent sources—(i) speakers (e.g., age, gender, size), (ii) speaking styles (e.g., hypo-to-hyper-articulation), and, most importantly for this paper, (iii) phonetic context (e.g., coarticulated stop + vowel sequences). Two contrastive views will first be described as they illustrate important theoretical differences, particularly in how they view the need for signal normalization. The traditional 'abstractionist' view is highly dependent upon signal normalization as a basic prerequisite for phoneme categorization; the exemplar view claims normalization is unnecessary, as the brain's memory substrates for speech basically encode the "everythingness of everything".

2.1. The Traditional Abstractionist View

Traditional accounts of speech assumed a neural representation characterized by discrete, idealized, static, and context-free symbolic message units forming the sequentially ordered 'primitives' of the spoken word. Hockett's (1955) well known description of planned speech as a sequence of differently decorated Easter eggs epitomizes this early conceptualization of the neural representation of speech. The pioneering speech perception studies at the Haskins Labs in the 1950s added a new twist to this view, particularly when they investigated the role of the second formant transition in categorizing stop + vowel stimuli. Liberman et al. (1954), having unique access to the world's first speech synthesizer, the pattern playback machine, discovered that despite the invariant perception of stop place categories, the acoustic signal was highly variable, for the same stop, across varied vowel contexts. For

example, the alveolar stop category /d/, across the seven vowel contexts, revealed seven different F2 transitions, in both *direction* and *extent* of the transition. No invariant acoustic cue could be identified despite the perceptual invariance of the stops. The necessity for some form of signal normalization, however, was recognized (Shankweiler et al., 1977). By more or less default, they went in the direction of abandoning the auditory signal in favor of coding speech in terms of (supposedly) invariant motor commands. Whether it be phonemic-sized acoustic-based neural entities or the motor gestures to produce them, the important point is "the idea that the information in the speech signal must be encoded relative to something" (McMurray et al., 2016: 53).

2.2. Exemplar Theory

The symbolic abstractionist view has been directly challenged by exemplar theory, characterized by a non-analytic, instance-based view of cognition (Jacoby & Brooks, 1984). In exemplar-based accounts stimulus variation is informative, and hence instances are believed to be stored in memory. In the words of Pisoni (1992: 1): The variable attributes of speech are retained as "part of the internal representation of speech in memory". A succinct summary might claim 'exemplarists' stress 'particulars' and 'traditionalists' stress 'abstractions'.

Exemplar-based accounts of variation can be found across many subdisciplines of linguistics: phonetics, phonology, morphology, semantics, syntax, and language acquisition (Pierrehumbert, 2001, 2003; Hawkins, 2003; Gahl & Yu, 2006). My focus will be limited to phonetic-based investigations. This view is perhaps best captured by a quote from Pisoni (1995): "This view of speech perception focuses on the encoding of specific instances and assumes that very detailed stimulus information in the speech signal is processed by the listener and becomes part of the memory representation for spoken language" (p. 5). A few representative studies that historically shaped this view are described below.

Mullennix et al. (1989) investigated the intelligibility of isolated spoken words with the independent variable being a single talker or 15 different talkers (male and female). Identification performance was better for words produced by a single talker. The voice source variability across trials when the words were spoken by a multitude of speakers affected recognition performance. Goldinger (1992) reported evidence of implicit memory for speaker-specific attributes of a talker's voice. Identification performance for spoken words was superior when the words were repeated using the same voice, as in the original list presentation, relative to being repeated by a different talker. Mullennix & Pisoni (1990) showed that attributes of a talker's voice could be perceived independently from the phonetic content of the word, and vice versa.

Talker variability effects were also extended to speaking rate differences (e.g., Sommers et al., 1994). Words produced at fast, medium, and slow rates were identified with less accuracy compared to words presented at one speaking rate. Findings such as these led to the claim that the listener's brain encodes very detailed talkerspecific information in episodic memory representations. As rationalized by Pisoni (1995) "If these sources of variability were somehow 'filtered out' or 'normalized' by the perceptual system at relatively early stages of analysis, differences in recall performance would not be expected in memory tasks like the ones used in these experiments" (p. 15). The surface logic seems to make sense, but only if one accepts the premise that a brief, one time exposure to words can result in permanent representations stored in auditory brain tissue.

Interestingly, the only source of signal variability that both initiated and shaped exemplar theory was based on speaker differences—e.g., varying talkers and speaking rates. In contrast, the sole variability source underlying the traditional abstractionist position, as represented by the Haskins group, was phonetic context, specifically the conundrum of *perceptual* invariance of stops despite the *acoustic* variability of vowel contexts shaping the F2 transitions (e.g., Liberman et al., 1954; Liberman et al., 1967; Liberman & Mattingly, 1985). This difference between the sources of phonetic variability is rarely, if ever, discussed. The important and essential difference between the two types of variation is the following: The fine-grained phonetic detail in speaker-based differences consists of signal elements that actually sound different—i.e., an F0 of 120 Hz is easily distinguishable from an F0 of 185 Hz. In contrast, the various F2 transitions comprising a given stop place category all sound the same. Thus, acoustic variability in coarticulatory, context-induced scenarios is phonologically non-distinctive. The variability is lawful and systematic, but it does not create perceptual changes within the allophones of each stop place category. It makes sense then, that exemplarists never investigate context-based coarticulatory effects because their subjects would simply hear the same stop.

While the findings of exemplar-based studies are indeed intriguing, they do not constitute, by themselves, a body of experimental evidence to suggest a theory of how neural substrates encode speech tokens. In fact, they defy neurophysiological explanation. Lavie (2007) described the existing descriptions of exemplar theory as "an impoverished explanatory apparatus" (p. 1). All too often proponents of exemplar models couch their views of speech perception and resultant brain representations in vague and fuzzy terminology, such as 'clouds' of exemplars (Pierrehumbert, 2001). Actual brain-based reality, however, is totally missing from *both* the abstractionist and exemplar views.

A relevant study comparing the effectiveness of normalization operations in speech category identification was conducted by McMurray & Jongman (2011). A speech corpus (N = 2,873 recordings) obtained from 20 speakers, producing eight English fricatives, across six vowel contexts, provided the data base. It was determined that 24 simple cues were available to distinguish place, voicing or sibilance. Three different input models based on different sets of informational assumptions were compared in a fricative categorization task:

- (1) *naïve invariance*: a small number of cues that had a robust correlation with fricative identity and no compensation for talker/vowel contexts;
- (2) *cue-integration*: used every available cue, without compensation (this condition is most similar to exemplar approaches);
- (3) *compensation*: used every cue, but after effects of talker and vowel contexts were applied (this represents the normalization approach).

A subset of these stimuli were presented to human listeners for fricative categorization. A classification model based on logistic regression was trained on the remaining stimuli contrasting the three input cue sets. The normalization/compensation model performed the best, with an accuracy level similar to human listeners (90%). The naïve invariance condition resulted in 74.8% correct perception, and the cue-integration model yielded 79.2% correct category identification. Compensation processes to account for coarticulatory effects in production are thus highly effective in signal categorization. Stop + vowel productions have long been considered the 'litmus test for invariance seekers', and hence the most demanding set of acoustic signals in need of normalization.

3. Neural Mechanisms Resolving Ambiguity due to Variation in the Input Signal

In the following sections, I will describe a neural representation/processing mechanism, documented across two different species and sensory systems, that function to absorb/normalize input signal variation. The two examples are (i) sound localization processing in the barn owl, and (ii) visual object recognition in the macaque. The existence of basically similar neural algorithms, shaped by sensory inputs over time, across two different organisms (mammalian and avian) and sensory modalities, illustrates the conserved nature of this normalization platform in evolutionary development. The structural and functional neural unit accomplishing this feat is the neural column. Mountcastle (1978) was the first to claim that the cerebral cortex is remarkably uniform in structure across all processing areas (sound, vision, motor, higher order). This uniformity is due to vertically arranged neurons distributed within the six-layers of each and every column comprising the 2–3 mm of the cerebral cortex. Moreover, columns are also present in subcortical processing areas such as the midbrain inferior colliculus (Wagner et al., 1987).

Before describing how the barn owl and macaque deal with signal input variability, a brief account of *tolerance limits in sensory processing* will be provided. Tolerance limits pertain to a neural 'filtering' principle that permits specific ranges or 'windows' of signal variations to be processed by neural columns.

A classic early example of tolerance limits was discovered by Maturana & Frenk (1963) recording from single ganglion cells in the retina of pigeons. Groups of such cells were specifically sensitive to visual stimuli consisting of horizontally-oriented edges. Different clusters of such cells exhibited varying tolerances in the input signal to elicit their firing. For example, the range of tolerance for one class of neurons was 25 degrees of inclination from a 0 degree horizontal edge. Said in another way, any edge stimulus varying within a 0-to-25 degree range of variation was 'good enough' to initiate a strong firing pattern from a given cell. Another group of ganglion cells operated within a 20, 15, or 10 degree range of tolerance from the absolute horizontal.

Barlow et al. (1964) and Oyster & Barlow (1967) reported similar results recording from retinal ganglion cells of the rabbit. The specific triggers for these cells were the speed and direction of image movement. Once again tolerance ranges were exhibited for specific stimuli. This commonly observed characteristic of neuronal sensitivities suggests the existence of prescribed limits of stimulus parameter variation for visual feature detection. Characteristically, what is shown in one sensory modality is also found in other modalities. Nelson et al. (1966) recorded from single neurons in the cat's inferior colliculus in response to complex, time-varying signals (FM sound sweeps). These 'meow' detectors revealed highly specific responses to (i) upward sweeps in frequency vs. downward sweeps, (ii) from a particular starting frequency-to-ending frequency, for each direction of change, and (iii) for given *rates of change* (Hz/sec) within the various starting-to-ending directional frequency ranges. The same classification scheme was also documented for amplitude modulated input signals. The entire range of coding specifications across frequency and amplitude dimensions revealed in a cat's 'meow' detector neuronal population could adequately describe the human speech signal, which basically consists of frequency changes over time.

4. Columnar Organization in Sound Localization Processing in the Barn Owl

Owls hunt for food at night, using sound cues arriving from various directions and distances. The two acoustic parameters necessary for azimuth localization (left/ right) are frequencies and their relative phase differences arriving at right and left ears. The frequencies emanate from the sounds of their prey, and the phase information emerges from the differences in time of arrival of the sounds at the two ears. The ear closer to the origin sounds responds sooner. However, there are inherent ambiguities in frequency and phase values that need to be overcome before the owl can strike and secure dinner. Here is a simple example: picture an oval running track with two runners at a given moment in time. One runner is in front of the other, apparently leading in the race. If you ask a child, "Who's winning the race?", the child would most likely respond "The guy in front". If it were the child of a physics professor, he/she might reply: "It's totally ambiguous as we do not know how many times each runner has run around the whole track, all we see is the phase difference between the two runners". Thus, phase information, without corresponding frequency information, is non-informative and ambiguous.

Wagner et al. (1987), recording from the central n. of the barn owl's inferior colliculus during actual sound localization maneuvers, has clarified how this coding ambiguity gets resolved. Neurons making up tonotopically organized 'delay lines' located in a lower brain stem nucleus of the barn owl (nucleus laminaris) initially encode interaural phase differences in sounds arriving at the two ears. The most activated cell in each of the tonotopic delay lines codes the temporal disparity in time of arrival of the two sounds—lead ear relative to lagging ear. These temporal disparities then project to the central n. in the midbrain of the barn owl, the site where Wagner et al. recorded from individual combination-sensitive neurons whose job is to encode all the various simultaneous frequency/phase pairings in the complex input signal.

Figure 1 shows a simplified schematic that captures the essence of how interaural time difference (ITD) columns resolve the inherent ambiguity/variation of these binaural input signals. The 3D schematic shows the results of the firing patterns of combination sensitive neurons vertically organized in columns throughout this nucleus. Frequencies (only a representative portion) are plotted along the y-axis, and phase differences, depicted in percentages, along the x-axis, and the *emergent* ITDs, along the z-axis. Notice that one column is shaded, the one coding an emergent ITD of 50 µsec. With radioactive tracers it was determined that this particular column, as a collective, sent its output to the shaded area of the higher external n., where there was an invariant coding of 30 degrees azimuthal location of the input sound.. That directional location equates to a lead arrival time of 50µsec to the right ear. The key point is that regardless of the different frequency/phase pairings encoded within the column, *they all contain a temporal commonality*—*the same ITD*—*of* 50 µsec! The column serves as a 'buffer', absorbing signal variation, to arrive at an invariant instance of time of arrival, which signals spatial location to the owl. The columns tolerate wide differences in lawful phase variations across the frequency spectrum of the complex input sounds.



Figure 1: Columnar organization to derive ITDs in barn owl's inferior colliculus

There is one problem, however, with this example of columnar functioning to yield an emergent normalization of highly variable input signals—all the inputs arrive co-temporally, at the same time. The owls are processing complex sounds with spectral energy distributed throughout the entire frequency scale. To make the theoretical jump from animal-to-human brains, all the variations of the input signal cannot be co-temporal, but rather experienced one at a time, repeatedly, over long development time spans. Phonological categories in children form over the first few years of normal exposure to the contrastive sounds of a natural language. The next example, from the macaque, will illustrate the existence of similar cortical columns that gradually develop with experience, but contain the same basic format and function as seen in ITD columns of the barn owl.

5. Columnar Organization for Signal Variability in Visual Object Recognition in the Macaque

Tanaka (1993) investigated object recognition in the inferotemporal cortex of the macaque. Visual images undergo lawful changes due to different illuminations, viewing angles, and articulation of the object. Tanaka's set of critical visual features to test a neuron's firing sensitivities were created by a systematic reduction method. Starting with images of natural objects (e.g., the head of a tiger), they first zeroed in on single neurons in a given cortical column that maximally fired to the complete stimulus. Then they systematically reduced and simplified the image, step by step, with each step being tested as to whether the neuron still responded to the altered image with the same magnitude of response as seen in the original complete image. Each step was a gradual reduction of the complexity of the image. When a given neuron ceased responding to a particular reduced image, the reduction process stopped and a basic critical feature was arrived at. A set of 12 critical features were thus derived and used to probe the columnar organization in anterior IT cortex. Figure 2 shows the step-by-step reduction process for the 'tiger image' from Tanaka (1993). The 'tiger' neurons responded equally to all stimulus reductions except the bottom two symbols (dark rectangles and white square).



Figure 2: Example of the reduction method to arrive at a critical visual feature

When vertical electrode penetrations were made within a given TE column, they first determined the critical feature from the mid region of that column. Further single neuron recordings within the vertical penetration revealed responsiveness to related or highly similar images to the optimal stimulus. The object feature was not represented by a single cell, but rather by the activity of *all cells within a given column*. The effective stimuli, composed of subtle variations of a given image, overlapped and provided a robust collective columnar response. Whilst the input signal contained subtle variations due to changes in illumination, viewing angle, and articulation of the object, the global organization of the column structuring the output showed little change despite the internal variation. As stated by Tanaka (1993): "The clustering of cells with overlapping and slightly different selectivity works as a buffer to absorb the changes" (p. 686).

Figure 3 shows the schematic from Tanaka (1993) illustrating the cortical columnar organization in area TE. Vertical penetrations within a given column revealed sensitivities to the same basic shape, in all their lawful permutations, as if they were 'visual object allophones'. The findings of Tanaka illustrate that in visual object recognition there is no stored template or 'prototype' that is matched to the input stimulus, but rather a flexible and collective process wherein the variations in the stored data (sets of columns) represent the various 'visual allophones' characterizing an object's features across the lawfully generated physical contingencies learned via visual experiences.



Figure 3: Columnar organization in area TE

6. How Might the Human Brain Normalize F2 Transitions?

Using the columnar model documented in the barn owl and macaque, the following section will attempt to extend this algorithm to the seminal non-invariance conundrum in speech perception, stop place categorization. Locus equation (LE) studies (e.g., Sussman et al., 1991, 1993, 1997) have demonstrated that, at the level of the stop

place category, the frequencies at which F2 transitions start (F2 onsets), and where they end in the vowel nucleus (F2 midvowel), display a linear and highly correlated relationship. Figure 4 shows a typical alveolar ([dV]) locus equation scatterplot, with 10 vowel contexts. Each [dV] token (e.g. *deet, debt, dat, dot, doot, etc.*) was randomly produced within a carrier phrase, five times, by a single speaker. The <x, y> coordinates are F2 onset frequencies plotted on the y-axis, and their corresponding F2 midvowel frequencies on the x-axis. The F2 transition is parameterized by two time points, where it starts and where it merges into the vowel. In the scatterplot below the regression slope was .394, y-intercept 1217 Hz, and R-squared .915. The R-squared values in LEs typically exceed .90, and the standard errors of estimate are usually less than 100 Hz.



Figure 4: Typical locus equation plot for an alveolar stop /d/

The following quote succinctly summarizes the LE paradigm: "[A] tremendous amount of orderly structure can be witnessed by plotting exemplars in an F2-onset frequency by F2-vowel-midpoint frequency space. What appears to be a nearly impossible categorization problem becomes less mystical when one sees the structure inherent in a different acoustic space" (Lotto & Holt, 2016: 76). LEs have clearly demonstrated that the variable F2 transitions, that previously led Motor theorists to abandon the auditory signal in favor of motor gestures, display an emergent level of orderliness when displayed as a higher order stop place category. Normalization has occurred, in a self-organized fashion, for free, when the whole stop place category is displayed by these <x, y> coordinates. No statistical algorithms are needed. The observation that lawful orderliness first emerges when the phonological category is displayed as a collective (rather than token-by-single token), suggests that the neural correlate of a phonological category should also be a collective, capable of representing all its allophonic members.

Linear scatterplots and contrastive LE slopes have been documented across stop place categories in every language thus far examined—including Arabic, English, Estonian, French, Spanish, Swedish, Thai, and Urdu (Lindblom, 1963; Duez, 1992; Sussman et al., 1993; Martínez-Celdrán & Villalba, 1995)—and thus might very well be a linguistic universal. The category-specific slopes of locus equations have been shown to be reliable phonetic markers for stop place (labial, alveolar, velar), as they capture the degree of anticipatory coarticulation of each vowel context on stop place occlusion (Krull, 1988; Sussman et al., 1991, 1993). Rather than viewing vowel context-induced variability as 'unwanted noise', the locus equation view maintains that differentially tweaking coarticulatory extents across stop place categories actually underlies the acoustic distinctiveness to contrast stop place categories in acoustic space.

6.1. Possible Neural-Based Correlates for Mapping Locus Equation Structure

An essential requirement across sounds comprising a category to qualify them as 'information bearing parameters' is a high degree of statistical regularity (Suga, 1989). When parameters of a communicative sound possess a high degree of statistical correlation, neuronal-based learning is optimized and subsequent representational mapping in neural tissue becomes highly feasible (Suga et al. 1978; Suga, 1989). In this section, I will suggest two brain-based processing mechanisms: (i) a class of neurons capable of encoding locus equation acoustic parameters, F2 onset in relation to F2 midvowel, and (ii) a neural structure ideally suited to map equivalence classes —the neural column.

A neuron capable of processing both the onset and offset frequencies of F2 transitions is well documented in neuroethology. They are referred to as 'delay-tuned' combination-sensitive neurons (e.g., Mittman & Wenstrup, 1995; Portfors & Wenstrup, 2001; Yavuzoglu et al., 2011). These higher-order auditory processing cells have been widely described in the mustached bat (e.g., Suga, 1994). One example is the derivation of target velocity in echo location. In this instance, the Doppler shifted frequency of the returning echo pulse (e.g., CF2, the second harmonic constant frequency segment) is processed relative to the CF2 frequency of the emitted pulse. The laws of physics determine the Doppler shift, and the bat uses this information to 'calculate' the speed of the target prey. The bat also calculates distance of the prey by the time delay between various harmonics of the pulse vis-à-vis returning echo. In both cases, tens of milliseconds separate the two biosonar signal components, just as they do in stop + vowel utterances (F2 onset relative to F2 midvowel Hz). The crucial point is that delay-tuned, combination-sensitive neurons are the ideal candidate neuron to encode the start and end of a F2 transition, arguably the most important acoustic cue in speech perception (Liberman & Mattingly, 1985).

Auditory combination-sensitive neurons tasked to map highly variable, but lawful input signals, in neural substrates would be expected to be organized within a neural entity capable of representing the entire equivalence class. One viable candidate is the neural column (or sets of columns). Why would phonologically-based sorting not use the same evolutionarily conserved mechanisms as other species had already developed, in dealing with ambiguous and highly variable encoding problems?
6.2. The Significance of Linearity and the Locus Equation Slope

A basic requirement that must exist to allow encoding of variable inputs within neural columns is a *shared physically-based commonality across the input stimuli*. An interesting similarity emerges when one compares the linear scatterplots of LEs to <x, y> scatterplots of the physical input signals underlying both echolocation in the bat and sound localization processing in the barn owl. Velocity-coding (Doppler shift) and distance tuning in biosonar echo processing are based on perfectly linear relationships between the two signal elements for each emergent property (Suga et al., 1983). Similarly, ITD maps in the barn owl (Wagner et al., 1987) are formed from linear <frequency–phase> relationships inherently formed by the laws of physics.

The LE slope is a statistically generated metric that represents the correlational value of the plotted frequencies F2 onset and F2vowel. Said in another way LE slopes, characterizing a given stop place category, statistically capture a lawful patterning of variable F2 transitions in acoustic space. Thus, they illustrate the existence of a shared *lawful commonality* across acoustically-coded <x, y> coordinates representing a stop place category. In sum, the laws of physics create the F2 transitions, and the brain utilizes these fine-grained acoustic stimuli for its own encoding purposes. Just as a linear regression slope captures and represents the entire spatial distribution of F2 transitions in acoustic phonetic space, the F2 *'particulars'* hypothesized to exist within neural columns can collectively signal the same stop place perception in an isomorphic neural space.

6.3. Speaker-Based Differences in Stop + V Coarticulation

Sussman et al. (1991) derived LE plots for twenty speakers, 10 male and 10 female. Within a stop place category speaker specific slope/y-intercept values also exhibited substantial variability. However, and this is a big however, when slope and y-intercept values were used in a discriminant analysis, to assess predicted [bdg] categorical identity, the result showed 100% correct stop place categorization. This result was subsequently replicated for Spanish speakers (Celdran & Villalba, 1995). Once again, tolerance limits for slope, and their requisite y-intercept values, allowed for absolute contrastive mapping of categories. The mean alveolar LE slope for male and female speakers was .43 and .41, respectively, with male speakers varying from .346 to .492 and female speakers from .27 to .50. Figure 5 below shows the clustering of LE slopes/y-intercepts across the 20 speakers. The red squares represent the 20 speakers producing [dV] LEs, the green triangles show the [gV] LEs, and the blue diamonds show the 20 [bV] LE parameters. It can easily be seen why the discriminant analysis yielded 100% correct category assignment—there is no category over-lap among the three stop place categories, despite the range of speaker-specific values seen within each stop place category. The bottom line: If stop place categories, produced across several variability-inducing scenarios-phonetic context + male-female differences, can be captured as three, non-overlapping, categorical clusters on a higher order LE <x, y> plot, the brain should not experience any processing road blocks in doing the same thing. The challenge is to explain how a single input stimulus finds its way to the higher order categorical representation. Visual object recognition in the columns of inferior temporal cortex of the macaque faces the same question: How does each separate visual experience of a shape find its way to the correct column?



Figure 5: Locus equation slopes and y-intercepts across 10 male and 10 female speakers for labial, alveolar, velar stop categories

6.4. A Hypothesized Algorithm for Developing Categorical Mapping within a Column

In Sussman et al. (1991), a hypothetical algorithm was presented to provide an initial attempt at formalizing this mapping puzzle. It was organized in three (temporally sequential) tiers of processing: (i) stop burst processing; (ii) F2 onset processing; and (iii) F2midvowel processing. Each layer had synaptic connections to combinatorial 'AND-gate' neurons that respond best to the joint presence of multiple input signals. Using [*dae*] as an initial input *CV*, how does this signal finds its way to the [d] column' within a developing 'speech sound map' (e.g. Guenther et al., 2006) driven by a child's own babbling and 'motherese' external input?

The first stage is envisioned as the most activated neuron responding to the spectral noise prominences in the /d/ burst, in combination with the most activated neuron responding to the tonotopic F2onset frequency. These dual input signals would converge and synapse onto the *same* 'AND-gate' combinatorial neuron coding the two input signals. This neuron then connects with another set of combination-sensitive neurons that combines the above pair with the tonotopically analyzed /ae/ F2vowel-activated neuron(s). Linear LE plots for a given stop place category signify that a given F2 vowel Hz has a strong predictability accuracy for the appropriate F2 onset Hz. The combined projections from the burst, F2 onset, and F2 vowel process-sing thus all converge onto the same combination-sensitive cells dedicated to integrating the three levels of signal input and predicting stop place identity. All CVs

with the same initial stop + assorted vowels activate similar combinatorial neurons coding that stop place. Why? Because they all possess an acoustic-based commonality as captured and reflected by the contrastive and linear locus equation scatterplots. As the infant, over time, hears words beginning with the same sound—'*daddy*, *doggie*, *daisy*, *dance*, *day*, *duck*, *deer*...'—the above circuitry develops its 'tuning' precision and slowly establishes perceptual identity and the resultant representations for the building blocks of phonology, the phonemic units of language.

Two experimental studies lend support to this conceptualization. Sussman et al. (1999) analyzed CV babbling and first word productions of an infant spanning the period of seven months to age 40 months. A total of 7,888 utterances were longitudinally analyzed, month by month (a total of 3,103 [bV], 3,236 [dV], and 1,549 [gV]). LEs scatterplots were generated from these transcribed data values. Babblingbased LEs bore very little resemblance to phonologically mature speakers. An interesting transformation was documented across development as babbling gradually transformed into first word attempts, and ended with the more sophisticated utterances of a 3-year-old. Specifically, initially flat 'labial' LEs generated from babbled CVs gradually became steeper, due to greater levels of anticipatory coarticulation; initially steep 'alveolar' LEs plots derived from reduplicated and variegated babbling gradually leveled off, due to decreased levels of anticipatory coarticulation, and thus more closely resembled the low-slope values of adult-like [dV] productions. These articulatory-based adjustments, documented by changing LE slope values, can be envisioned as a parallel developmental progression of a maturing 'speech sound map'.

However, when LEs are derived from children diagnosed with the neurological disorder known as 'developmental apraxia of speech' (DAS), their mean slopes across [bV], [dV], and [gV] productions were not contrastive relative to age-matched peers, but highly similar—labial = .642, alveolar = .703, and velar = .749 (Sussman et al., 2000). It is no wonder that their speech exhibits a high degree of unintelligibility. Their speech motor control deficiencies preclude precise control of anticipatory coarticulation to acoustically separate and contrast stop place classes. Their phonologically-organized speech sound maps are thus inherently impoverished, precluding precise acoustic mapping of the acoustic elements of speech sounds with eventual production of these sounds.

7. Summary and Conclusions

An effort was made to introduce neural-based reality into discussions of contextinduced phonetic variability in stop place perception. In describing the basic differences between exemplar versus traditional abstractionist views of phonetic variability, it was stressed that neither approach provided a realistic account of how variability is actually processed in the brain. Abstractionist (viz. motor theory) accounts were credited with citing the need for normalization routines to remove 'noise', a view foreign to exemplar accounts, who maintain every input token is informative and hence stored. To accomplish this goal, two neural-based examples from neuroethology investigations, sound localization in the barn owl and visual object recognition in the macaque, were described. Both avian and mammalian species were shown to possess (i) columnar structures that encoded stimulus variations, (ii) within specified tolerance ranges, that (iii) were linked by lawful physically-based, relationships. By virtue of the entire column functioning as a collective unit, the encoded variability served to eliminate or absorb the inherent 'noise'. There is no matching of 'on-line' input signals to stored 'prototypes'.

The basic similarities between the neuroethology examples and human speech perception for stop place coding were then described using the locus equation paradigm as a theoretical bridge between animal and human models of processing highly variable sensory inputs. An attempt was made to conceptualize a neural account of stop place categorization by using the columnar model from neuroethology, in combination with the remarkably linear and orderly data from normal productions of stop consonants produced with varied vowel contexts. The neural analog of a LE slope was hypothesized to be the contents of neural columnsencoding the collective acoustic commonalities of the F2 transitions characterizing each stop place category. Thus, in principle, columnar outputs coding stop place identity are loosely analogous to what a contrastive LE slope captures. The LE encodes the F2 transition onset and offset on an $\langle x, y \rangle$ scatterplot, the brain is hypothesized to encode the same physically paired frequencies within sets of neural columns. The ultimate outcome is an invariant perception of a speech sound despite highly variable instances of that sound when in context. It is hoped that these conjectures will spark further discussions and innovative thinking to further advance our understanding of these encoding and representational issues.

In closing, the advent of ECoG electrode array studies performed on human subjects have provided the first glimpse into the 'how' of speech processing. Chang et al. (2010) provided direct evidence of cortical population response patterns for the categorical representations of /ba/-/da/-/ga/ from a 14-item synthesized continuum systematically varying in F2 onsets. Mesgarani et al. (2014) reported the encoding of phonetic features directly tuned to a multiplicity of spectrotemporal acoustic cues. The conjectures put forth in this article will gain added validity as future ECog studies further clarify the nature of acoustic-phonetic representations of speech in human temporal cortex.

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Three Ways to Link Merge with Hierarchical Concept-Combination

Chris Thornton

In the Minimalist Program, language competence is seen to stem from a fundamental ability to construct hierarchical structure, an operation dubbed 'Merge'. This raises the problem of how to view hierarchical concept-combination. This is a conceptual operation which also builds hierarchical structure. We can conceive of a garden that consists of a lawn and a flower-bed, for example, or a salad consisting of lettuce, fennel and rocket, or a crew consisting of a pilot and engineer. In such cases, concepts are put together in a way that makes one the accommodating element with respect to the others taken in combination. The accommodating element becomes the root of a hierarchical unit. Since this unit is itself a concept, the operation is inherently recursive. Does this mean the mind has two independent systems of hierarchical construction? Or is some form of integration more likely? Following a detailed examination of the operations involved, this paper shows there are three main ways in which Merge might be linked to hierarchical concept-combination. Also examined are the architectural implications that arise in each case.

Keywords: Merge; Minimalist Program; hierarchical concept combination

1. Introduction

Hauser et al. (2002) note that underlying language there must be a faculty that is "hierarchical, generative, recursive, and virtually limitless with respect to its scope of expression" (Hauser et al., 2002: 1569). By implication, the language system must have, at its heart, an operator which can relate multiple objects to a single object in the formation of a hierarchical unit. Recursive application of this operator must be what gives rise to structurally complex expressions. The Minimalist Program dubs this fundamental operator 'Merge'. Chomsky deduces its existence as follows:

An elementary fact about the language faculty is that it is a system of discrete infinity. Any such system is based on a primitive operation that takes n objects already constructed, and constructs from them a new object: in the simplest case, the set of these n objects. Call that operation Merge. Either Merge or some equivalent is a minimal requirement. With Merge available, we instantly have an unbounded system of hierarchically structured expressions. (Chomsky, 2005: 11-12)



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Chomsky also notes that Merge has the potential to be applied to conceptual entities. Used this way, he observes, the operator would implement a compositional medium of thought with an unlimited generative capacity. As he says,

Emergence of unbounded Merge at once provides a kind of language of thought, an internal system that makes use of conceptual atoms (perhaps pre-existent) to construct expressions of arbitrary richness and complexity. (Chomsky, 2007a: 16)

No other internal compositional apparatus is needed, Chomsky maintains, to explain the productivity of thought. While acknowledging it "is often argued that another independent language of thought must be postulated", he considers the arguments not to be compelling (Chomsky, 2007a: 16).

The view is shared by, among others, Hauser (2009) and Hinzen (2009, 2012). For Hinzen, Merge's capacity to implement a language of thought is further evidenced by the inherently grammatical nature of thought. Hinzen argues that a "science of grammar is or can be a science of human thought because it uncovers the principles and organization of thought, and it can do so because our mode of thought is uniquely grammatical" (Hinzen, 2012: 642). This leads to the conclusion that "insofar as our mode of thought is species-specific and needs to find an explanation, grammar is the most likely such explanation" (Hinzen, 2012: 646). On this view, generative grammar is not only the mediation of language, but also of thought: It "is the essential mechanism we need, with no additional and independent language of thought required" (Hinzen, 2012: 647).

Underlying this position is the assumption that grammar (or more fundamentally Merge) is the only generative system of hierarchical construction the mind possesses. Chomsky rejects the possibility of there being any hierarchically generative system other that Merge, commenting that "To date, I am not aware of any real examples of unbounded Merge apart from language" (Chomsky, 2007b: 20). Hinzen takes the same position in the case of grammar more generally, arguing that

there is no known non-grammatical way in which meanings of that specific kind arise, or on what generative system they should be based. (Hinzen, 2012: 646)

This raises the question of how to view hierarchical concept-combination. This is a conceptual mechanism of the envisaged type. Concepts are readily put into hierarchical combinations, and the process of doing so features prominently in ordinary thought. In conceiving of a residence consisting of a house and garden, or a bouquet consisting of a rose, orchid and tulip, or a meal consisting of a burger and fries, we put concepts together in a way that makes one the accommodating element with respect to the others taken in combination. A hierarchical structure is produced in which the accommodating concept forms the root. Since what is obtained is itself a concept, the procedure is inherently recursive. The garden that is conceived as contributing to the make-up of a residence can, itself, be conceived as consisting of a lawn and flower-bed. Concepts have the potential to be assembled compositionally, and multi-level structures can be obtained in this way.

Hierarchical concept-combination (HCC) makes use of conceptual entities to construct compositional structures of arbitrary depth, then. This is akin to the capacity Chomsky attributes to Merge, for using conceptual atoms to construct "expressions of arbitrary richness and complexity" (Chomsky, 2007a: 16). Are Merge and HCC the same operator, then? HCC implements a language of thought that is inherently compositional. Chomsky notes that Merge does too. Are these two languages of thought really the same language? Can we say that Merge = HCC?

The answer is not entirely straightforward. If Merge and HCC are the same mechanism, each should be able to fulfil the functions of the other. In practice, the relationship is not quite symmetrical. HCC distinguishes between an accommodating concept, and concepts that are accommodated *by* it. Merge makes no such distinction. While HCC can implement Merge, Merge can only implement HCC on certain assumptions, then. Setting this reservation aside, the two mechanisms can be seen as functionally equivalent, on which basis HCC might implement Merge, or Merge might implement HCC. But this poses its own problems. If we assume the two mechanisms are implemented separately—one in the language system and one in the conceptual system—that would imply a wasteful duplication of mental resources. If we assume there is only one implementation, there is the problem of explaining how this could simultaneously serve the role of Merge in the production of language, and of HCC in the production of hierarchical conceptualizations.

What is argued below is that there are two ways in which these two mechanisms might be connected. The less radical scheme keeps the language system in its usual form, but assumes that one of the two mechanisms provides services to the other on a client-server basis. This raises the question of how the provision is accomplished: What changes are implied for the interface between the language and conceptual systems? The more radical arrangement is one which keeps the conceptual system in its usual form, but assumes that HCC sends hierarchical *structures* to the language system for translation into symbol sequences. This raises different questions: How the translation is accomplished is clearly one. Counting the arrangement in which the two operators work independently, there are then three possible ways in which HCC and Merge might be related.

The remainder of the paper sets out the analysis in detail. There are five main sections in all. The section immediately to follow (Section 2) looks at hierarchical concept-combination from a more formal perspective. A shorthand is introduced which allows constructions to be specified in the briefest possible way. This is then used to develop a number of examples showcasing the compositional generativity of the mechanism. Section 3 then looks at Merge and considers the ways it may be related to HCC. The latter part of this section focuses specifically on the case where HCC is considered to contribute hierarchical structures to the language system, the 'semantics-first' arrangement as it is dubbed below. Section 4 then draws the evidence together and considers what is implied. Finally, Section 5 offers some concluding comments.

Some technical points should be mentioned at the outset. Material dealing with conceptualization follows the approach of Murphy (2002) in avoiding use of special fonts in the naming of concepts. Where there is any ambiguity, the phrase 'the concept of X' is used to indicate that X is a concept name. Following normal practice in linguistics, the dot '.' is used as a connective in phrasal

concept names. The concept of an old man thus has the name 'old.man'. Some of the material dealing with language makes use of interlinear glosses. All the glosses presented can also be found in the online resource 'The World Atlas of Language Structures' (Dryer and Haspelmath, 2011). References to the present contents of this resource use the acronym 'WALS'. The internet location of the resource is http://wals.info.

2. Hierarchical Concept-Combination

The capacity that concepts have, to be put into hierarchical combinations, has not been previously studied in any depth. This may be because the operation is such a familiar and ubiquitous feature of thought. The opportunity to form a construction of this type exists whenever one concept has the capacity to accommodate one or more others, taken in combination. Examples are easily concocted; e.g., a family that consists of a mother and child, or a salad consisting of lettuce, spinach and cucumber, or a garden consisting of a lawn and a flower-bed. In each case, concepts are brought together in a way that makes one the accommodating element with respect to the others. The idea constructed is a hierarchical structure in which the accommodating concept provides the root. Hierarchical concept-combination is not to be confused with *generic* concept combination, however. This is a more diverse process that has been modeled in a range of ways (e.g. Hampton, 1991; Thagard, 1997; Rips, 1995; Wisniewski, 1997; Costello and Keane, 2001; Hampton, 1997, 2011).

Since an idea derived by hierarchical combination of concepts is itself a concept, the operation is inherently recursive. We can conceive of a residence that consists of a house and a garden, where the garden is conceived as consisting of a lawn and flower-bed. Or we might conceive of a meal that consists of a steak and salad, where the salad is envisaged as consisting of feta and fennel. In such cases, a structure of two levels is obtained. In principle, new levels can be added without limit. Hierarchical combination of concepts can give rise to multi-level structures in this way.

A structure assembled in this way is not a concept hierarchy in any of the usual senses, however. It is not, for example, a generalization hierarchy (a taxonomy or 'is-a' tree). In the concept of a family consisting of a mother and child, the concept of a family does not generalize the concept of a mother. It does not play the role of a hyponym. Neither is the structure a part-whole hierarchy (a meronomy or 'has-a' tree). In a meronomy, each hierarchical entity is defined to be the composite of the cited parts. There can be only one whole for any combination of parts, whereas there can be multiple hierarchical accommodations for the same combination. A mother and child might be conceived as forming, say, a vocal duo, or a darts team, as well as a family.¹ Another standard form of concept hierarchy was established by Gentner (1983). In her model, each hierarchical entity is a predicate which defines a concept in terms of lower-level attributes and/or predicates. This differs from the situation in hierarchical concept-combination, where each hierarchical concept-combination, where each hierarchical concept-combination.

¹ An alternative way to make the distinction is to say that a part-whole hierarchy defines the restricted case of hierarchical combination in which the accommodating concept is just the concept of a composite (i.e., a set).

chical entity specializes a concept: It is a realization of the concept *constituted* in a specific way. Structures built by hierarchical concept-combination are not predicate structures for this reason.

An interesting aspect of hierarchical concept-combination is its productivity. Concepts can only be combined hierarchically in particular ways. We can conceive of a family that consists of a mother and child. But the idea of a mother that consists of a family and child makes no sense. These three concepts cannot be put together in this way. Because of its meaning, the concept of a mother cannot accommodate this combination. It cannot be the root of a hierarchical structure in which the accommodated combination includes the concept of a family.

It is the semantic properties of concepts which define the hierarchical combinations that can be formed, then. Accordingly, a given set of concepts gives rise to a particular set of structures. This set has the potential to be empty. Imagine, for example, we have just the concepts mother, child and father. There is no concept within this set that can accommodate any combination of the others. The implied set of hierarchical combinations is thus empty. But say we start with the set: singer, guitarist, drummer, duo, band. Multiple hierarchical combinations are then legitimized. One is the concept of a duo consisting of a guitarist and a singer (a singer-guitarist duo). Another is the concept of a duo consisting of a guitarist and a drummer (a drummer-guitarist duo). Since the concept of a duo can accommodate any pair of individuals, and there are three such combinations, there are three duo concepts that can be constructed.

Taking the semantic capacities of the band concept into account, the set of structures expands further. Since a band can also consist of any combination of music-making individuals, there is a band-based counterpart for each of the duo concepts. But a band that consists of multiple duos can also be envisaged. There are some two-level structures to be acknowledged in result. A band might combine a singer-guitarist duo with a singer-drummer duo, for example. This is another idea with a hierarchical structure of two levels. At one level, the duo concept is the accommodating element; at the other, the band concept is.

Another interesting aspect of HCC is its unboundedness. Infinitely many constructions can potentially be derived. A hierarchical combination of existing concepts constructs a concept that is inherently new: it is a compositional construction built from existing concepts, which differs from all of them. This new concept may enable new hierarchical constructions to be assembled, giving rise to further concepts and constructions in an ongoing way. Given a sufficient initial endowment of concepts, HCC can, in this way, provide an infinitely productive language of thought. The minimal requirement for infinite productivity is that every construction provides a concept that facilitates at least one further construction. This guarantees there will be infinitely many.

As noted above, HCC has not previously been studied as a conceptual mechanism in its own right. All work on concepts acknowledges this medium to some degree, however. In general, concept construction is modeled as application of a constructive operator to a set of existing concepts, e.g., taking the conjunction of the concepts male and unmarried to define the concept of a bachelor (Murphy, 2002). But this is closely related to hierarchical concept-combination. Any construction which involves application of a constructive operator to certain operands can also be viewed as an act of hierarchical concept-combination. The accommodated combination equates to the set of operands, while the accommodating concept equates to whatever idea is realized by the construction, with the operands abstracted away. Put another way, the accommodating concept is whatever concept is imposed on the operands by the operator. For example, constructing a conjunction of concepts can be seen as forming a hierarchical unit in which the concept of conjunction is the accommodating element, and the conjoined concepts make up the accommodated combination. What is obtained is an instance of the accommodating concept, conceived as constituted in a particular way. The study of concepts takes the possibilities of HCC into account to this extent (e.g. Laurence and Margolis, 1999; Carey, 2009).

2.1. HCC in Shorthand

To demonstrate the practical possibilities of hierarchical concept-combination, examples of some complexity will need to be set out. Since English descriptions of complex structures quickly become unreadable, it is helpful to introduce a shorthand at this point. The convention henceforth will be that a hierarchical structure in which concept X is conceived as accommodating some combination of concepts, will be denoted by enclosing all the concepts in square brackets with X placed first. Thus

[X Y Z]

is shorthand for a hierarchical combination in which concept X is the accommodating element with respect to Y and Z. The accommodating concept—the hierarchical root—is emboldened for emphasis. There can be any number of concepts in the accommodated combination, and they are not in any order. Embedding of structure is then dealt with by bracketing in the obvious way. The concept of an X encompassing² the combination of a Y and Z, where the Z itself encompasses the combination of B, D and E, has the shorthand

 $[\mathbf{X} \mathbf{Y} [\mathbf{Z} \mathbf{B} \mathbf{D} \mathbf{E}]]$

The examples introduced above can all be expressed more succinctly using this approach. The concept of a family made up of a mother and child, for example, can be expressed as

[family mother child]

The concept of a residence encompassing a house and garden, where the garden itself encompasses a lawn and flower-bed can be expressed as

[residence house [garden lawn flower-bed]]

Any construction in the shorthand relies on knowledge of the cited concepts, and how they are named in English. The basic knowledge of English that allows 'a family consisting of a mother and child' to be correctly interpreted is also required to interpret [**family** mother child]. The knowledge that 'family' names the concept

² The terms 'accommodating' and 'encompassing' are used interchangeably in characterizing the root element of a hierarchical unit.

of a family, 'child' the concept of a child etc., is part of what gives a construction its meaning. The only difference between an English specification of a hierarchical concept-combination, and one expressed using the shorthand, is that in one case accommodation is designated by the phrase 'consisting of', whereas in the other it is designated by square-bracketing and constituent positioning.

If cited concept names are considered to be well-defined, then the shorthand can legitimately be viewed as a formal notation for concept construction by hierarchical combination. The assumption that these terms are well-defined might be made on the grounds that the have definitions in English dictionaries. In principle, one might try to eliminate this appeal to knowledge of English by providing a formal definition of the concepts in question. This is ruled out in practice, since a general way of defining concepts has never been established (Carey, 2009).

Provided concept names are well-defined, expressions in the shorthand remain semantically precise regardless of their complexity. Since the only construction used is conceptual accommodation, it makes no difference how many times this is applied. If a 1-level construction is semantically precise, so too is a *n*-level construction, where n > 1. This can be illustrated using a three-level form. Consider the idea of a meal consisting of a steak and a salad where the salad consists of lettuce, cucumber and a dressing, and the dressing consists of oil, vinegar and salt. This idea has a precisely defined meaning provided we possess the cited concepts, and correctly interpret the indicated accommodations. The shorthand

[meal steak [salad lettuce cucumber [dressing oil vinegar salt]]]

is semantically precise on the same conditions.

The shorthand conforms to the following Backus-Naur (BNF) specification:

{spec> ::= (concept-name)
{spec> ::= "[" (spec> (spec> + "]"

The non-terminal $\langle \text{spec} \rangle$ denotes the specification of a concept. This is defined to be either the name of a concept, or a square-bracketed sequence containing two or more $\langle \text{spec} \rangle$. Use of the '+' superscript allows that hierarchical combinations can have any number of encompassed elements. Without this annotation, the effect would be to enforce combinations with only one.³

Viewing the shorthand as a formal notation raises the question of how it should be classified. What type of notation is this exactly? The convention of placing the accommodating concept first in sequence seems indicative of a prefix or Polish notation—one in which the operator of a construction is placed before its arguments. But this classification is incorrect strictly speaking. The operation implied is hierarchical accommodation *by means of* the initially placed concept. It is the initial concept deployed as the accommodating element. The initial concept is not itself the constructive operator, and the shorthand is not a prefix notation for this reason.

The shorthand is also not in any sense a version of predicate logic. This is an important caveat, as predicate logic has often been used as a way of specifying hierarchical concepts (e.g. Gentner, 1983). A hierarchical construction in predicate

³ Notice that since the encompassed elements in a construction have no order, it is always the case that [X Y Z] = [X Z Y].

logic does not describe a hierarchical concept-combination. The operation of logical predication is not the operation of conceptual accommodation. In one case, the result is a truth value, in the other, it is the specialization of a concept. (This is one reason for avoiding a predicate-style format in which the accommodated combination is enclosed in round brackets, and the accommodating concept is appended at the front, e.g., X(Y,Z) used as shorthand for the concept of an X constituted of a Y and Z. The other reason for avoiding this format is the desire to align bracketing with concept realization. In the proposed approach, every bracketed entity realizes a concept.)

The shorthand is neither a prefix notation, nor a version of predicate logic then. More appropriate is to call it a programming language for concepts. The shorthand has a kinship with LISP, a functional programming language often used in AI (McCarthy et al., 1985/1962). LISP also uses prefix positioning to denote a particular deployment of a named entity, on which basis we might view the shorthand as a version of LISP in which function-calls evaluate to concepts. But, here again, the correspondence is not perfect. Deployment of a computational function is not the same thing as imposition of an encompassing concept. The treatment of arguments also differs. In a programming language such as LISP, arguments are given particular roles by positioning. This is not the case in the shorthand, where the encompassed elements form an unordered combination.

We can now return to the main objective, which is to demonstrate the expressive power of HCC by means of examples. An initial task is to show how varying the size of the accommodated combination can affect the outcome. Imagine we are provided with a base of four concepts: the concept of a flight, the concept of a drive, the concept of a journey and the concept of an excursion. The set of given concepts is then: flight, drive, journey, excursion. Since a journey can be made-up of a flight and a drive, a potential hierarchical combination is

[journey flight drive]

This places the concept of a journey into the accommodating role, with flight and drive as the accommodated combination. It realizes the idea of a journey made up of a flight and drive. Another possibility is

[excursion flight drive]

This expresses the subtly different concept of an excursion encompassing a flight and a drive. While the same combination is accommodated, the accommodating element differs, with the result that a different idea is obtained. What we obtain is the idea of a particular type of excursion, rather than a particular type of journey.

Also of interest are hierarchical combinations incorporating a single accommodated concept; e.g.,

[journey drive]

This constructs the idea of a journey consisting solely of a drive. Another combination yields the idea of a journey solely consisting of a flight:

[journey flight]

Minimal constructions like these are termed 'singular accommodations' or just 'singles' below. Intuitively, they can be seen as classifications. The second, for example, can be seen to express the idea of a flight that is also classified as a journey. But notice there is no implication of either element being more general than the other. Singles do not define hyponyms. The signified relationship is hierarchical accommodation which, in the case of a single accommodated element, implies 'both' (i.e., mutual accommodation).

Singles are also inherently reversible. An X that is classified as a Y can also be seen as a Y classified as an X. Or, to put it another way, an X solely constituted of a Y can also be seen as a Y solely constituted of an X. By definition, therefore

 $[\mathbf{X} Y] = [\mathbf{Y} X]$

Important to the expressive power of HCC is the possibility to place relational concepts in the encompassing role. With this done, the effect achieved is that of a relational schema. An illustrative example is

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[understanding teacher lawyer]
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This constructs the concept of an understanding encompassing a teacher and a lawyer (or an understanding between a teacher and a lawyer, as it would normally be described). The accommodating concept is implicitly an imposed relation, and what is constructed is a schema in result. But notice that no schema-making apparatus is involved. The concept of understanding provides the key contribution. Deployed in the accommodating role, it provides the 'glue' that holds the accommodated concepts together. The relational arrangement is captured purely by hierarchical combination—by taking one concept to encompass the other two.

Singles can be used to refine concepts of this type. For example, the following two-level structure might be specified:

[understanding [agent teacher] [recipient lawyer]]

This expresses the concept of an understanding encompassing a teacher and a lawyer, in which the teacher is classified⁴ as agent, and the lawyer is classified as recipient. It builds the concept of a teacher understanding a lawyer, rather than the other way around. This begins to give a sense of how complex meanings of a compositional type can be realized by HCC.

The process of adding levels to a structure can continue as long as suitable concepts are available. We might, for example, write

[development [understanding [agent teacher] [recipient lawyer]]]

This adds a new level of meaning: The teacher's understanding of the lawyer is now classified as a development.

Use of singles, relational concepts and embedding increases the expressive power of hierarchical concept-combination, then. With all these possibilities put to use, the kinds of meaning we express using language are more easily obtained.⁵ Consider the following, for example:

[seeing.action [subject John] [object [definite.thing book]]]

⁴ Recall that singular accommodation implies mutual classification.

⁵ Having recognized the way concepts can be compositionally constructed by HCC, it is natural to treat 'meaning', 'concept' and 'idea' as interchangeable terms.

This constructs the idea of a seeing action encompassing John classified as subject, and a book classified as object, in which the book is also classified as a definite.thing. Taking into account the meaning of the subject and object concepts, what is composed is the idea of some individual John⁶ seeing a definite book. It is the idea of an action done by a particular individual to a particular thing. We could express this in English by saying 'John sees the book'.

A more elaborate example is

[yesterday.event [giving.action [subject [indefinite.thing man]] [object bread] [indirect.object John]]]

Key to the meaning of this four-level construction is the first accommodated concept. Itself a structure, it expresses the idea of a giving action encompassing an indefinite man (classified as subject), bread (classified as object) and John classified as an indirect object. This yields the idea of an event in which an indefinite man gives bread to John. The event is then itself classified as a 'yesterday.event', i.e., an event occurring yesterday. The final product is the idea of a man giving bread to John yesterday. This is something we could express in English by saying 'yesterday a man gave bread to John'.

Some specialized forms of meaning, such as questions, can also be captured. Consider this, for example:

[question

[[event drinking.action focal.thing]
[subject [definite.thing teacher]]
[object [definite.thing [substance water]]]]

The central construction here is

[event drinking.action focal.thing]

This expresses the idea of an event encompassing a drinking.action and a focal.thing. Encompassed by this are water and a teacher, classified as subject and object respectively (and also as definite objects). This idea is then itself classified as a question. The final result is thus (the idea of) a question encompassing the idea of a definite teacher drinking some definite water. This is something we could express in English by asking 'Is the teacher drinking the water?'

These examples give a sense of the expressivity and productivity of hierarchical concept-combination. They reveal this to be language-like medium, in which complex meanings can be constructed. As noted, the generativity of the medium is unbounded in principle. If every construction that can be formed on some given base legitimizes at least one further construction, there are infinitely many meanings that can be derived. This is an important factor in the connection between HCC and language. Both are mechanisms which allow infinitely many meanings to be composed.

⁶ For present purposes, names of individuals are taken to name the concept of the individual in question.

3. Merge

The focus can now return to Merge, and the question of how this operator is related to HCC. Informally, Chomsky characterizes the behavior of Merge as "Take two objects, make another object" (Chomsky in Boeckx, 2009: 52). More precisely, the operator "takes two syntactic objects α and β and forms the new object $\gamma = {\alpha, \beta}$ " (Chomsky, 2001: 3). In building a hierarchical unit, Merge applies a particular constructive operation. The hierarchical unit constructed from α and β is defined to be ${\alpha, \beta}$. It is the *set* made up of the two constituents.

That HCC has the capacity to implement Merge can then be demonstrated. The hierarchical construction that Merge obtains by

 $\gamma = \{\alpha, \beta\}$

can also be obtained by a hierarchical combination in which the concept of a set is the accommodating element, and α and β form the accommodated combination. The corresponding construction is

$$\gamma = [\mathbf{set} \ \alpha \ \beta]$$

In both cases, the hierarchical unit obtained specifies a set comprised of α and β .

HCC can also implement the operation known as 'internal Merge'. This involves re-merging the output of a construction with one of its constituents (e.g., in the case above, re-merging γ with α). What this produces is a two-level structure in which an element of the accommodated combination at the first level is also within the accommodated combination at the second. From the conceptual point of view, this is a perfectly legitimate state of affairs. Provided the constituents to which Merge applies can be viewed as concepts, HCC can implement the operation involved.

We can be confident that HCC has the capacity to implement Merge, then. Whether Merge has the capacity to implement HCC is less clear. One problem is the fact that HCC can by applied to combinations of any size, whereas the input to Merge is a binary set. This is straightforwardly overcome, however. Merge has the capacity to produce an input set of any size by hierarchically merging binary sets. Merge can be applied to sets of any size in this way.⁷ The more serious obstacle is the fact that Merge appears to disallow variation in the accommodating concept. What is constructed in every case is a set.⁸ Is there any way of deploying Merge that would allow variation in this?

The internal variant of the operation is potentially of use. As noted, internal Merge is the special case in which a merged entity is *re-merged* with one of its constituents. One constituent in particular is selected. In principle, this might be the means of differentiating an accommodating concept. In favour of this scheme is the way it connects the unbounded generativity of Merge to that of HCC. In the latter case, the unboundedness results from the compositional nature of the operation: Concepts are put together in a hierarchical assembly. What is obtained is inherently new (in the sense of being different to all the combined constituents), on which basis further constructions can be obtained in an ongoing way.

⁷ My thanks to an anonymous reviewer for pointing this out.

³ A hierarchical structure formed by application of Merge is a meronomy in this sense.

The unbounded generativity of Merge, on the other hand, is considered to stem from the way internal Merge can be re-applied any number of times. There is some debate as to whether this yields the right kind of generativity for language. Hinzen (2009: 137) makes the point that Merge cannot bring about 'categorial change', while Boeckx (2009) argues that its output is not genuinely new. In Boeckx's view, "once you combine two units, X and Y, the output is not some new element Z, but either X or Y." A related concern is the fact that a hierarchical assembly of object combinations can be reduced to (or expressed as) a non-hierarchical combination. This raises the question of whether the structure is hierarchical in the fullest sense. These concerns are not directly relevant, here, however. All that matters is that internal Merge is potentially the means of achieving the discrimination required for HCC. This also has the attraction of explaining the operation's unbounded generativity in a new way.

Subject to certain qualifications, then, it can be concluded that HCC can implement Merge, and Merge can implement HCC. The latter arrangement is problematic in one respect; but it is not unreasonable to assume the difficulty can be overcome. Taking the functional equivalence of the two mechanisms to be established, what should we then infer about the language system? Chomsky notes that either Merge or "some equivalent" is the minimal requirement for production of language (Chomsky, 2005: 11). Might HCC be the equivalent in question?

Assuming that it is induces a radically different conception of how language is produced. The hierarchical structure produced by HCC is a *semantic* object rather than a syntactic one. If this is the seed from which an utterance is derived, we have to assume there is some apparatus capable of turning it into a linguistic form. There has to be some mechanism which takes a semantic construct and derives from it a sequential-symbolic representation (i.e., an utterance). On this understanding, production of language would be accomplished on a 'semantics-first' basis, rather than a 'syntax-first' one.

Is there any way of putting this semantics-first arrangement on an operational footing? How could a hierarchical concept-combination with a certain meaning be translated into a semantically equivalent symbol sequence? The obvious way to accomplish this involves running semantic interpretation 'backwards'. For the language system to work there has to be knowledge of what symbols (i.e., words and morphemes) mean. This lexical knowledge is normally assumed to be invoked only at the stage of semantic interpretation. But the mapping can also be used to identify the symbol for a particular concept. The concept names used in a hierarchical concept-combination are potentially translated to symbols in this way.

But how are the the symbols to be got into a syntactically correct order? Here, the obvious solution is to make use of grammatical preferences. A sequential encoding of a concept structure, using symbols for the cited concepts, must distinguish the symbol that represents the accommodating concept. This has to be given a particular position in the sequence, otherwise the original construction cannot be inferred. Consider the typical case of a structure with two accommodated elements. This yields three symbols in all: one for the accommodating concept, and two for the accommodated concepts. Put into a sequence, these three symbols encode the original structure provided the accommodating symbol can be identified. This critical symbol has to be given a particular position in the sequence. It has to go first, last or in the middle. Given there are two ways of ordering the accommodated symbols, this yields a total of $2 \times 3 = 6$ orderings in all. Letting X, Y and Z be the symbols in question, the six possible orderings are XYZ, XZY, YXZ, ZXY, YZX, ZYX.

The way grammatical preferences might be exploited then begins to become apparent. Languages typically have a preference to use a particular verb-phrase structure, where the six options are VSO, VOS, SVO, OVS, SOV, OSV. If the verb in a verbal construction is assumed to correspond to the accommodating element of a hierarchical concept-combination, the six verbal structures are then identical to the six symbol orderings for a typical concept structure. The ordering that the language is known to prefer can potentially be applied. Might this be enough to get symbols into the right order? Clearly, by itself, it would not. It fails to deal with cases involving anything other than two accommodated concepts. But the general idea of applying grammatical preferences can be put to use in different ways. This approach can be the means of obtaining syntactically correct outputs in a number of cases, as the examples of the next section illustrate.

4. Symbolic Encoding by Application of Grammatical Preferences

To illustrate the way grammatical preferences can be used to translate a semantic form (a hierarchical concept-combination) into a linguistic form (a symbolic sequential encoding) with the same meaning, it is convenient to return to one of the HCC examples used above:

[seeing.action [subject John] [object [definite.thing book]]]

Recall that this constructs the idea of John seeing a particular book, i.e., an idea that can be expressed in English by 'John sees the book'. How can the HCC be translated into this expression? Grammatical preferences of English that apply in this context include (1) a preference for SVO ordering, (2) a preference to identify subject and object by ordering, and (3) a preference for head-initial organization in simple phrases. These can be captured by means of the following three rules.

2 1 3 \leftarrow^{a} [= subject object] 2 \leftarrow^{b} [subject/object =] 1 2 \leftarrow^{c} [= =]

These rules are notated on a right-to-left basis, with labels placed over the arrows for easy reference. Each rule shows the preferred ordering for a particular semantic construction (i.e., HCC). The ordering appears to the left of the arrow, and the semantic construction to the right. The first rule (labeled \leftarrow^{a}) encodes the preference for SVO organization; the second (labeled \leftarrow^{b}) encodes the preference to encode subject and object classifications by means of ordering, while the third (labeled \leftarrow^{c}) encodes the preference for head-initial organization in simple phrases.

The notation works in the following way. Rule $\stackrel{a}{\leftarrow}$ applies to any hierarchical concept-combination which conforms to the shorthand:

[= subject object]

The structure can have anything as its accommodating element (the '=' is a wild-

card) but the accommodated combination must *comprise* subject and object concepts. (Recall that, in the shorthand, accommodated concepts have no order.) A subject concept is specified either by name (i.e., as 'subject') or as a construct for which 'subject' is encompassing either explicitly or implicitly. This means [**subject** John] is a subject concept, as is [**definite.thing** [**subject** John]].

The numbers on the left of a rule specify the way symbols should be ordered. Each number indexes an element of the specification on the right, while its *position* says where symbols arising for that element should be placed. Rule \leftarrow^a has '2 1 3' on the left. This means symbols arising for whatever matches the 2nd element should be placed first, followed by symbols for whatever matches the 1st element, followed by symbols for whatever matches the 3rd element. Given the structures it can match to (and the assumption that verbs signify accommodating concepts) this rule captures the preference for SVO ordering.

Rule $\stackrel{\text{b}}{\leftarrow}$ uses '/' to denote alternatives. The specification matches any structure in which the first element is either a subject or object concept. The designation on the left is just '2', meaning only the encompassed element is symbolized. Given the structures it can match to, this rule captures the preference for expressing subject and object classifications implicitly. The final rule deals with any single (i.e., any concept with a single accommodated element). It specifies that the symbol(s) for the accommodated element. Given its coverage, this rule expresses the preference for head-initial organization in simple phrases. Earlier rules take precedence, so $\stackrel{\text{a}}{\leftarrow}$ has priority over $\stackrel{\text{b}}{\leftarrow}$, which has priority over $\stackrel{\text{c}}{\leftarrow}$.

With these rules defined, a syntactically valid expression of the HCC's meaning can then be derived, provided the concepts cited in the structure are symbolized as follows.

 $book \leftarrow book$ $the \leftarrow definite.thing$ $John \leftarrow John$ $sees \leftarrow seeing.action$

Each line here specifies the symbol to be used for a particular concept. The concept is specified to the right of the ' \leftarrow ', and the symbol (word or morpheme) to the left. The symbol specified for the concept of a book is defined to be *book*, for example.

Translation of the HCC, in accordance with the specified rules, then proceeds as follows. At the start of the process, the object to be translated is the conceptual structure itself. The only rule whose right-hand-side matches this object is \leftarrow^a , which is an organizational rule. Applying it has the effect of decomposing the object into three constituents: the referents of the specified ordering. These objects are then translated in the same way. Whenever an object to be translated matches the right-hand-side of a lexical rule, it is immediately translated to the corresponding symbol. Once all the constituents realized by applying an organizational rule to an object have been translated, their encodings are put in the specified order, and this sequence becomes the translation of the object itself. Eventually, the entire conceptual structure is rendered into a sequential-symbolic form.

The processing can be shown schematically as follows.

 $\rightarrow [seeing.action~[subject~]ohn]~[object~[definite.thing~book]]]$

 $\rightarrow [subject John]$ $\leftarrow John (John)$ $\leftarrow bohn (John)$ $\leftarrow sees (seeing.action)$ $\rightarrow [object [definite.thing book]]$ $\rightarrow [definite.thing book]$ $\leftarrow the (definite.thing)$ $\leftarrow book (book)$ $\leftarrow the book$ $\leftarrow the book$ $\leftarrow the book$

 $\stackrel{a}{\longleftarrow}$ John sees the book

This listing uses indentation to visualize recursion. Each line represents application of a rule. For each application of a lexical rule, there is a line which ends with the relevant concept name. For example, translation of the concept name 'book' to the symbol *book* is denoted by the line

 \leftarrow book (book)

For each application of an organizational rule, there is a line showing the concept that is processed and—at with same indentation below—a second line showing the symbol sequence assembled. Use of rule $\stackrel{b}{\leftarrow}$ to turn [definite.thing book] into *the book* thus has an upper line of the form

 \rightarrow [definite.thing book]

and a lower line of the form

 $\stackrel{\mathrm{b}}{\longleftarrow}$ the book

At completion of processing, the final translation obtained is *John sees the book*, which is a syntactically valid way of expressing the meaning of the original conceptual structure.

This example illustrates how a hierarchical conceptual structure can, by application of grammatical preferences, be translated to a syntactically valid utterance with the same meaning. It gives a sense of how HCC might fulfil the function of the equivalent of Merge that Chomsky envisages. But notice the very different conception of language production that arises. The process is not seen to be shaped by knowledge of syntax. It is seen to stem from a capacity for hierarchical concept-combination, coupled with an ability to apply grammatical preferences in the derivation of symbolic encodings. Production of language is seen to be a kind of assembly-line process, the first stage of which is construction of a semantic object in the conceptual system, and the second stage of which is encoding of that object into a sequential symbolic form.

More complex examples can also be assembled. All the HCC examples of Section 2 can be put to use in this way. We can also vary the language in which the output comes to be expressed. Consider again the utterance 'John read the letter'. Translated into Japanese, this becomes

Johnga tegamio yonda.

For an assembly-line analysis of this sentence we require a hierarchical conceptcombination which expresses the correct meaning. As previously noted, a construction with the meaning of 'John read the book' is

[[past.behavior reading.action] [subject John] [definite.thing letter]]

How can this be translated into syntactically valid Japanese? Grammatical preferences of Japanese in this context include (1) a preference for SOV ordering, and (2) a preference for head-final organization in simple phrases. These can be captured as follows:

 $231 \xleftarrow{a} [= subject definite.thing]$

 $21 \xleftarrow{b} [==]$

Given the concepts it can match to, use of '2 3 1' in rule $\stackrel{a}{\leftarrow}$ expresses the preference for SOV organization, while rule $\stackrel{b}{\leftarrow}$ expresses the preference for head-final organization in simple phrases. A syntactically valid expression is then obtained, provided the cited concepts are symbolized as follows:⁹

 $John \leftarrow John$ $tegami \leftarrow letter$ $yon \leftarrow reading.action$ $da \leftarrow past.behavior$ $ga \leftarrow subject$ $o \leftarrow definite.thing$

Translation of the conceptual structure then proceeds as follows:

```
\rightarrow [[past.behavior reading.action] [subject John] [definite.thing letter]] 

\rightarrow [subject John] 

\leftarrow John (John) 

\leftarrow ga (subject) 

\leftarrow b John ga 

\rightarrow [definite.thing letter] 

\leftarrow tegami (letter) 

\leftarrow o (definite.thing) 

\leftarrow b tegami o 

\rightarrow [past.behavior reading.action] 

\leftarrow yon (reading.action) 

\leftarrow da (past.behavior)
```

 $\stackrel{\scriptscriptstyle \mathrm{b}}{\longleftarrow}$ yon da

 $\stackrel{a}{\longleftarrow}$ John ga tegami o yon da

 (i) John-ga tegami-o yon-da. John-SUBJ letter-OBJ read-PST 'John read the letter.'

See also WALS, Ch. 82, Ex. 2.

Lexical preferences are derived from the analysis of (Kuno, 1973: 10).

With word-breaks imposed, the output is *Johnga tegamio yonda*, which is the desired Japanese sentence.

Another example taken from Section 2 is

[yesterday.event [giving.action [subject [indefinite.thing man]] [object bread] [indirect.object John]]]

Recall that this builds the idea of an indefinite man giving bread to an individual, John, at a particular point in time, namely yesterday. The meaning is one we could express in English by saying 'yesterday a man gave bread to John'. A sentence from the Suriname language of Arawak with a not dissimilar meaning is

Miaka aba wadili sika khali damyn.

This means 'yesterday a man gave cassava bread to me'. To capture this meaning, the conceptual structure above needs to be modified in two ways. The recipient of the action needs to be specified as 'me' rather than 'John', and the object needs to be 'cassava.bread' rather than 'bread'. This produces

```
[yesterday.event
[giving.action
[subject [indefinite.thing man]]
[object cassava.bread]
[indirect.object me]]]
```

How can this structure be translated into Arawak? Grammatical preferences of this language in this context include (1) a preference for SVO organization; (2) a preference for dealing with subject and object by ordering; (3) a preference for head-final organization in simple phrases denoting an indirect object; and (4) a preference for head-final organization elsewhere. These can be captured by the following four rules.

2 1 3 4 $\stackrel{a}{\longleftarrow}$ [= subject object indirect.object] 2 $\stackrel{b}{\longleftarrow}$ [subject/object =] 2 1 $\stackrel{c}{\longleftarrow}$ [indirect.object =] 1 2 $\stackrel{d}{\longleftarrow}$ [= =]

With these rules defined, a syntactically valid Arawak expression is obtained provided cited concepts are symbolized as follows:¹⁰

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¹⁰ All preferences derived from the analysis of (Pet, 1987).

⁽i) *Miaka aba wadili sika khali da-myn.* yesterday INDEF man give cassava.bread 1SG-to 'Yesterday a man gave cassava.bread to me.'

```
khali \leftarrow cassava.bread

sika \leftarrow giving.action

aba \leftarrow indefinite.thing

myn \leftarrow indirect.object

wadili \leftarrow man

da \leftarrow me

miaka \leftarrow yesterday.event
```

Mapping of the conceptual structure then proceeds as follows. (Notice some lines are truncated.)

```
→ [yesterday.event [giving.action [subject [indefinite.thing man]] ...
```

```
← miaka (yesterday.event)
```

 \rightarrow [giving.action [subject [indefinite.thing man]] [object ...

→ [subject [indefinite.thing man]]

```
\rightarrow [indefinite.thing man]
```

 \leftarrow *aba* (indefinite.thing)

 \leftarrow wadili (man)

```
\stackrel{d}{\longleftarrow} aba wadili
```

- $\stackrel{\scriptscriptstyle \mathrm{b}}{\longleftarrow}$ aba wadili
- \leftarrow sika (giving.action)
- \rightarrow [object cassava.bread]

 \leftarrow *khali* (cassava.bread)

```
\stackrel{\scriptscriptstyle \mathrm{b}}{\longleftarrow} khali
```

```
\rightarrow [\text{indirect.object} \text{ me}]
```

```
\leftarrow da (me)
```

```
\leftarrow myn (indirect.object)
```

 $\stackrel{a}{\longleftarrow}$ aba wadili sika khali da myn

 \leftarrow^{d} miaka aba wadili sika khali da myn

With word-breaks imposed, the output is *Miaka aba wadili sika khali damyn*, which is the desired Arawak sentence.

This example can also be used to give a sense of how the approach might explain movement—the "curious but ubiquitous phenomenon of displacement in natural language" as Chomsky describes it (Chomsky, 2009a: 31). In the statement 'yesterday a man gave cassava bread to me', the initial word can be moved to final position without affecting the meaning. The statement then becomes 'a man gave cassava bread to me yesterday'. If we assume that in an English version of the above, two organizational rules are invoked by the structure [**yesterday.event** ...], one having '1 2' as its ordering, and the other having '2 1', the selection between them is potentially made at random. On this basis, the optionality of the two forms can be explained by saying either way of formulating the sentence is potentially derived.

To complete this series of examples, we should also look at

```
[question
[[drinking.action focal.thing]
[subject [definite.thing teacher]]
[object [definite.thing [substance water]]]]]]
```

Recall that this builds an idea that would be expressed in English by asking the question 'Is the teacher drinking the water?' Say we would like to develop an analysis of this question expressed in German. The question then takes the form

Trinkt der lehrer das wasser?

How can this German question be derived from the conceptual structure? Grammatical preferences of German in this context include (1) a preference to encode subject and object classifications by ordering alone; (2) the preference for VSO organization given a meaning classified as a question; (3) the preference for SVO organization otherwise, and (4) the preference for head-initial organization in simple phrases. These can be encoded by the following four rules.

2 $\stackrel{a}{\leftarrow}$ [subject/object =] 2 3 4 $\stackrel{b}{\leftarrow}$ [question [= subject object]] 2 1 3 $\stackrel{c}{\leftarrow}$ [= subject object] 1 2 $\stackrel{e}{\leftarrow}$ [= =]

With these definitions given, a syntactically valid, German expression of the construct's meaning is obtained provided cited concepts are symbolized as follows:¹¹

```
lehrer \leftarrow teacher
wasser \leftarrow water
trink \leftarrow drinking.action
das \leftarrow [definite.thing substance]
der \leftarrow definite.thing
t \leftarrow focal.thing
```

Notice the use of a structured specification in the case of *das*. This is required to capture the restricted range of this determiner.

Mapping of the conceptual structure then proceeds as follows:

→ [question [[drinking.action focal.thing] [subject ...

- \rightarrow [drinking.action focal.thing]
 - \leftarrow *trink* (drinking.action)
 - $\leftarrow t$ (focal.thing)

 $\stackrel{\mathrm{e}}{\longleftarrow}$ trink t

 \rightarrow [subject [definite.thing teacher]]

 \rightarrow [definite.thing teacher]

(i) *Trink-t der Lehrer das Wasser?* drink-3SG DEF teacher DEF water 'Is the teacher drinking the water?'

¹¹ Lexical preferences are derived from the analysis of (Dryer and Haspelmath, 2011, Ch. 116, Ex. 6).

 $\leftarrow der \text{ (definite.thing)} \\ \leftarrow lehrer \text{ (teacher)} \\ \leftarrow e^{-} der lehrer \\ \leftarrow der lehrer \\ \rightarrow \text{ [object [definite.thing [substance water]]]} \\ \leftarrow das \text{ ([definite.thing substance])} \\ \leftarrow wasser \text{ (water)} \\ \leftarrow e^{-} das wasser \\ \leftarrow b^{-} trink t der lehrer das wasser \\ \end{pmatrix}$

Once standard word-breaks and capitalization have been imposed, the output is found to be the desired German question: *Trinkt der Lehrer das Wasser*?

If we remove the question classification in the original conceptual form, only the inner structure remains:

```
[[drinking.action focal.thing]
  [subject [definite.thing teacher]]
  [object [definite.thing [substance water]] ] ]
```

This realizes a meaning we might express in English by the statement 'the teacher is drinking the water.' Applying the rules to this reduced structure then invokes the default SVO ordering, with the effect of placing the verb between rather than before subject and object. The processing is as follows:

```
\rightarrow [[drinking.action focal.thing] [subject ...
```

```
\rightarrow [subject [definite.thing teacher]]
```

```
\rightarrow [definite.thing teacher]
```

 \leftarrow der (definite.thing)

```
\leftarrow lehrer (teacher)
```

```
\stackrel{\mathrm{e}}{\longleftarrow} der lehrer
```

```
\stackrel{a}{\longleftarrow} der lehrer
```

 \rightarrow [drinking.action focal.thing]

```
\leftarrow trink (drinking.action)
```

```
\leftarrow t (focal.thing)
```

```
\stackrel{\mathrm{e}}{\longleftarrow} trink t
```

- $\rightarrow [object \ [definite.thing \ [substance \ water]]]$
 - \leftarrow *das* ([definite.thing substance])

 \leftarrow wasser (water)

```
\stackrel{a}{\longleftarrow} das wasser
```

```
\xleftarrow{}^{c} der lehrer trink t das wasser
```

With word-breaks and capitalization imposed, the output is then *der Lehrer trinkt das Wasser*, which expresses the assertion 'the teacher is drinking the water'.

The examples of this section demonstrate that, at least in certain cases, syntactically valid outputs can be obtained by mapping conceptual structures to symbol sequences in accordance with grammatical preferences. Is there any reason to believe this might be possible more generally? Can the assembly-line model be applied in more than just this handful of cases? There is a case for thinking the approach may be no less general than conventional syntactic analysis. The argument is based on the idea that any syntactical analysis can be converted into an assembly-line analysis. This is done by decomposing the syntactic analysis into two parts, one dealing with hierarchical structure, and the other dealing with sequential structure, where the former is an HCC, and the latter are the rules defining grammatical preferences and symbolization. The decomposition separates the specifically hierarchical aspect of the syntactic analysis from the specifically sequential specification.

The decompositional process can be illustrated using 'John sees the book' again. This utterance takes the form of a verb phrase in which 'sees' is the verb, 'John' is the subject, and 'the book' is the object. The structure can be analyzed as follows:

```
(_{VP} \operatorname{sees}(_{N} \operatorname{John}) (_{NP} (_{DET} \operatorname{the})(_{N} \operatorname{book})))
```

To decompose this analysis into two parts, we proceed as follows. First, we replace each grammatical constituent with a semantically equivalent conceptual constituent. In the simplest case, the constituent is a content word, and the replacement is just the corresponding concept name. The two content words here are 'John' and 'book', but both can be seen as concept names in their own right, so no change is needed. The second step involves replacing each grammatical construction with a semantically equivalent conceptual construction. This is a hierarchical concept-combination in which the encompassing concept has the meaning that the grammatical construction imposes on its subordinate elements. Or, to put it another way, the encompassing concept is whatever idea is realized by the construction, once the constituents are abstracted away.

In this case there are two such constructions: the verb phrase and the noun phrase. In the latter, the word 'the' is an article (an ART.DEF). As this is the definite article, a particular meaning is implied—that what is referred to is a definite as opposed to indefinite book. The effect is to impose the meaning of the book being a definite thing. The construct is thus replaced with an HCC which imposes the relevant classification:

[definite.thing book]

This has the effect of classifying¹² the book as a definite.thing.

The verb 'sees' imposes the meaning (in the same sense as above) of a seeing action on the subordinate subject and object. This is thus replaced with the construction

[seeing.action John [definite.thing book]]

This expresses the idea of a seeing action encompassing John and a definite book. Still needed is discrimination of subject and object. This is where the grammatical structure captures meaning by the ordering of branches. The SVO ordering of the verb phrase has the effect of classifying 'John' as subject, and 'the book' as object. Branches in the conceptual structure are unordered, so for the conversion, we need to add the relevant classifications. The structure then becomes

¹² Recall that mutual accommodation implies mutual classification.

[seeing.action [subject John] [object [definite.thing book]]]

This is the structure that we already know expresses the meaning of 'John sees the book'. The semantic part of the assembly-line analysis can be derived from the syntactic analysis in this way. The other part of the analysis then comprises the grammatical preferences, both lexical and organizational, that produce the sequential symbolization.

The semantics-first approach, which results from assuming HCC fulfils the function of what Chomsky calls 'some equivalent' of Merge, may have a reasonable degree of generality, then. If a conventional syntactic analysis can be translated into a semantics-first account, the two approaches have the same explanatory range. What seems most problematic about the semantics-first model is that it eliminates the role normally attributed to syntactic knowledge. But the idea that languages *have* syntactic structure is retained. The assumption is that this can be seen as the confluence of two shaping influences, one being HCC, and the other being the grammatical preferences of the language in question. On this basis, the assembly-line model is closer to the norm than it may seem. Fully acknowledged is the fact that languages have structure, and that taxonomizing this structure reveals syntax. What is added is the observation that this structure may be the result of an interaction between two forces.

5. Discussion

Taking all the evidence into account, what can be concluded? Some aspects of the situation are certainly beyond dispute. At the heart of the language system there has to be a mechanism of hierarchical construction which assembles expressions of arbitrary richness and complexity. As Chomsky notes, "Either Merge or some equivalent is a minimal requirement." (Chomsky, 2005: 11-12) The capacity to combine concepts hierarchically is also central to the conceptual system. A mechanism of hierarchical concept-combination has to exist.¹³ Both Merge and HCC must, then, be implemented in the mind.

What is at issue is their relationship. Hauser et al. characterize the functionality of Merge as "hierarchical, generative, recursive, and virtually limitless with respect to its scope of expression" (cf. Hauser et al., 2002: 1569). Precisely the same description can be given to HCC. An equivalence between the two mechanisms is suggested and, on close inspection, this is found to be nearly perfect. HCC can reproduce Merge, and subject to certain assumptions, Merge can do the same for HCC. In consequence, HCC might be the equivalent of Merge that Chomsky envisages. Assuming this to be so results in the semantics-first interpretation of language production, as described above.

If we set the semantics-first model aside, two possibilities then remain. One is that Merge and HCC are completely disconnected. This is a viable option. Merge can be seen to play its usual role in the language system, while HCC operates separately in the conceptual system. This conforms to the idea of the two systems

¹³ It is not claimed here that this is the only way conceptual structure can be built. Reinhart's observation that ordering of constituents generally plays no role in conceptual structure (Reinhart, 1976) is consistent with HCC being the constructive mechanism implied, however.

being functionally independent. But it does entail assuming significant duplication of cognitive resources. We have to assume the mind possesses two functionally equivalent ways of constructing meanings compositionally. There must be two distinct generative mechanisms, and they must be resourced independently.

The other possibility is that one of the two mechanisms provides constructive services to the other on a client-server basis. The advantage of this is that it avoids assuming duplication of resources, while retaining the standard conception of language being produced on a modular 'syntax-first' basis. Challenging questions do arise, however. For this arrangement to work, the interface between the language and conceptual systems must have the capacity to mediate the provision of constructive services. How is this accomplished? Whichever operator is the 'server', we have to assume it can be manipulated in a way that allows both constructions of syntax, and constructions of HCC to be obtained. How this dual functionality is operationalized becomes a critical issue.



Figure 1: Alternative conceptions of the Merge-HCC relation: (A) syntax-first processing in the standard Minimalist architecture; (B) semantics-first processing.

If we rule out the idea of Merge and HCC being completely disconnected on the grounds that this entails too great a duplication of mental resources, what remains is either the syntax-first arrangement, or the previously described semanticsfirst arrangement. These are illustrated schematically in Figure 1. Panel (A) represents the syntax-first case. This is essentially the standard Minimalist architecture, with Merge as the central element. There is one interface which conveys constructions to the conceptual system (C-I), and another which externalizes them via sound and gesture (S-M). The only modification is the assumption that Merge provides constructive services to HCC, or vice versa, and that the Merge/C-I interface mediates this.

Panel (B) illustrates the semantics-first alternative. Here, the hierarchical structure underlying an utterance is seen to be constructed in the conceptual system, by hierarchical concept-combination. The flow of information is left-to-right. The conceptual system (C-I) is assumed to send hierarchical structures to an intervening symbolization module, which then uses grammatical preferences to derive syntactically well-formed outputs. These are then sent for externalization via S-M in the usual way. Like the syntax-first model, the semantics-first model has a mix of pros and cons, some of which have already been discussed. The key advantage is that it avoids the need for linguistic Merge. HCC is taken to be the Merge-equivalent that Chomsky envisages. This makes compositional thought the generative system behind language, a strategy which Hinzen notes would be appealingly parsimonious (Hinzen, 2012: 637). Another positive feature of the interpretation, not previously mentioned, is its ability to reconcile views on language and thought. It has been seen that HCC is a medium in which compositional meanings can be constructed, and that, like Merge, it is limitless in its scope of expression. Some theorists have doubted whether there is any medium other than language which is compositional in this way (e.g. Chomsky, 2007b; Hinzen, 2012). The existence of HCC shows there is, and this has implications for the debate about how language and thought are related.

The debate has particularly focused on the issue of whether thought or language is prior. With the structural forms of language assumed to be defined by grammar (syntax), the key question has been whether it is thought which shapes grammar, or grammar which shapes thought. Theorists inclined towards the former arrangement include (Bates and MacWhinney, 1979, 1987; Bickerton, 1990; Fodor, 2001; Elman, 2004; Kirby, 1999; Jackendoff, 2002; Tomasello, 2003; Clair et al., 2009; Chater and Christiansen, 2010; Tomasello, 2008). Theorists inclined to the view that it is grammar which shapes thought include (Fitch and Chomsky, 2005; Chomsky, 2012, 2009b; Hauser, 2009; Hinzen, 2009).

The existence of HCC raises the possibility of an intermediate position. It allows that thought might shape grammar at the same time as grammar shapes thought. Under the semantics-first arrangement, the hierarchical forms of HCC are seen as shaping the hierarchical structure of utterances, while their sequential-symbolic form is seen to be shaped in another way—by grammatical preferences. On this view, thought shapes the *hierarchical* forms of language only. The idea of thought shaping language in this partial sense does have some support in the literature. Jackendoff, for example, observes that meaning would "be the first generative component of language to emerge" (Jackendoff, 2003: 664), due to being a "combinatorial system independent of, and far richer than, syntactic structure" (Jackendoff, 2002: 123). It also conforms to Hauser's view of language as a "mind-internal computational system designed for thought and often externalized in communication" (Hauser, 2009: 74).

But the claim that grammar shapes thought is then also validated to some degree. Grammar is seen to be a formulation in which hierarchical constructions of thought obtain a sequential form. On this basis, the position that "thought itself is fundamentally linguistic" (Corballis, 2014: xiii) is not invalid. Nor is Hinzen's observation that in use of language "we see new forms of meaning arising in ways that exactly reflect a narrow range of grammatical operations and options" (Hinzen, 2012: 646). On the semantics-first model, the structures which convey these meanings are seen to be modulated by the ways in which ordering is imposed. But this still allows that, in some sense, "the generative system of language underlies and is actually indistinguishable from the generative system that powers abstract thought" (Hinzen, 2009: 125). Grammar is seen to express the compositional structures of thought, accommodating Chomsky's observation that "language evolved, and is designed primarily as an instrument of thought" (Chomsky, 2009a: 29).

In other respects, the semantics-first model is less attractive. There is no implementational question, since HCC can fully perform the function of Merge. But the model changes the conception of how language is produced in a radical and potentially unacceptable way. The indications are that syntactically well-formed utterances can be produced by mapping hierarchical concept-combinations to symbol sequences in accordance with context-specific grammatical preferences. This explains how an inherently unordered object—an HCC—can give rise to an inherently ordered one—a sequence of symbols. But it also has the effect of eliminating conventional syntax from the account. Explicit syntactic rules are seen to play no role.

This *might* be seen as advantageous. The requirement to explain how the language system adheres to, and applies rules of syntax is dissolved, as is the requirement to discover what the rules are. Instead, there is a requirement to explain how grammatical preferences can turn conceptual structures into symbol sequences. Assuming, fewer rules are required for this, the effect is to simplify the account. This is one way the model might be seen as more parsimonious. There are others. Semantic and syntactic processing are normally seen as separate. The language system is assumed to perform syntactic processing independently. Hinzen calls this "the spirit of the autonomy of syntax" (Hinzen, 2012: 638). Consequently, there is a need to explain how semantic processing comes to influence language production, an objective that has been called the "final frontier" of linguistics (Fitch, 2009: 306). Under the semantics-first model, this requirement is eliminated. Semantic processing is now the first stage in an assembly-line process from which syntactically correct utterances emerge. This makes semantics an integral part of syntax. At the same time, it makes the grammatical preferences which shape the second stage functionally critical. This might also be seen as beneficial, however, as it answers a puzzling question. Grammatical preferences (e.g. for head-initial organization) have often been seen as problematic from the explanatory point of view (Polinsky, 2012).

The semantics-first model is not without explanatory benefits, then. The problem is that most of them can also be seen as costs. The model can be seen as failing to respect the autonomy of syntax, and as ignoring the distinction between syntax and semantics. By making semantics an integral part of syntax, it effectively eliminates the traditional idea of a syntax/semantics interface. The model can also be seen as blurring the distinction between syntax and morphology, and as negating the principle that grammatical preferences are functionally neutral. It can only be adopted, it seems, at the price of flying in the face of established theory.

There is no clear winner between the syntax-first and semantics-first interpretations, then. Both present a mix of advantages and disadvantages. Can we escape the impasse by assuming the existence of a more primitive operator, from which both Merge and HCC are descended?¹⁴ Might it be that Merge and HCC have a common ancestor, without being directly related? It is difficult to see how there could be an ancestor of HCC, even in principle. Any ancestor from which HCC is derived must subserve the capacity to combine concepts in a way that makes one the accommodating element with respect to the others. But in that case, the an-

¹⁴ My thanks to two anonymous reviewers for suggesting this possibility.

cestor is HCC itself. There seems to be no way to reduce this operation to a more primitive form. Merge can perhaps, be seen as a descendent of HCC, since the operation it performs is a special case of HCC. But the existence of a common ancestor seems to be ruled out.

6. Concluding Comments

The Minimalist approach sees Merge as the generative mechanism behind language. But it also acknowledges that any unbounded system of hierarchical construction might suffice. Hierarchical concept-combination, it seems, fits the bill so could be all that is needed. But this turns the language system on its head. The generative mechanism behind language is now in the *conceptual* system and, more awkwardly still, is a generator of semantic rather than syntactic structure. It is a medium for assembling arbitrarily complex meanings by compositional thought. The only way to accommodate this is to change the central role of the language system altogether. No longer can this be the building and interpreting of syntactic structure. Instead, it has to be sequential-symbolic encoding/decoding of hierarchical structure native to the conceptual system.

This, the semantics-first or assembly-line model, is one way in which Merge and HCC might be related. Arguably, the most interesting option, it is also the one which produces most epistemic upheaval. The other two possibilities conform more to established theory. The first is that Merge and HCC are completely disconnected. The second is that one of these mechanisms uses the other on a clientserver basis. The latter raises thorny questions about implementation, while the former entails assuming an inherently implausible duplication of resources. On the present evidence, then, it is hard to establish which of the three arrangements is closest to the truth.

Empirical investigation could certainly pay dividends in this situation. The semantics-first model gives rise to specific predictions. Syntactically correct utterances are seen to stem from the way HCC interacts with sequential symbolization. Knowledge of syntax plays no role. But if knowledge of sequencing conventions, combined with a capacity for HCC, suffices to produce utterances conforming to syntactic rules, linguistic performance should run well ahead of syntactic evidence. Language learners should be seen to produce utterances that conform to syntactic rules without ever encountering any examples of the rules in question. Experimentation probing this capacity is one way of empirically testing the semantics-first model, then. (According to some theorists, evidence of this capacity already exists in the form of poverty-of-stimulus effects. The claim remains controversial, but should it ultimately be validated, this would favour the semantics-first model.)

Another prediction of the semantics-first model stems from its commitment to the idea of assembly-line processing. If language production involves two distinct stages of processing, the first semantic, the second non-semantic, this should be reflected in the neurological evidence. Under the standard model of language production, syntax is seen as relatively autonomous. This entails that semantic processing should follow or co-occur with non-semantic processing. Under the semantics-first model, it is the other way around. Semantic processing must be complete before non-semantic processing can even begin. The processing in the brain that mediates production of an utterance should exhibit two stages, then: the first inherently semantic, the second inherently non-semantic. If evidence of this division already exists, or can be obtained, that would favour the semantics-first interpretation. Resolution of the question of how Merge and HCC are related in the mind is likely to come from empirical investigation, then. Assessment of evidence that already exists may also be able to shed some light. It is hoped that future work will make progress in these ways.

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Optimality and Plausibility in Language Design

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The Minimalist Program in generative syntax has been the subject of much rancour, a good proportion of it stoked by Noam Chomsky's suggestion that language may represent "a 'perfect solution' to minimal design specifications." A particular flash point has been the application of Minimalist principles to speculations about how language evolved in the human species. This paper argues that Minimalism is well supported as a plausible approach to language evolution. It is claimed that an assumption of minimal design specifications like that employed in MP syntax satisfies three key desiderata of evolutionary and general scientific plausibility: Physical Optimism, Rational Optimism, and Darwin's Problem. In support of this claim, the methodologies employed in MP to maximise parsimony are characterised through an analysis of recent theories in Minimalist syntax, and those methodologies are defended with reference to practices and arguments from evolutionary biology and other natural sciences.

Keywords: biology; evolutionary plausibility; Minimalism; philosophy of science; syntax

1. Introduction

There is no point in using the word 'impossible' to describe something that has clearly happened. (Douglas Adams)

The Minimalist Program (henceforth, often referred to as Minimalism or simply MP) in generative syntax has been the subject of much rancour, a good proportion of it stoked by Chomsky's suggestion that "language design may really be optimal in some respects, approach[ing] a 'perfect solution' to minimal design specifications" (Chomsky, 2000a: 93). A particular flash point has been the application of Minimalism to speculation about how language evolved in the human species, most prominently represented by the Merge-only hypothesis in generative syntax (Chomsky, 2000b) and the saltationalist claims often made in parallel (Hauser *et al.*, 2002). To date, Anna Kinsella (Parker) has carried out the most extensive investigation into how well motivated Minimalism may be in relation to the evolution of human natural language syntax (Parker 2006; Kinsella, 2009,

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2015; Kinsella & Marcus, 2009), undertaking to look at "what we know from evolutionary biology about what typically evolving systems look like, what kinds of properties they have, and then applying this to questions about the plausible nature of language" (Kinsella & Marcus, 2009: 187). The conclusion is a strongly dissenting one, claiming that a more suitable approach "may reverse this [Minimalist] trend, and look towards possible imperfections as a source of insight into the evolution and structure of natural language" (Kinsella & Marcus, 2009: 207). The vote of *evolutionary plausibility*, it is claimed, counts against Minimalism.

This paper presents the countering view that what we know about biological design—and the kinds scientific inference needed to explain it—substantiate Minimalism as a plausible evolutionary hypothesis. Towards this end, section 2 makes some clarifications about the methodology and objectives of Minimalist syntax and introduces some technical language for discussing the virtues of Minimalism as a metric of evolutionary plausibility. In sections 3 and 4, I characterise the methodologies employed in MP through an analysis which exemplifies the use of redundancy, economy, and efficiency in Minimalist syntax. Building on this characterisation, sections 5 and 6 mount a defence of those methodologies with reference to practices and arguments drawn from contemporary evolutionary biology and neighbouring natural sciences.

2. Optimality and Evolution

2.1. 'The Best of All Possible Language Faculties'

In the following passage, Kinsella and Marcus lay out an argument against the Minimalist conception of language evolution.

[A]t least one strand of recent linguistics—its tendency towards a presumption of perfection—is at odds with two core facts: The fact that language evolved quite recently (relative to most other aspects of biology) and the fact that even with long periods of time, biological solutions are not always maximally elegant or efficient. To our minds, anyway, the presumption of perfection in language seems unwarranted and implausible [...]. (Marcus & Kinsella, 2009: 207)

A plausible account of language evolution, they claim, leaves scant margin for optimal design. They consider the following metrics against which one could assess this claim:

Language might be considered optimal if communication between speaker and hearer were as efficient as possible. [...] Another possible measure of optimality might be in terms of the amount of code that needs to be transmitted between speaker and hearer for a given message that is to be transmitted. [... C]ould language be a system that yields an optimal balance between ease of comprehension and ease of acquisition? (Kinsella & Marcus, 2009: 196)

It is clear from these speculations that the notion of perfection under consideration takes optimal *communication* to be the relevant metric. A casual examination of the range of biological traits provides *prima facie* confirmation of Kinsella & Marcus' (2009) scepticism: The biological world is teeming with messy, unlikely solutions to environmental pressures, an observation which undergirds Kinsella and Marcus' well-founded conviction that language *qua* communicative system is more akin to Rube Goldberg machine—or a 'Kluge' in Marcus' (2009) terms—than a precision-engineered device.

The Minimalist conception of optimal design, however, is fundamentally different insofar that the faculty of language (FL) is not a communicative system—or a 'functional' system of any kind—but rather FL is a theory of a physical object. A more appropriate comparison is Turing's well-known study of morphogenesis which explains biological design by appealing to necessary interactions of matter-what neurobiologists Reeve & Sherman (2001: 64f.) referred to as "the surprisingly ordered of simple underlying processes". Optimality in the functional sense is quite distinct to optimality in the latter, developmental sense. There is no contradiction, for instance, in the design of zebra stripes being suboptimal with respect to its function as camouflage yet also highly optimal as a solution to the developmental (i.e. biochemical) gully that must be breached to bring about this evolutionary novelty. The question of interest to Minimalists is to "what extent language is a 'good solution'" to the conditions imposed by other cognitive systems with which language interacts (Chomsky, 2000a: 9). This latter conjecture is in keeping with the Minimalist hypothesis that much of human language design can be explained by the introduction of a hierarchical form of structure to an existing "conceptual-intentional" cognitive system (roughly, the faculty of thought) and its externalisation through a sensori-motor system (roughly, the capacity for producing sound); which is to say, syntax is for thought in the sense that its structure was largely determined by the constraints of a preexisting conceptual-intentional cognitive faculty.

In the context of language evolution, then, optimality is a *causal* hypothesis about how our changing biology has structured cognitive systems with respect to one another, and not a normative claim about the adaptive value of cognitive traits. The statement "even with long periods of time, biological solutions are not always maximally elegant or efficient" thus represents a departure both from the Minimalist conception of FL as an instance of biological design and from the Minimalist conception of optimality as a causal rather than normative (adaptive or functional) metric.¹ This latter notion of optimality recalls the Leibnizian form of optimism proffered by computational neuroscientist Cherniak to describe the maximally efficient component placement that characterises the human brain: the human language faculty represents the "best of all possible language faculties" (quoted in Chomsky, 2005: 6, Cherniak's actual phrase is "the best of all possible brains" 1995: 522; see also section 6 below). Kinsella & Marcus' (2009) criticisms on the basis of the communicative efficacy of language thus rebut a misconstrued version of the Minimalist conception of optimality.

¹ Kinsella does briefly give a more accurate portrayal of Minimalist desiderata in other places. For instance, she and Marcus argue that "it is unrealistic to expect language to be a perfect or near-perfect solution to the problem of mapping sound and meaning, and equally unrealistic to expect that all of language's properties can be derived straightforwardly from virtual conceptual necessity" (Kinsella & Marcus, 2009: 203).

2.2. Darwin's Problem and Parsimony

The question immediately posed when adopting this understanding of optimality is: What makes one theory of Narrow Syntax more optimal than any other theory?² A simple gloss to the Minimalist conception of optimality is what philosophers of science have taken to calling 'parsimony' (Popper, 1959; Simon, 1969; Kitcher, 1976; Sober, 2015)—the kind of simplicity and elegance that is typical of good scientific theories in all of the natural sciences. One aspect of parsimony which has arisen in the context of language is what has dubbed 'Darwin's Problem' (Boeckx, 2009: 45): Postulating a large number of events resulting in FL is almost certainly inappropriate given the short space of time available and Darwin's Problem therefore militates for a saltationalist account of language; in other words, an account in which the novel language phenotype emerged rapidly with only a few evolutionary events.

2.3. Three 'Optimalities'

With these clarifications in mind, it will be useful to introduce some terminology for understanding how the different claims of linguists, cognitive neuroscientists, and evolutionary biologists can fit together to form a clearer picture of what Minimalism could mean as a theory of linguistic evolution. A well-established distinction in the Minimalist literature is that between methodological and substantive minimalism. The former, Chomsky notes, has a merely "heuristic and therapeutic value" (Chomsky, 2000b) for enquiry. It is methodological insofar that its motivation is not unique to linguistics-it is a general principle of science-and in that it does not rely on any ancillary hypotheses about the structure of the world. Substantive minimalism, contrastively, is the extent to which the causal hypothesis outlined in section 2.1 above is true of language. An example of substantive minimalism which I will elaborate on below is the apparently pervasive phenomenon of 'least effort' principles in syntax. The conclusion to Darwin's Problem reached by Minimalists, quite opposite to that reached by Kinsella & Marcus (2009), is that, because there is a great deal of phenotypic change to be explained in only a short span of evolutionary time, it must be assumed that something "comes for free", or is given a priori, to explain the dramatic variation. There is an obvious analogy here between the form of Darwin's Problem and that of the wellspring of generative metatheory, the poverty of the stimulus argument (or 'Plato's Problem'): The structure of FL is underdetermined by the environment, similar to the circumstance encountered by the child learner, because of the insufficient time and environmental resources available to ensure the correct final state emerges.

² Narrow Syntax represents one half of the distinction made in Hauser *et al.* (2002) between the faculty of language *broadly* conceived, and the faculty of language *narrowly* conceived. The former denotes every aspect of FL which is *sufficient* for human language—the presence of a tongue, the ability to distinguish sounds of the appropriate length and quality, and so on. The latter is a subset of the first, denoting only the aspects of FL which are *uniquely necessary* for language. That is to say, Narrow Syntax is the computational system which differentiates human language from other linguistic traits common to non-linguistic (and therefore also non-human) forms of cognition.

The methodological and substantive motivations for Minimalism are equally important to the enterprise and converge on similar theoretical objectives. Crucially, however, the two are different in their justifications. It must be recognised that the optimality of the physical/biological object 'language' is a distinct proposition to the optimality of the formalisms making up the theory of the physical/biological object 'language' and that this in turn is a distinct proposition to the simplicity of the causal-historical sequence of events which resulted in the design of language. Though related, these are each distinct propositions that pertain to different kinds of scientific inference. The first of these propositions is a claim about the organisation of a physical structure in the world-the question is whether or not nature is capable of producing (structurally) optimal biological traits. We may call this doctrine *Physical Optimism*. A second prong of parsimony, which we can contrastively dub Rationalist Optimism, contends that redundancy is undesirable in theories on epistemological rather than purely empirical grounds. We may designate as Rational Optimism any supra-empirical principle of scientific theory selection that is not an ontological commitment about the nature of the physical world.³ The last of these propositions, constituting a resolution to Darwin's Problem, will henceforth be referred to as Causal-Historical Optimism.

We can distinguish, then, three justifications for parsimony which may figure into the plausibility of an evolutionary account of language design: Rational Optimism, Physical Optimism, and Causal–Historical Optimism. It must be noted that the three are not entirely independent; a physically optimal language faculty (the biological object) obviously increases the plausibility of a saltationist approach to Causal–Historical Optimism because a physically optimal language faculty is easier for evolution to reach. Similarly, a parsimonious biological object will naturally lend itself to the existence of a n optimal theory of language. These connections are explored further in section 5 and section 6 below.

3. The Explananda of Minimalism

3.1. Parsimony and 'Principled Explanation'

In addition to establishing that parsimony is a virtue for explaining language design, it must also be shown that MP is in fact a parsimonious theory in the appropriate ways. Here it is important to accurately characterise the methodology and objectives of syntactic Minimalism. One of the main objectives established in the Minimalist literature is the need to provide a 'principled' explanation for the properties of language with the corollary that any theoretical posits which are not principled ought to be considered suspect. A property of language, according to

³ Bar for a single perfunctory (though, strangely, not wholly dismissive) mention of this epistemological aspect of scientific parsimony, Kinsella and Marcus never satisfactorily address its significance: "In one respect, this notion [of parsimony in syntax] is admirable (if unsurprising): Linguistic theorizing, like all scientific theorizing, should be guided by considerations of parsimony" (Kinsella & Marcus, 2009: 199).

Chomsky, can be considered principled insofar that it "can be reduced to [1] the third factor and to [2] conditions that language must meet to be usable at all" (Chomsky, 2005: 10; numerical annotations mine).

The 'third factor' is a somewhat enigmatic reference to elements of what Cherniak and others have termed non-genomic nativism—that is, aspects of biological design which follow from geometrical and computational necessities and are thus neither inherited nor acquired.⁴ The second element of principled explanation, "virtual conceptual necessity", refers simply to the virtue of building theories from first principles and abandoning unnecessary theoretical machinery. The boldest formulation of Minimalist syntax, the so-called Strong Minimalist Thesis, is based on the hypothesis that FL minimally satisfies the requirements of (1) the third factor and (2) virtual conceptual necessity. The task of Minimalist syntax, then, is to determine which elements of the theory are minimally satisfying—that is, which are necessary—and to achieve as much empirical coverage of the relevant facts of language as possible using only these elements plus those which can reasonably be derived from the third factor.

In practice there are three basic categories of parsimony used in MP. The first implores us to make maximal use of existing explanatory technology to explain facts. The motivation here is clear enough—the reduction of explanatory *redundancy* is the salient virtue. The second strategy is to use the minimal technology necessary to explain the requisite facts, what we may call the *economy* of explanatory technology. The first two of these are two sides of the same coin which I will call *unification* for obvious enough reasons. The third maxim is to assume a general condition of computational *efficiency* in computation. Below I introduce three simple and fairly uncontroversial syntactic explananda—discrete infinity, displacement, and binding theory—and in section 4, I demonstrate how MP applies the desiderata of redundancy, economy, and efficiency to derive a more parsimonious theory of these explananda.

3.2. Discrete Infinity

One of the earliest discoveries pertaining to the formal properties of human natural languages was that they do not belong to the class of regular languages which can be generated by a finite-state machine (Chomsky, 1956, 1959). A finite-state machine is an abstract formal device, essentially a more restricted Turing machine, which consists of an input, a set of states, and a set of rules for changing state based on the input. Finite-state machines generate only a subset of the possible languages; more powerful abstract devices, which differ principally in their capacity to 'remember' strings from the input, are required to generate the full set of possible languages, including human natural languages. As an illustrative point, Berwick *et al.* (2011) have shown that the song of Bengalese finches *can* be generated by a finite-state machine and consequently belongs to the class of regu-

⁴ An example I will elaborate on in section 6 is the structure of neural arbors which are optimally spatially arranged, not because of a process of adaptive design, but because of a geometrical necessity shared by physical phenomena of numerous scales and origins branching rivers, crystalline structures, and so on.

lar languages. Finch song conforms to this pattern as it contains sequences of notes repeated and reused throughout the duration of the song, but never reuses these sequences inside other sequences (Berwick *et al.*, 2011: 115; see Figure 1).

A finite-state grammar without dependencies can be represented as:

anbm

What Chomsky showed in the mid-1950s is that, unlike finch song, human language (or, really, the English language) belongs to a larger set of languages that can contain dependencies. Unlike finite-state grammars, the dependencies contained in human languages require the ability to shift the value of a string onto a 'stack' while a second string is being processed and recall it at a later point. This capacity for memory is captured by the formalism of a push-down stack automaton.⁵ What this means is that a valid string can be, for instance, a sequence of *as* followed by the same number of *bs*, a string which is mirrored (*aaabbb-bbbaaa*), repeats itself (*aaabbb-aaabbb*), and so on, as represented in the following abstract grammar:

anbn

This fact is evident in English when sentences are of the kind 'If S_1 , then S_2 '. Strings of this type cannot be generated by finite-state machines because a string in S_1 may depend on a string arbitrarily distant to it. In the string in (1), for instance, the verb in S_2 must agree in number with the subject of S_1 .

(1) If $[s_1$ the boy_a gets the girl] then $[s_2$ he is_a happy]

The resulting dependency looks like ' $a^{1}b^{2} \dots b^{2}a^{1}$,' a subset of those generated by a *context-free* grammar.

This basic characteristic has returned to prominence in recent discourse framed as discrete infinity. Discrete infinity, the Minimalist claim goes, marks a *sui generis* property of human cognition insofar that the capacity to generate hierarchically arranged combinations of discrete units constitutes a larger subset of the set of possible languages than any organisation of the discrete units alone could produce. Human language is thus formally distinct to the communication systems of other species.

⁵ Grammars which can remember more than one value—taking the form *anbncn*—are contextsensitive. There is some evidence that human languages are mildly context-sensitive, for instance in 'such that'-sentences (Higginbotham, 1984):

⁽i) The girl_a such that the dog ran from her_b to him_c sat down on the bench.

Whether context-sensitivity is a substantive aspect of linguistic cognition or merely an artefact of domain general processing is unclear.



Figure 1: Formal properties of human and non-human language. Left: The Chomsky hierarchy; each category of languages is a subset of those generable by the larger set. Top right: A finite-state grammar of the Bengalese finch. Letters indicate song notes and numbers indicate probabilistic state transitions (Berwick et al., 2011: 117). Bottom right: phrase structure rules and a sentence in a dependency grammar.

3.3. Displacement

A second phenomenon unique to human languages is that lexical items are often interpreted semantically in a position different from that of their phonological expression. This *displacement* effect is readily discernible in what have traditionally been considered to be the product of transformations in a covert (i.e. phonologically unpronounced) level of syntax—D(eep)-structure in Chomsky (1981). As an example of displacement, consider the sentences in (2) and (3):

(2) Children hate broccoli.

Semantically, this sentence states:

(2) Gen x (child (x): hates broccoli (x))

Or "Typically, for *xs* such that *x* is a child, *x* hates broccoli". When a question is formed from this proposition we get:

(3) What do children hate *t*?

The semantic proposition expressed by the sentence is "For what *x* is it the case that children hate *x*?". In this case, the unknown element *x* does not appear adjacent to the verb *hate*, as *broccoli* does in (1), but rather it appears adjacent to *do* in the form of the pronoun *what*. Our semantic interpretation is nonetheless that children hate *x*, as indicated by the paraphrase "Children hate what?" Displacement, then, is the idea that elements like *what* are interpreted twice—in this case, once as a subject of the verb *do* and again as the object of the verb *hate*.

3.4. Binding Theory

The final explanandum to be treated here is binding theory, which aims to explain the distribution of co-indexed nominals. The basic data are shown below:

- (4) [Mary's father]_{*i*} hated himself_{*i*}.
- (4') *[Mary_i's father] hated herself_i.
- (5) John_i saw him_j.
- (5') *John_i saw him_i.
- (6) Jane_{*i*} saw Jane_{*j*}.
- (6') *Jane_i saw Jane_i.

The sentence pair in (4) shows that the reflexive anaphor *him-/herself* may not be co-indexed with antecedent inside a genitive phrase. Similar relationships hold for (5)–(6) where the co-indexed nominals and possible interpretations of indexation are strictly limited in grammaticality. The key insights are that the distribution of co-referring nominals is closely related to (i) the *locality* of an antecedent and (ii) the antecedent being *c-commanded* by the element with which it is co-indexed.

Locality here refers to the notion of belonging to the same 'domain' where a domain may be constituted by a phrase boundary. C-command determines the relationship between the antecedent and the anaphor (see the simplified tree structures in Figure 2). In (7), for instance, *John* is both co-indexed with and ccommands the reflexive anaphor *himself*, but the unacceptability of (7) is a result of the reflexive not being 'local enough' to its antecedent.

(7) *[$_{\beta}$ John_{*i*} thinks [$_{\alpha}$ that Mary saw himself_{*i*}]]

That is, because β —and not α —is the binding domain of John, *himself* is not bound in its domain and ought to take a pronominal.



Figure 2: The binding domain and c-command. (a) John c-commands and is co-indexed with himself, but the domain of John is β , not α . (b) α c-commands β when the phrase containing $\alpha - XP$ in the above tree—contains β or any phrase containing β .

3.5. Summary

The picture of FL suggested by the above—though far from factually or historically complete—is one of several highly distinct formalisms explaining what appear to be quite heterogenous axiomatic systems. *Prima facie*, this heterogeneity suggests that there must be numerous historical-causal events, each responsible for the distinct formal properties of language. In the section to follow, the MP practices of redundancy, economy, and efficiency will be demonstrated with respect to four of these systems: phrase structure rules, transformations, ccommand, and the notion of a binding domain.

4. Minimising Syntax

4.1. The Objectives of Minimalism

The Minimalist conjecture is that at least some of these formalisms must be eliminated if an evolutionarily plausible account of FL is to be given. This section exemplifies the methodologies of redundancy, economy, and efficiency as they are applied to reaching the goal of a plausible FL. The aim is to articulate the kind of desiderata Minimalism employs in accounting for the above linguistic facts in a maximally parsimonious way.

4.2. The Merge-Only Hypothesis

The strongest, and possibly most controversial, theory to have emerged from MP is the Merge-only hypothesis which proposes that Narrow Syntax is constituted by a single computational operation, MERGE.⁶ This conjecture is made on the grounds that MERGE is a virtually necessary component of any computational system which can generate a non-finite set of strings (i.e. a system capable of producing an unbounded array of embedded strings); any computational operation responsible for the dependencies ubiquitous in human languages, the claim goes, will require an operation which embeds an object within another object and this operation can be abstractly described as MERGE. Thus, the significant claim of MP is that MERGE is conceptually necessary, not merely conceptually sufficient. The methodological tenet of *redundancy* requires that all other conceptual apparatuses in the theory should be considered suspect, and the methodological tenet of economy requires that this virtually necessary component should be employed for maximal explanatory coverage. The Merge-only hypothesis is a clear demonstration of a unification which achieves both a reduction in redundancy and a maximal use of economy. MP is largely an exercise is making maximal use of MERGE, as well as some efficiency assumptions which are attributed—enigmatically, as it stands—to the third factor, again in line with the definition of principled explanation given in section 2.

⁶ As an anonymous reviewer points out, Merge-only is something of a misnomer if Merge alone is not capable of satisfying the legibility conditions of the sensori-motor and conceptual-intentional systems. The role of interface conditions is more central in recent Minimalist proposals.

Chomsky (2000b) presents a theory of MERGE which accounts for both the unbounded character described in section 2.1 and the displacement effect described in section 2.2. However embedding is achieved, the Minimalist claim goes, that operation must resemble the abstract computation MERGE such that:

$$MERGE(\alpha, \beta) \rightarrow K = \{\alpha, \beta\}$$

Where α and β are lexical items drawn from the lexicon and K is a new syntactic unit formed by applying MERGE to α and β . This new complex syntactic object K can then be MERGED with another syntactic object, so that:

$$MERGE(\gamma, K) \rightarrow \{ \gamma \{ \alpha, \beta \} \}$$

Unlike finite-state grammars, in a grammar of this kind the new objects can grow in length to become complex strings, which in turn can be MERGED with other complex strings. Returning to (1), reprinted here as (8):

(8) If $[_{S_1}$ the boy gets the girl] then $[_{S_2}$ he is happy]

In terms of the abstract formal characteristics of human languages, sentences like (1)—with the dependency structure ' $a^{1}b^{2}$... $b^{2}a^{1}$ —can be accounted for because the values of complex strings like S_{1} and S_{2} can be 'remembered' as a complex, merged whole as captured by the push-down stack formalism employed by Berwick *et al.* (2011: 120).

4.3. The Copy Theory of Movement

Recall that displacement involves a lexical item interpreted in two positions as shown in (2) and (3), reprinted here as (9) and (10).

- (9) Children hate broccoli. "For *x*, *x*s hate broccoli."
- (10) What do children hate *t*?"For what *y*, *x*s hate *y*."

The mystery is that, in the second sentence, the semantic interpretation of *y* appears to occur in both object and sentence initial position. A natural exposition may claim that an operation is acting on *y*, shifting it upwards. Call this second operation MOVE. This would account for displacement, but at the cost of the additional stipulation of a second operation. The account in Chomsky (2000b) forwards an argument to the effect that MERGE can account for the same explananda as MOVE and is thus methodologically preferable. This unification is possible, he claims, if it is assumed that MERGE can apply both to new objects drawn from the lexicon, as outlined above, but also to objects already inside the merged syntactic object.

This latter version of MERGE operates in the following way:

$$MERGE(\alpha, K) \rightarrow \{\alpha \{\gamma \{\alpha, \beta\}\}\}$$

That is, MERGE calls the object α which is already merged within the object { γ { α , β }} thus making α the new head of the object { α { γ { α , β }}}.We can distinguish EX-TERNAL MERGE, where the two objects MERGED are different, from this operation of INTERNAL MERGE, where one of the objects MERGED is internal to the complex object. If one of the internally merged objects is not phonologically pronounced, this will give the appearance of α having 'moved,' as indicated in Figure 3. This is sometimes referred to as the copy theory of movement. As outlined in Chomsky (2007), 'copy' is a *façon de parler* and not a bona fide operation; the two identical instances of α results simply from MERGE applying internally in line with the most economic principle, namely that neither object is altered by the operation of MERGE (the so-called 'No Tampering Condition').

 $MERGE(\alpha, K) \rightarrow \{\alpha \{\gamma \{\alpha, \beta\}\}\}$



Figure 3: The copy theory of movement. Displacement and discrete infinity can be explained with a single unified theory if we assume that MERGE can apply to objects within the syntactic structure.

The copy theory of movement is an example of unifying parsimony in that two conceptual technologies (MOVE and MERGE) have been subsumed under a single, more encompassing one, thus eliminating redundancy.

4.4. C-Command and INTERNAL MERGE

An attempt to account for the technological complications of c-command and minimal domain which exemplifies the Minimalist method is that of Hornstein (2001).⁷ Recall the breakdown of binding theory in section 2 above, particularly that the distribution requires that (i) the *locality* of an antecedent and (ii) the antecedent being *c-commanded* by a co-indexed element. The two key technologies which must be explained are thus the notion of a 'domain' and the formal notion of c-command. Hornstein (2001) claims that the copy theory of movement makes sense of binding without these 'messy' stipulations:

As an anonymous reviewer points out, Hornstein's proposals importantly rely on the existence of the operations Move and Copy—for instance, to account for Improper Movement restrictions. I've overlooked these inconsistencies here, as they go well beyond the scope of this paper, and continued the discussion in terms of the copy theory of movement.

[The Minimalist Program] already has a notion of local domain, i.e., 'minimal domain,' as part of its theory of movement. [...] Standard considerations of theoretical parsimony would favor eliminating one of these locality notions.

(Hornstein, 2001: 153)

For instance, if INTERNAL MERGE is applied to an element α of an XP, the following will result:



Figure 4: α_1 *will c-command* α_2 *as a result of INTERNAL MERGE.*

In the copy theory, the higher α will form a 'chain' (in GB parlance; see Chomsky, 1981) with the lower α simply because they are the same element copied via IN-TERNAL MERGE. The c-command relation emerges from the requirement that α attach to the root node purely because any element MERGING with an internal element will be dominated by a phrase dominating the internal element (see Figure 4) and the economy condition Shortest Move is capable of explaining the requirement for locality. This is because, for example, in (11) MERGING *John* to sentence initial position would violate it.

(11) *[,John, thinks [, that Mary saw himself,]]



Figure 5: Shortest Move can account for the local domain of binding theory.

Hence, Hornstein's approach to binding is an exemplification of how the requirements of binding theory can be met with a Minimalist methodology employing no greater technological complication than MERGE and Shortest Move.

4.5. Summary

Efficiency conditions are not motivated in the same way MERGE is—it is not a conceptual necessity that language is computationally efficient. Proceeding from

the virtual conceptual necessity of MERGE, MP unifies the theoretical machinery of three distinct formal systems under this single mechanism. Discrete infinity, displacement, and c-command—probably the most formally conspicuous aspects of human natural language syntax—can be accounted in a near maximally unified theory of syntax. The additional of Shortest Move further derives a local domain restraint which has applications in many areas of syntax and is exemplary of the use of efficiency. The dictum of efficiency can therefore still make a claim to being parsimonious if it can unify numerous heterogeneous conceptual technologies under a single mechanism.

5. Rational Optimism

5.1. Two Justifications for Rational Optimism

Rational Optimism represents an *epistemologically* motivated justification for parsimony based on the conjecture that simpler theories are ipso facto more likely to be true theories. Contrary to Kinsella, an evolutionary story with fewer mutations is in fitting with evolutionary biological practice. One candidate is a probabilistic or 'frequentist' approach to causal inference which validates the intuitive assumption that a single common cause of two events is more plausible than multiple independent causes. The frequentist interpretation of parsimony lends itself particularly well to the saltationist hypothesis for language since it is part of the central methodology of cladistics, the science of evolutionary history. A second approach differs from the first in that it takes as its focus the possibility of error in scientific models rather than the likelihood of causes. This is a strong justification of unification as a methodology and is routinely used in the natural sciences to reduce the level of error in modelling by estimating the 'overfit' of a theory with respect to an impoverished data set. Both of these justifications, if correct, constitute a supra-empirical principle of parsimony that support MP's methodology and hypotheses.

5.2. Likelihood and Parsimony

Let's proceed with the first, frequentist, interpretation of plausibility and evaluate its utility to the notion of parsimony as it pertains to language evolution. An example of how parsimony may increase likelihood, taken from Sober's (1988) discussion of Reichenbach, can get us on our way.

Given a pair of correlated facts—say, both my and my neighbour's car doors being scratched—a simple explanation for the pair may be that my neighbour has dinged my car door with his or her own car door thus causing the damage to both door simultaneously. Call this hypothesis E_1 . A more complex explanation, requiring the postulation of more agents and causes, is that a third neighbour dinged both of our car doors independently. Call this E_2 .

- (E_1) Neighbour 1 damages both his/her car door and my car door at the same time.
- (*E*₂) Neighbour 2 damages Neighbour 1's door and my door in two separate incidents.

Assume both neighbours have an equal probability of damaging my car door they will each do so around once a year, giving them each an approximately 0.3% probability of having damaged my car door on any particular day this year—and that instances of car door damage nearly always result in both doors being damaged—about 90% of the time. E_1 , as well as being simpler, confers a much higher likelihood on the outcome.⁸

5.2.1. Conjunctive Forks

Following the logic of Sober's discussion of the notion of a 'conjunctive fork,' as formulated by Reichenbach (1956), we can get some initial purchase on why likelihood improves with parsimony. We may say that a correlation between events is *probabilistically dependent* when one conspicuously co-occurs with another. A correlation occurs, then, in the case that:

$$Pr(A_1 | A_2) > Pr(A_1) \times Pr(A_2)$$

Which is to say, correlation occurs when the observed probability of two events— A_1 and A_2 —occurring together is greater than the observed probability of them occurring independently. Having knowledge of A_1 therefore gives us probabilistic knowledge of A_2 which the probabilities of each event alone would not reveal. In the above case of the damaged car door, there is a very high probability of damage being caused to both doors involved. Call this probability *T*. It was also the case that the cars in question were neighbours, so when the probability of damage is present for A_1 it is also present for A_2 . Call this assumption *C*.

The interesting fact which Reichenbach noted is that if causal hypothesis E_1 is assumed then the presence or absence of T under the assumption of C is sufficient for us to estimate the probability of both doors being damaged. It is no longer necessary to posit the dependence of one event on the other because knowing the probability of damage and the fact that the two agents are neighbours explains the correlation. If we posit a joint cause of A_1 and A_2 in this way, Reichenbach claims, we have a conjunctive fork: A postulated cause which renders the probabilities of two correlated events independent. What we have described here, then, is a way of understanding why postulating common causes—that is, postulating *fewer* causes—leads to better explanations. This 'Principle of the Common Cause' claims that positing fewer causes for the same net effect will, *ceteris paribus*, deliver a better explanation.

5.2.2 The Principle of the Common Cause and Cladistic Parsimony

Sober provides a succinct example of the utility of parsimony to historical inference which will make the association clearer. Sober has in a mind a particular

⁸ We can see how this is so arithmetically by attending to the probabilities of E_1 and E_2 respectively. The probability of one neighbour damaging my door, plus the probability that both doors will have evidence of having being damaged is Pr(.003)(.9). The probability of E_1 is therefore greater than the probability that Neighbour 1 and my car doors will have each been damaged by Neighbour 2 independently, which is Pr(.003)(.003).

problem of historical inference, namely the principle of cladistic parsimony. As the name suggests, cladistic parsimony the similarities between species is best explained by positing common ancestry wherever possible. This precept has an inverse: As well as maximising the number of posited common derived characters,⁹ we should minimise the number of posited homoplasies—parallel, or convergent, similarities which have evolved independently.

This virtue can be demonstrated by taking a simple case like that in Fig. 6, where each branch—A, B, and C—represents a species.



Figure 6: Cladistic parsimony. Two possible ancestries (bottom) for a set of characters (in table, above). Adapted from (Sober, 1988: 30).

Faced with the problem of reconstructing the ancestry of a character will mean deciding whether any two of A, B, and C have a common ancestor which the other lacks. The only evidence available to us is the presence or absence of various characters, as represented in the table at the top of the figure and we further assume that all three species have at least one common ancestor. The problem here is that, while positing the ancestry depicted in the figure on the left perfectly explains the distribution of characters 1–45 and 46–50, we must then assume that B and C each evolved character 51 independently. By contrast, the ancestry depicted in the figure on the right explains the homology in characters 1–45 and 51, but we must assume that A and B each independently evolved characters 46–50. According to cladistic parsimony, the *best* theory of the historical ancestry of these characters is therefore (AB)C, as it posits the fewest homoplasies.

⁹ A tangential note on the terminology of cladistic analysis: What I have simply called a 'derived character' (i.e., any non-zero character in the figure) is a vernacular term for an apomorphy. Any apomorphy which is inherited from a direct common ancestor (A and B in the figure on the left) is a synapomorphy. By extension, what I have called an 'ancestral character' is a plesiomorphy (all zero-valued characters in the figure) which, when shared, become symplesiomorphies (B and C in the figure on the right). Since my discussion of cladistic parsimony is less central than Sober's, I stick with the less jargonistic 'derived' and 'ancestral' character, using 'shared' or 'common' to indicate homology.

Increasing the resolution from many clades and their respective characters to a single species (*Homo sapiens*) and its characters should not alter the conclusions drawn from Sober's reasoning: If parsimony is generally a virtue in predicting the causal-historical breakdown of phylogenies, it ought to be a virtue in predicting the causal-historical breakdown of phenotypes. We are justified, then, to assume that Rational Optimism provides a good rationale for inferring as few events as possible in the causal history of language evolution.¹⁰

5.3. Parameters, Parsimony, and Plausibility

A second supra-empirical principle of plausibility aims to reduce the number of assumptions or parameters a theory must entail Popper (1959) believed that parameters—or, rather, a paucity of them—were an important aspect of parsimony in the philosophy of science. For him, the nature of the question was exhausted by the ductility of a theory; that is, more brittle theories—those with fewer valued parameters—are more easily falsified than very ductile ones, which can be stretched this way and that in virtue of their many manipulable parameters: "The epistemological questions which arise in connection with the concept of simplicity," he therefore claimed, "can all be answered if we equate this concept with *degree of falsifiability*" (Popper, 1959: 140; original emphasis) Popper's is one understanding of how fewer parameters can aid a theory in achieving veridicality, though a suitably positivist one. It is prototypical of Rational Optimism, however, in that no observation or observations could diminish its force; it is properly *a priori*.

5.3.1. The Problem of 'Over-Fitting'

The central idea of parameter parsimony is that fewer uncertain variables reduces the potential for error. The below figure presents a single set of data points for the two variables *x* and *y* and two polynomials which potentially describe the relationship between the points.

(ii) A *major* change in developmental chronology can lead to a vast phenotypic change. This requires that all the correct developmental conditions to be in place prior to the saltation.

¹⁰ It does not follow from the likely paucity of past evolutionary events that language design is simple, or that the change which resulted in language design was simple. It does not follow because there are two circumstances under which a saltation can lead to a trait, each with different entailments for a parsimony-based metric of evolutionary plausibility.

⁽i) A *minor* change in developmental chronology can lead to vast phenotypic changes. This requires only that the nature of the design in question is relatively easy to realise in physical media.

The state of affairs described in (i), and not that in (ii), is the scenario hypothesised in MP but it remains that cladistic parsimony licenses no inferences about the causal-history and structure of language *except that* fewer mutation-events are preferable.



Figure 7: An illustration of a curve-fitting problem.

In (a), a simple linear regression is posited by a first-degree polynomial curve.¹¹ The nearly arbitrary straight line plot is clearly unsatisfactory, revealing nothing of interest about the relationship between x and y: A straight line can be drawn through any data and this will rarely yield any interesting analysis or further predictive accuracy.

The inverse of this point is that for any data (x_i ... x_n), there is a n-1th degree polynomial which plots a line perfectly through every x. We see this in (b), where every point is fitted exactly by the curve. Surprisingly, however, perfect performance on the input data will with extreme rarity translate into satisfactory predictive accuracy when the curve is extrapolated to a larger set of data. This problem affects all finite data sets (i.e., every possible data set), but is particularly troublesome for very small ones. It is known as the problem of 'overfitting,' where the theory incorporates experimental error and other forms of noise—such as sampling error—thus leading to an amplification of minor fluctuations in the data not relevant to the target phenomenon.

5.3.2. The Akaike Information Criterion

The Akaike Information Criterion is a method for predicting the degree of overfit for any given problem of inductive extrapolation. Sober argues that the Akaike Information Criterion provides a justification for (and metric for the degree of) unification in scientific inference. The difference between true curves and curves which contain error is estimable, according to the Akaike Information Criterion, because error is proportional to the parameters which can potentially deviate from the true curve. That is, we can estimate the degree to which higher-degree polynomial curves will overfit the data if we know the rate at which error increases with each additional parameter. However, too few parameters—like a straight line—will obviously harm goodness-of-fit. The overfitting problem is thus a question of trade-off between parsimony and goodness-of-fit. The virtue of parsimony is, in this respect, inversely linked to the potential for error.¹²

¹¹ The greater the degree of polynomial, the more complex the curve its expresses will be. The first-degree polynomial in (a) expresses a straight line, a second-degree polynomial will express a parabola, and so on.

¹² Other matters of interest are how the trade-off is to be achieved and how it is to be justified. Call the true curve C_t and the one most accurate relative to the known data C_a . We can now ask how close C_t will be to C_a , or the overfit of C_a . As set out by Forster & Sober (1994), the

5.4. Summary

We may, with Sober and Forster's imprimatur, think that the Akaike Criterion "provides a ready characterization of the circumstances in which a unified model is preferable to two disunified models that cover the same domain." (Forster & Sober, 1994: 13) The Akaike Criterion therefore provides a robust rationale for the methodology of unifying technologies in MP by establishing a concrete link between the desire to minimise the number of parameters accounting for data in a theory, and to maximise the employment of existing parameters to achieve optimal coverage. Unifications are, in essence, an exercise in minimising probable error. The frequentist interpretation of parsimony is similar in that it derives its power from a supra-empirical principle. It differs, however, in that it provides a justification for the saltationalist solution to Darwin's Problem by demonstrating the intuitive virtue of evoking common causes for evolutionary characters.

6. Physical Optimism

6.1. Spontaneity, Efficiency, and Physical Optimism

The guiding rationale of Rational Optimism is that simple science is better science. A separate concern is the degree to which the biological world, and more particularly cognition, is typified by optimal design as defined by MP. Contrary to Kinsella & Marcus' (2009) findings, evidence from the 'extended synthesis' of evolutionary biology, comparative ethology, and impressive new findings from dynamic neuroscience demonstrate saltationalism and computational optimality to be highly plausible outcomes of language evolution. The core idea is that even highly complex aspects of biological design are substantially constituted by "the surprisingly ordered systems of simple underlying processes" (Reeve & Sherman, 2001: 64f.) which emerge spontaneously and are explained by simple changes in the organisation of matter. A particular subset of these "self-organising" systems—what have been called neuro-oscillations—has been implicated in the processing of phrase-level speech signals (Ding *et al.*, 2015).

This result may vindicate Minimalist hypotheses about the origins of syntactic cognition: In light of these findings, it is highly plausible that the salient

(i) $L(F_a)_{SS} + 2k(\sigma^2)$

Akaike Information Criterion provides a method for estimating the overfit of C_a with respect to the number of variables in the polynomial expressing the curve. It does so by generalising to the *family* of curves to which C_t and C_a belong, respectively, rather than considering the specific curves themselves. Call the family of curves to which C_a belongs F_a and the likelihood (in the technical sense) of the data given this family of curves $L(F_a)$. Akaike's Criterion states that the difference of C_a and C_t will be approximately equal to:

In (i), *k* is the number of parameters in the polynomial expressing the family of curves, and *SS*—or the *sum of squares*—is a statistical method for finding the total variance from the mean (which therefore tracks goodness-of-fit). σ^2 relates to the size of the data sampled and reflects the notion that overfit is linked to sampling error. Notice, then, that in the absence of error ($\sigma^2 = 0$) the difference of *C_a* and *C_t* will just be the likelihood of *F_a* subject to *SS*.

aspects of language design emerged via what Benítez-Burraco (2014) has described as a perturbation of the robust equilibrium of pre-anatomically modern human's brain oscillatory rhythms. The emergence of human language can be seen through this lens as a perturbation of a highly conserved (evolutionarily ancient) self-organising system and a subsequent 'tuning' of the resulting system to result in a novel and robust phenotype. This is an appealing elaboration on the Minimalist story that provides "a better view of the genetic underpinnings of language and the molecular mechanisms that channel variation at all levels of analysis" (Benítez-Burraco, 2014: 1).

6.2. Spontaneity, Invariance, and Darwin's Problem

The short span of evolutionary time available to account for linguistic knowledge requires not only that there are few evolutionary events responsible for language, but also that there is a possible alteration in the organisation of physical (brain-) matter capable of producing such a phenotype in only a few steps. This scenario becomes far more plausible if there are organisations of matter which do not just reach new states rapidly, but which are also 'canalised' insofar that they will reach the required end state from any of a wide range of initial states. Spontaneity and invariance are thus key desiderata of Physical Optimism with respect to Causal-Historical Optimism-and consequently a solution to Darwin's Problem. Self-organising systems satisfy both of these desiderata; they emerge quickly and across a variety of environments. That is, the structure of some highly abstract organisations of physical matter are such that they will inexorably trend towards a state and then remain in that state indefinitely. Kauffman (1991) describes such stasis points as 'attractors' for this quality of inevitability. Stasis points are extremely robust in that they attain in a wide range of physical realisations, they emerge rapidly due to their 'attracting' capacity.¹³

Kauffman provides us with a simple example of self-organisation, which will get us on our way. "The approach begins," Kauffman starts, "by idealizing the behavior of each element in [a] system [...] as a simple binary (on or off) variable" (Kauffman, 1991: 64). That is, we ignore all but the details necessary for the general design. The particulars of this system, a network of three communicating elements, are represented in Figure 8.

¹³ These kinds of explanations fall quite naturally out of a very attractive potential framework for explaining the emergence and physical realisation of language, an approach amenable to a style of evolutionary explanation dubbed 'rational morphology' by Kauffman. This approach follows a rich tradition of biological enquiry tracing its intellectual prehistory backwards from Turing's (1952) analyses of morphogenesis, through Thompson's (1917) laws of growth, back to the original rational morphologists who counted among their numbers Goethe and Cuvier.



Figure 8: A self-organising network. A simple Boolean network (left) and table of possible states (right). Adapted from (Kauffman, 1991: 66).

The figure on the left is a network of three elements, each conforming to a Boolean operator, and each interacting with the other two by sending and receiving signals reflecting their current state (active '1' or inactive '0'). In this network, *A* functions as an AND operator, while *B* and *C* both function as OR operators. When *both B* and *C* are active, *A* will either remain or become active itself, depending on whether it was active previously. *B* and *C* will remain or become active if *either* of the other two elements are active. The table on the right describes all the $(2^3 =)$ 8 starting permutations of the network and their respective successor states.

The important facts to notice are that in line L1, where all the states are inactive, there is stasis. In lines two and three, where only one of either *B* or *C* is on, the network will cycle endlessly between those two states. In all other initial states (lines four to eight), *A*, *B*, and *C*, will all rapidly become active and the network will again be in stasis. A remarkable upshot of these new discoveries in the area of neuro-oscillations is that both of the empirically motivated desiderata of MP—Causal-Historical Optimism and Physical Optimism—are satisfied. The framework is, furthermore, an intuitive explanation for why human nature language syntax has been so amenable to formalistic, axiom-based explanation. Selforganising systems are 'emergent', meaning they arise when highly abstract patterns of interacting matter result in a what Wagner (1989) calls an 'epigenetic trap': A robust equilibrium that is both attractive—matter in other states tends towards the equilibrium state—and invariant—matter of numerous scales is susceptible to the patter.

Consider, for instance, that

- 1. Syntax is *indivisible*; there is no 'half unboundedness.'
- 2. Syntax has the characteristic of being *discrete* in the sense that symbols and contrastive features are interpreted as independent units.
- 3. Syntax is readily describable in geometric terms, suggesting that

there is something metaphysically necessary determining the structure of syntactic cognition.¹⁴

4. Syntax exhibits the *scale-invariance* which is the most conspicuous feature of self-organising systems.

These four characteristics are conspicuously "unbiological" (Block, 1995) and are strong reasons for suspecting that self-organisation is an appropriate form of evolutionary explanation for human language.

6.3. Homeostatic Rhythms and Cortical Entrainment

Human natural language requires a form of hierarchical processing, which it has been hypothesised involves the Merging of syntactic objects of increasing size. This sort of scale invariance is a distinctive feature of self-organising systems, and lends itself naturally to the dynamical interpretation. That sanguinity has been known for decades: Conjecture about Fibonacci sequences is more or less *de rigueur* in considerations of evolution of language. The other reason for favouring a dynamical interpretation is more recent and inspires considerably more confidence: EEG imaging has begun to provide strong evidence that the brain comes pre-equipped with a means for encoding multiply scalar dependencies. The basis of this progress is a deepened understanding of how *homeostatic rhythms* respond to input signals. The rhythms in question are the commonplace wave frequencies—beta, delta, theta, etc.—which emerge from the excitation and discharge of cortical structures. What is novel is the discovery of how interference patterns among these frequencies encode information. Patterns interfere with one another in much the same way as people do: The loudest ones cause the most disruption.

Another way of thinking about interference is to consider the waves created by displaced water from a pebble or the stern of a boat. Waves of greater magnitude—from heavier pebbles or faster boats—will consume ones of lesser magnitude. The same is true for brainwaves. A 'louder' wave with greater amplitude influences 'quieter' ones. This becomes of great significance when the relationship between wave amplitude *A* and frequency *f* is plotted on a log scale. The result is a neat perfect line: *A* covaries almost perfectly with $1/f^n$. Neuroscientist György Buzsáki elaborates on why we should think this an important correlation:

[T]he inverse relationship between frequency and its power is an indication that there is a temporal relationship between frequencies: perturbations of slow frequencies cause a cascade of energy dissipation at all frequency scales. *One may speculate that these interference dynamics are the essence of the global temporal organization of the cortex.* (Buzsáki, 2006: 119; emphasis mine)

"Thus", he claims a few pages later, "it should not come as a surprise that power (loudness) fluctuations of brain-generated and perceived sounds, like music and

¹⁴ This geometric character is particularly evident, for instance, in Kayne's (1981) discussion of 'unambiguous paths' in the binding of anaphora.

speech, and numerous other time-related behaviors exhibit 1/f power spectra" (Buzsáki, 2006: 123).¹⁵

There has been good confirmation of the hypothesis that cortical entrainment of theta band oscillation responds to linguistically relevant syllabic units, with phase patterns observed to discriminate between actual and nonactual human natural language sentences (Ding et al., 2015). Poeppel's lab has extended this significance to the phrasal level via precisely the mechanisms of rhythmic entrainment just described (Figure 9), showing that cortical responses closely track the temporal envelopes of phrase-level syntactic objects (Ding *et al.*, 2015: 4). The interaction of different frequencies at varying spatio-temporal scales depicted in the figure allows for hierarchical structure in signal processing.



Figure 9: Cortical entrainment of temporal envelopes. The table on the left depicts ten distinct oscillating frequencies in the mammalian brain (Buzsáki, 2006: 114). Top right is an illustration of low frequency delta waves overlaid by higher frequency theta and beta waves. The interaction of these different frequencies at varying spatio-temporal scales allows for hierarchical structure in signal processing (bottom right).

What this suggests is that one *sui generis* property of human syntax—its capacity for hierarchical embedding—is a consequence of the power law holding between different rates of cortical oscillation.

These findings have recently been developed into concrete proposals for the recent evolutionary history of human syntactic cognition by Murphy (2015, 2016a, 2016b) and Ramírez (2015) which provide a plausible explanation for several syntactic phenomena (Murphy, 2015). Murphy (2016a) describes how the coupling of higher frequency gamma and lower frequency theta waves could provide a kind of "binding memory" that preserves the complex wholes of phrases.

¹⁵ This gradient has been known since the mid-nineteenth century. For instance, Weber's Law—named for Ernst Weber (*fl.* 1830-40)—noted the basic configuration in the exponential ratio of 'just noticeable' perceptual characters to the strength of stimulus. Well-noted examples include the phenomenological experience of heaviness compared to an object's actual weight, and the perceived versus actual change in illumination of a light source.



Figure 10: An 'oscillatory tree' demonstrating the alignment of syntactic-level phrases with oscillatory frequencies (Murphy, 2016a).

An interesting corollary of this schema is that it may explain *XX (Boeckx, 2013) and *{t,t} (Narita, 2015; in Murphy, 2015: 13), violations in which elements of the same category (e.g., NP, VP, CP) cannot occur adjacently.

- (12) * John_{NP} Mary_{NP} at eapples.
- (13) * [which picture of the wall]_{*i*} do you think that [the cause of the riot]_{*j*} was $\{t_i, t_j\}$?

These patterns may occur, Murphy contends, because only a single binding from the high frequency gamma wave can be sustained at one time, adding further explanatory weight to the oscillatory framework.

6.4. Efficiency and Energy-Minimisation

What, though, could possibly justify the assumption of efficiency in linguistic computation, as required by Shortest Move? Moreover, even if such a rationale exists, why make the assumption that it is the case for language? An oft-discussed case of actual 'in-the-world' efficiency is that of Cherniak's neural optimisation research. A good place to start is the irregularities which prompt Cherniak's interest. There are two: First, the quantity and internal angle of neuron 'arbors'the branchings of dendritic cells (see Figure 11)—display a pattern characteristic of a diverse many natural systems-rivers, crystals, trees (actual ones, bark, leaves, etc.), inter alia. Second, neural components of numerous scale are organised so as to minimise the length of 'wire' (neural connective tissue) required for their interconnection. Each of these discoveries exhibits an unusual degree of optimisation, where optimisation is intended to denote a measure of efficiency rather than functionality. The first yields a 'local' form of optimisation, in that arbors are optimal with respect to properties of individual cells. The second is a 'global' form of optimisation which pertains to the whole network under consideration.

The two distinct kinds of optimisation have different relevance. With respect to local optimisation, our primary interest is in the mechanism of optimisation. The optimality in question in represented in Figure 11.



Figure 11: Steiner tree problem and branching neural axon. See text for description. Bottom adapted from (Cherniak et al., 1999: 6003).

Above are an unsolved (top left) and a solved (top right) 'Steiner tree'—a method of calculating the minimum distance (line length) required to connect a distribution of points. This pattern is evidenced in a number of natural domains in addition to neurons—blood vessels, lung bronchi, plant roots, coral formations, antlers, rivers junctions, geological cracks, and lightening discharge patterns (Cherniak, 1992: 504). Below is an illustration of an actual dendritic arbor. The value of each internal angle θ_i and the number of branching axons b_n is observed to be close to the optimal predicted by an appropriate Steiner tree.¹⁶ This, and the aforementioned examples, are all likely to be products of a simple 'tug of war' energy-minimization mechanism, similar to the formation of soap bubbles and snowflakes. In all these instances, competing pressures (opponents in the tug of war) fall into an equilibrium state with minimally expensive arc angles and quantity. The significance of this mechanism is its easy congruence with the notion of self-organisation given above; efficiency and self-organisation are strange but happy bedfellows.

A second notion of optimality makes plain the relation to spontaneous order. The basic idea is similar the first, but now the metric of interest is *component placement*: We can predict with surprising accuracy the organisation of (1) the brain relative to the body, (2) the functional regions of the brain relative to one another, and (3) the internal structure of functional components like nerve ganglia. This remarkably general coverage can be achieved by invoking a single, simple rule:

¹⁶ In fact, it is not close unless it is assumed—plausibly—that the task is to conserve the *volume* of connective tissue rather than length, and that the diameter of branches is less than that of trunks. Branches will consequently have a lower 'cost' per unit of length compared with trunks.

The adjacency rule: If two components *a* and *b* are connected, then *a* and *b* are adjacent.

"The rule is a powerful predictor of the anatomy", he claims, "a kind of 'plate tectonics of the cortex'" (Cherniak, 1994a: 98). It predicts, for instance, that (a) and not (b) in Figure 12 will be the observed layout of three components. The most intuitive demonstration of the rule is the morphologically ubiquitous location of the brain in the head, a fact Cherniak claims extends naturally from the surfeit of sensorimotor connections in the morphospace's anterior instead of its posterior.¹⁷



Figure 12: Representation of a component placement problem. (a) requires greater wire-length than (b), where component placement is optimal with respect to the adjacency rule (Cherniak, 1994a: 96).

Cherniak (1994a: 101) claims that "[a]n Occam's Razor of the nervous system, the simple *logos* 'Save wire' invokes a significant portion of the vast neurowiring diagram". It is fair to say, then, that this is no coincidence. Despite the extraordinary productiveness of the 'save wire' principle, neither Cherniak nor anyone else has a precise grip on what the perfect optimisation of component placement would be. This lack of understanding is not for lack of a conceptual appreciation of the task, but because of its intrinsic computational complexity: Searches for optimal paths are prototypically NP-complete. This familiar refrain throws new light on the problem of component placement:

To convey a sense of the computational intractability of exhaustive search for exact solution... it can be noted that the number of possible layouts of *n* components on *n* discrete positions (whether they form a one, two, or three-dimensional array) is *n*! For merely the layout problem of the 50 main areas of the human cerebral cortex, there are $50! = 3.04 \times 10^{64}$ alternative placement possibilities. The number of attoseconds (10^{-18} sec) in the 20 billion year history of the universe is 10^{35} . Hence, if natural selection could test one layout per attosecond, all the time since dawn of the Universe, much less since emergence of life on Earth, would not suffice for this exhaustive search.

(Cherniak, 1994b: 2426)

¹⁷ We may wonder just how unusual the degree of observed optimisation is and consequently whether it could have been a product of mere chance. With respect to the global measure of optimisation, Cherniak estimates the null hypothesis of random component placement is improbable to a degree of certainty greater than p = 0.0001.

The optimality of component placement is the inverse of the '747 in a hurricane' dilemma: We are forced by necessity into the assumption that nature has employed a means of spontaneous order.

6.5. Summary

These conclusions are, inevitably, speculative; inevitably because the very idea of evolutionary plausibility pushes at the boundaries of contemporary enquiry. Yet, it is uncontroversial in most scientific domains that parsimony is one of the desiderata which can be used to determine which is preferable of two or more competing theories at a given level of organisation. The Principle of the Common Cause is sufficient to warrant the inference of parsimony with respect to the number of causes responsible for language design. A distinct motivation, but one no less important, is that the brittleness of a theory-its paucity of parameters for potential error-motivates a unification-based approach. These conceptions of 'Rational' optimism apply not to a theory of causes implicated in the design of syntax, but, rather, to the theory of syntax which is the target of that explanation. Physical Optimism follows naturally from the characterisation of language as self-organising, and goes part of the way towards explaining how an independently motivated efficiency condition may be realised in physical media which we suspect is self-organising. The presumption of Physical Optimism also solves Darwin's Problem by providing a plausible scenario in which spontaneous emergence of order can overcome underdetermination.

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Architecture of Human Language from the Perspective of a Case of Childhood Aphasia — Landau-Kleffner Syndrome

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This paper addresses Landau-Kleffner syndrome (LKS), a childhood aphasia, from the perspective of I-language and the critical period for first language acquisition. LKS involves a language disorder and behavioral disturbances resembling autistic spectrum disorders due to electroencephalographic abnormalities with continuous spike-and-waves during sleep over the temporal regions. Comparing LKS with other childhood syndromes, the architecture of language is explored through elucidating the linguistic mechanisms behind the language disorder in LKS on the basis of Hickok & Poeppel's (2007) dual-stream model of speech processing. It is claimed that early onset LKS provides further support for the critical period for first language acquisition and modularity of mind (the faculty of language), and that verbal auditory input during the critical period is most crucial for language recovery and development in LKS. Considering that electroencephalographic abnormalities affect cognitive/motor functions, ameliorating neural dysfunction in the affected brain areas with proper application of transcranial direct current stimulation is recommended.

Keywords: critical period; dual-stream model of speech processing; electroencephalographic (EEG) abnormalities; Landau-Kleffner syndrome (LKS); transcranial direct current stimulation (tDCS)

1. Introduction

Landau-Kleffner syndrome (LKS) is a clinically rare language disorder of acquired childhood aphasia involving epilepsy (with or without clinical seizures) that emerges with epileptiform electroencephalographic (EEG) abnormalities over the

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temporal lobes.¹ The child with LKS first undergoes a period of normal development of language, but usually after the onset of the disorder, the 'language attained' starts regressing.² In LKS, typically, both language comprehension and language production acutely or insidiously become virtually impossible, often leading to apparent deafness and mutism in children suffering from it (for more details, see e.g. Gordon 1990; Tharpe & Olson 1994; Kaga 1999, 2011; Pearl et al. 2001). Moreover, the EEG abnormalities cause behavioral and psychiatric disturbances such as hyperactivity, aggressive behavior, impulsivity, and attentional problems, which resemble autism spectrum disorders (Stefanatos 2011; Mikati et al. 2010; see also section 2.1.3).

Ever since Landau & Kleffner's (1957) first report of the syndrome, over 200 cases (Stefanatos 2011) have been reported in the literature (see also Ansink et al. 1989; Tharpe & Olson 1994, and references therein). Specifically, 81 cases were reported between 1957 and 1980, and 117 cases between 1981 and 1991 (Makati et al. 2010). This implies the disorder is rare; but it has become the most frequently described form of acquired aphasia in children (Stefanatos 2011) and many more cases than reported should definitely exist (Mikati et al. 2010). Since LKS is often mistaken for psychiatric or developmental language disorders (Campos & De Guevara 2007), the frequency of the clinical condition is underestimated (Stefanatos at el. 2002).

LKS has been extensively investigated in fields of medicine such as child neurology, and various accompanying symptoms of LKS including the electrophysiological states in patients with LKS have been identified (for reviews, see e.g. Pearl et al. 2001; Stefanatos 2011; Stefanatos & DeMarco 2011). On the other hand, little attention has been paid to LKS in contrast to other language disorders in the field of biolinguistics (see Benítez-Burraco 2013, who briefly mentions this clinical case under the category of 'specific language impairments').³ There seem to be two main reasons for this state of affairs.

¹ Throughout the discussion, we will use 'childhood aphasia' as a cover term to describe the state of aphasia in children in general. In the literature, the term 'acquired childhood aphasia' is sometimes employed to refer to cases where children sustained language deficits due to some lesions (localized or diffuse) in language areas after they acquired the core of their first language (Van Hout 1997). Thus, in acquired childhood aphasia, there are clear postnatal organic lesions involved in the brain. Generally, children with acquired childhood aphasia have intelligence of normal development except for the language domain. On the other hand, there are cases in which there is no organic lesion that was incurred in the brain, but children suffer from loss of the use of their first language in the process of first language acquisition or after the core of their first language was acquired, presumably due to some congenital brain malfunctioning. This latter type corresponds to what Tuchman (1997) calls 'acquired epileptiform aphasia', as some kind of epileptiform brain activity is typically implicated here. Although the former type of childhood aphasia is quite similar to aphasia in adults (Van Hout 1997), the latter type of childhood aphasia is peculiar to children and LKS is an exemplar (Landau & Kleffner 1957). In what follows, when we refer to acquired childhood aphasia, we will use the term 'ordinary child aphasia' for the sake of simplicity.

² See Gordon (1997 and references therein) for opposing case reports in which three quarters of LKS patients exhibit language disturbances before the onset of the syndrome. Stefanatos (2011) also points out that LKS can occur with pre-existing language problems as well.

³ See Tsimpli et al. (in press) for detailed systematic discussion on language pathology, which deals with representative language-related pathological conditions other than LKS in the framework of Universal Grammar (UG). See also Benítez-Burraco (2016) for a biolinguistic approach to representative language disorders other than LKS in clinical linguistics.

First of all, LKS itself is a relatively rare clinical syndrome among children (Office of Rare Diseases 2008, cited in Stefanatos 2011). Second, if LKS happens to children, there are many cases where it comes after the onset of the critical period (Lenneberg 1967), with initially normal first language acquisition, followed by the syndrome of childhood aphasia, and then possibly later disappearance of the symptom within the critical period. This corresponds to the case of 'ordinary LKS' (see also fn. 5 and section 2.3). Thus, the state of childhood aphasia looks just temporary and so does not seem to matter much (but see the discussion in section 3.3 about the relevance of ordinary LKS to the concepts of modularity of mind and modularity of the faculty of language).

The primary aim of this paper is, therefore, to bring more attention of the biolinguistic community to this childhood aphasia by investigating it particulary from the perspective of I-language and the critical period hypothesis (Lenneberg 1967).⁴ We will focus on what we call 'early LKS'—a sub-type of LKS in which language regression can start as early as at around the age of 18 months before the solid establishment of the core of the first language.⁵ Differentiating early LKS from autism spectrum disorders (ASD), particularly autistic regression (AR), is especially significant because it would contribute to avoiding misdiagnosing of patients with LKS as having such developmental disorders as ASD/AR.

Furthermore, early LKS proves to be a quite interesting case in considering the nature of human language, if children with early LKS eventually (re)-start producing their first language while comprehending it at the same time with surprising speed and grammaticality, because the period of childhood aphasia lasts relatively for a long time until recovery, if any. We will submit that the notion of early LKS plays a pivotal role in elucidating the architecture of human language (and cognition) in connection with modularity of mind, modularity of the faculty of language, and a certain version of the critical period hypothesis for first language acquisition (see the discussion in section 3).

This paper is organized as follows. Section 2 attempts to lay out the fundamental characteristics of LKS, while comparing it with other syndromes such as ordinary child aphasia and ASD, especially AR, as well as the age-specific epileptic syndrome called 'benign childhood epilepsy with centrotemporal spikes' and 'continuous spike-and-waves during sleep'. Section 3 addresses some biolinguistic considerations concerning the critical period hypo-thesis for first language acquisition and modularity of the faculty of language as well as modularity of mind, while elucidating the linguistic mechanisms behind verbal auditory agnosia and loss of expressive speech in LKS. Section 4 discusses some implications for biolinguistic research, medical intervention, treatment, and research, and developmental and educational therapy for children with LKS. Section 5

⁴ I-language is an abbreviation, where 'I-' stands for individual/internal/intensional, as originally proposed in Chomsky (1986). On this conception, human language is regarded as a brain-internal biological system. We will assume that this conception of human language is fundamentally correct throughout this paper.

⁵ Given that a child will acquire the core linguistic competence by around 3 years of age (Pinker 1994; O'Grady 2005) and that the beginning age of the peak incidence of LKS is also 3 years of age (see section 2.1.1 for more), as a first approximation, we will define *early LKS* as LKS with its onset before 3 years of age. Just for expository purposes, we will refer to the remaining cases of LKS as 'ordinary LKS' in what follows (see section 2.3 for discussion).

concludes this paper. In a modest attempt in this direction, we will address issues related to the architecture of human language in connection with LKS, while pointing out the significance of studying LKS for the purpose of investigating the biological nature of human language. This in turn could lead to shedding new light on the nature of LKS, and, hopefully, to discovering its cure eventually.

2. Landau-Kleffner Syndrome (LKS)

LKS is a label for the observed symptomatology of a kind of childhood aphasia acquired in the course of development (= ontogeny), presumably caused by more than one etiology with various degrees of deficits and recovery (see e.g. Mikati et al. 2010; Stefanatos 2011; Stefanatos & DeMarco 2011). In addition to an acquired aphasia, LKS has two other main symptoms: EEG abnormalities with continuous spike-and-waves during sleep often accompanied by epileptic seizures, and certain particular behavioral disturbances. We will first explain the cardinal characteristics of this childhood language disorder in light of medical/clinical, linguistic, and behavioral profiles, and later compare LKS with other clinical cases for the sake of more precise understanding of the childhood language disorder to lay out the background for discussion in section 3.

2.1. Fundamental Characteristics of LKS

2.1.1. Medical/Clinical Profile

Although the exact etiology (or etiologies) of LKS still remain unknown, rather diverse and relatively common clinical cases such as encephalitis, hemophilus influenza, and meningitis have been reported as possible causes in the literature (Mikati et al. 2010; see also Pearl et al. 2001 for a review).⁶ Both males and females are equally affected by LKS, with the male to female ratio of approximately 2 to 1. Although LKS-affected children with the onset of the disorder from 3 to 8 years old account for 80% of this clinical syndrome (Kaga 2000), its onset ranges from 18 months to 13 years, with its peak incidence between 3 and 7 years (Tharpe & Olson 1994; Temple 1997; Uldall et al. 2000).⁷ According to Stefanatos (2011), the recent deviation of the onset is usually between 2 and 7 years of age, ranging from 18 months to 14 years.

Unlike ordinary child or adult aphasia, no consistent organic brain lesion site has been found in children with LKS so far (Gordon 1990; Deonna 1991). Computed tomography and magnetic resonance imaging findings on patients with LKS are normal, while single photon emission computed tomography and positron emission tomography studies show temporal lobe abnormalities in brain

⁶ Other clinical cases reported in the literature as possible causes of LKS are the following: abnormal zinc metabolism, toxoplasmosis, neurocysticercosis, temporal astrocytoma, temporal ganglioglioma, subacute sclerosing panencephalitis, inflammatory demyelinating disease, a genetic predisposition, and mitochondrial respiratory chain-complex I deficiency (see e.g. Pearl et al. 2001; Kang et al. 2006, and references therein).

⁷ See Uldall et al. (2000) for a case report of LKS with onset at 18 months. Onset as early as 18–22 months and as late as 13–14 years has also been reported (see Stefanatos 2011 and references therein).

perfusion and glucose metabolism—decreased perfusion and hypometabolism, respectively (DaSilva et al. 1997; Pearl et al. 2001, and references therein).⁸

A particularly significant fact is that patients with LKS suffer from abnormal epileptiform electrical activity in the brain occurring particularly during sleep (Patry et al. 1971), which is related to the existence of paroxysmal EEG abnormalities and acquired aphasia in the LKS-affected patients (Pearl et al. 2001 and references therein; see also Stefanatos 2011). Epilepsy is a disorder of electrical activity in the brain consisting of the sudden temporary abnormal hypersynchronous firing of a group of brain cells (neurons) (Deonna 2000).⁹ Specifically, the epileptiform EEG abnormalities in LKS are caused by continuous spike-andwaves during sleep or electrical status epilepticus during sleep, during over 85% of the slow sleep period (Gordon 1997 and references therein) over the temporal (and/or parietal) regions (Deonna 1991), and in some studies with magnetoencephalography, the source of the epileptiform activity is more precisely located in the superior temporal gyri and sylvian fissure (Morrell & Lewine 1994; Paetau 1994; Morrell et al. 1995). EEG abnormality findings are the most striking during sleep, but awake EEGs obtained in the early stages of LKS may show isolated or unilateral perisylvian spike discharges, while sleep EEGs show extremely frequent or even constant bilateral electrocerebral seizure activity despite the absence of clinical seizures (Mantovani 2000). Moreover, EEG abnormalities are commonly recorded with the presence of bilateral discharges (Stefanatos 2011), which hinders 'plasticity' of the brain before lateralization and consequently leads to cognitive and behavioral disturbances as well as language deterioration (see also section 2.3 for more discussion).

As for seizures, 70% of LKS patients with the EEG abnormalities result in either clinical or sub-clinical epileptic seizures (Mikati et al. 2010). According to Stefanatos (2011), however, the presence of clinical seizures is not a necessary feature of LKS. Moreover, the clinical seizures are generally infrequent and LKS-related epilepsy can be easily controlled by a single anti-epileptic medication: benzodiazepines such as clobazam (Pearl et al. 2001), valproate, and ethosuxi-mide (Mikati et al. 2010).¹⁰ Since it is well-known that temporal lobe epilepsy is a kind of refractory epilepsy and is generally hard to control by a single anti-epileptic medication (see e.g. Helmstaedter et al. 2003 and references therein),

At least some LKS patients are known to involve metabolic abnormalities, or hypometabolism in the brain (see DaSilva et al. 1997 and references therein), presumably due to malfunctioning of the relevant neuronal circuitry. If Kang et al. (2006) are correct in assuming that some sub-cases of LKS are related to mitochondrial respiratory chain-complex I deficiency, the relevant LKS-affected children would be likely to have metabolic problems and weight problems such as obesity. Taking vitamin substance such as L-carnitine, which helps fat turn into energy in mitchondria and facilitates energy metabolism in neurons (Kang et al. 2006), could be one solution.

⁹ See Jefferys (2010) for a detailed review of the history of our current understanding of the basic mechanisms of epilepsy and seizures, and Treiman (2001) for a concise explication of GABAergic mechanisms in epilepsy in particular. See also Buzsáki (2006) for detailed discussion on various issues on rhythms/oscillations of the brain.

¹⁰ The other pharmacological protocols include corticosteroids, adrenocorticotropic hormones, and intravenous immunoglobulin. Multiple subpial transection as a surgical treatment (Morrell et al. 1995) has also been administered for a subgroup of LKS patients (see Stefanatos 2011; Stefanatos & DeMarco 2011, and references therein).

this pharmacological characteristic could be one of the important clinical markers in making a correct diagnosis of LKS.

Furthermore, seizures in LKS characteristically cease by the beginning of adolescence (Honbolygó et al. 2005), while seizures in other clinical conditions do not necessarily have this property. Moreover, not only the seizures but also EEG abnormalities in LKS tend to disappear between the ages of 8 and 13 years (mean of 10 years) (Massa et al. 2000; Ramanathan et al. 2012), which can be another clinical marker for LKS.

As a consequence of the epileptiform activity over the temporal lobes, language regression, or an acquired aphasia with verbal auditory agnosia and loss of expressive speech, occur. Mikati et al. (2010: 259) explain that the International League Against Epilepsy defines LKS as "childhood disorder in which an acquired aphasia, multifocal spikes and spike and wave discharges are associated". Deonna (2000) also explains that epileptic activity in one or, more often, both cortical auditory areas in the temporal lobes results in an acquired auditory agnosia, or a failure of the brain to decode sounds. Thus, children with LKS are ultimately suspected to have hearing impairment (Mikati et al. 2010).

Originally, Landau & Kleffner (1957: 529) suggested that "persistent convulsive discharge in brain tissue largely concerned with linguistic communication results in the functional ablation of these areas for normal linguistic behavior" (see also Paquier et al. 1992). Recently, Stefanatos (2011: 964) has also expressed the view that "the aphasia is thought to result from a more protracted functional disruption of the neural substrate necessary for normal language caused by the persistent epileptiform discharges evident on the EEG". In this connection, it is to be noted that, as Mikati et al. (2010) report, improvement in EEG is associated with language restoration in LKS.

With regard to the prognosis of language regression in LKS, approximately 50% of patients recover fully while the remaining 50% recover partially or suffer from permanent aphasia/dysphasia (Mikati et al. 2010). This remarkable prognosis compared with other cases such as ASD/AR in terms of language restoration could stem from the fact that the EEG abnormalities, which affect language and other cognitive functions of LKS patients, tend to cease by puberty. Less favorable data show, however, that approximately two-thirds of LKS patients will remain with some persistent language disability and half are severely affected to the extent that they will never regain expressive language, while about one-third can recover from the language disorder (Msall et al. 1986; Paetau et al. 1991, and references therein). Even so, the feature of higher possibilities of perfect or partial language restoration of LKS patients has attracted attention from researchers in the field of medicine, neuropsychology, and child development.

2.1.2. Linguistic Profile¹¹

LKS-affected children have language regression in both receptive and expressive linguistic abilities to varying degrees. Now, a question of vital importance is

¹¹ See Stefanatos & DeMarco (2011) for more detailed linguistic and other cognitive characteristics of a child with LKS based on a variety of neuropsychological evaluation results.

which stage(s) of language processing is/are affected in LKS. Given that approximately half of patients with LKS fully recover from the state of aphasia, it is unlikely that the core central system of language is impaired fatally. It is more likely that the more 'peripheral' system(s) of language could be affected in LKS. In the following, we will discuss what constitutes verbal auditory agnosia in detail and how it causes speech impairment of LKS patients.

Regarding the auditory dimension of LKS, as already mentioned in the last section, children with LKS often appear to have a hearing loss because of their reduced response to speech and even to environmental sounds (McAllister & Greathead 1991). Thus, the first symptom of the receptive language disorder in LKS is an apparent 'word deafness', or verbal auditory agnosia. This auditory agnosia can extend to familiar environmental noises such as ringing bells and phones. As Hurley & Hurley (2009) point out, because children with LKS fail to respond to linguistic and even environmental sounds, quite often, they will be judged to have been suffering from a hearing loss or may be misdiagnosed as having autism or other developmental disorders (see also Tharpe et al. 1991). The degree of the verbal auditory agnosia in LKS can deteriorate from a remaining ability to follow simple verbal commands into a total inability to comprehend any verbal input and total unresponsiveness (Tharpe & Olson 1994 and references therein). As Deonna (2000) remarks, prolonged disruption of the activity of auditory cortex during the critical period of language development can permanently impair some components of auditory function.

Nevertheless, pure-tone audiograms and brainstem auditory evoked responses are normal in children with LKS (see Denes et al. 1986; Paquier & van Dongen 1993; Pearl et al. 2001, and references therein). Furthermore, dichotic listening tasks show one-ear extinction contralateral to the affected temporal cortex due to the epileptic focus during the active phase of LKS, and long-latency auditory evoked potential testing with children having recovered from LKS demonstrates that LKS affects the associative auditory cortex in the temporal lobe (indicated by unilateral voltage reduction involving the N1c peak), while the primary auditory cortex in the temporal lobe remains intact (indicated by the normal N1b peak) (see Wioland et al. 2001 and references therein). Taken together, these facts seem to indicate that, although sequences of sounds reach the primary auditory cortex, they will not be further processed properly in the associative auditory cortex due to the long-term epilepsy-induced dysfunction of those language-related areas in LKS (see Rapin et al. 1977; Matas et al. 2008, and references therein).

Initially, the problematic level of verbal processing in LKS was thought to be the level for decoding of phonemes (Korkman et al. 1998), hence a problem of phonological processes. However, as Deonna (2000) suggests, given the fact that the acute phase of LKS can affect some children in such a way that they can recognize neither linguistic sounds nor non-linguistic environmental sounds (e.g., door bell and phone ringing), it seems that LKS will affect (a) much earlier stage(s) of auditory processing than phonological processing of linguistic input. Deonna (2000) also points out that linguistic sounds are much more complicated acoustically than environmental sounds, which explains why all children with LKS suffer from verbal auditory agnosia, while only sub-groups have difficulties
in recognizing environmental sounds. If this applies to LKS in general, and given the fact that LKS affects articulation at the same time, it seems quite natural to assume that the LKS-affected part for language comprehension is concerned with processes involved with auditory-articulatory phonetics rather than phonology proper. In fact, Vance et al. (1999: 546) note that "a deficit at one level may have consequences for processing at other levels". Thus, if spectrotemporal/auditory analysis of acoustical features of speech sounds is disturbed, the expected correct phonetic analysis of them could not be associated with corresponding phonological units, say, phonemes, which is crucially necessary for speech perception and comprehension. This view is compatible with our proposal that I-language, including phonology (cf. Berent 2013 on I-phonology), remains virtually intact in LKS (see section 3).

There are good reasons to believe that this is indeed the case. Plaza et al. (2001) report the case of a child with LKS with verbal short-term memory impairment and dissociation between efficient phonological ability and verbal auditory deficits. The patient dramatically recovered language and acquired the ability for reading and spelling. They conclude that the patient developed phonological ability from predominantly visual input and that the apparent verbal short-term memory impairment is due to deficits at the level of cortical auditory processing rather than at the level of phonological processing.

In addition, Boyd et al. (1996) examined a child with LKS during a multiple subpial transection operation to the left temporal lobe, by recording intraoperative event-related potentials with respect to the discrimination of phonemes (/ba/ vs. /ga/) in the course of electrocorticography. They found that the child maintains discrimination of phonemes despite the apparent global aphasia. At first blush, this observation seems to be at variance with our scenario about the deficit level in LKS, but it should be noted that the event-related potentials recording for the left temporal lobe in the patient in Boyd et al. (1996) was carried out by inserting an earphone into his right ear under an anesthetized condition. It seems plausible that, without any distraction due to anesthesia and with direct insertion of an earphone into his right ear, the acoustic signals might be more clearly and easily perceived and analyzed spectrotemporally than otherwise. Hence, the observed syllable discrimination between /ba/ and /ga/ based on the more or less successful phonetic analysis seems to be quite expected. If this were to hold, we can still maintain our scenario here.

Although Denes et al. (1986) use the terms such as 'phonemes', 'phonemic discrimination/identification', and 'phonological representations', it seems that malfunctioning of the phonetic system for analysis of acoustic signals rather than the phonological one is what is responsible for what they describe as 'childhood phonemic deafness'. In fact, they even use the term 'the phonetic level' when they explain about their patient's inability to discriminate or identify 'phonemes'. Interestingly, Denes et al. (1986) observe that, although brainstem auditory evoked responses and primary cortical auditory responses are normal, their patient with LKS exhibit an asymmetry with respect to discrimination/identification of segments: While the patient can easily discriminate/identify vowels in linguistic stimuli, he cannot discriminate/identify consonants in them. They claim that this asymmetry can receive a natural explanation in terms of the physi-

cal characteristics of the difference between vowels and consonants, by saying that "while natural vowels usually average 100 to 150 msec, consonants are characterized by rapid frequent changes within the first 40 msec of onset of the stimulus" (p. 264). If this is the case, it would provide a strong reason to believe that what is at stake in the language disorder in LKS is malfunctioning of spectro-temporal analysis of acoustic signals at the phonetic level.

Given that proper phonetic analysis of acoustic signals is a prerequisite for forming proper links with abstract phonological representations corresponding to the acoustic signals, our scenario here is compatible not only with Denes et al. (1986) but also Vance et al. (1999), who argue, on the basis of auditory processing tasks, that phonological representations are highly likely to be inaccurate or insufficiently specified in children with LKS, suggesting that "ongoing auditory processing difficulties, from the onset of LKS, will have inhibited the development of accurate and well-specified phonological representations" (p. 551).

Next, let us turn to the question of language production. If the processes for auditory phonetics are impaired in LKS, it is natural to assume that the processes for articulatory phonetics are also affected because articulation of speech sounds must be carried out via pairing of motor movements and phonetic specifications of each speech sound (see section 3 for details on the mechanism behind language production). With regard to supra-segmental aspects of speech in LKSaffected children, Matas et al. (2008) report a case of a LKS-affected patient with severe receptive and expressive language impairment. The patient "produced gestures and unintelligible verbal utterances, which were key words with intense phonetic-phonological alterations, and surprisingly preservation of the melodic contour, accent and rhythm of his native region" (p. 68). This kind of preservation of prosodic aspects of language shows that LKS does not affect the brain areas related to prosody (see also Landau & Kleffner 1957 for a case in point), as supported by the fact that "traces of improved right hemisphere integrity can be observed" in the patient on the basis of the middle latency response (MLR) and the cognitive potential (P300) (Matas et al. 2008: 69).

With respect to the semantic system, as Matas et al. (2008) point out, although the lack of full expressive language prevents us from analyzing the integrity of the semantic system in a sophisticated fashion, appropriate reactions to situations with visual input such as gestures and objects suggest the preservation of the semantic system (but see also the discussion on the effect of LKS in the thought system in section 3.3). Interestingly enough, the patient with LKS in Denes et al. (1986) maintains the abilities on lexical semantics, which is revealed through reading and writing tasks.

Finally, as for the syntactic system, we would like to suggest that LKS will not eradicate the potentiality of at least the core syntactic mechanism for building up hierarchically structured expressions. Recall that of all LKS-affected patients, approximately 50% recover fully while the remaining 50% recover partially or suffer from permanent aphasia/dysphasia (Mikati et al. 2010). Given this fact, the null hypothesis seems to be that the core syntax is not damaged in LKS but the degrees of manifestation of expressive language depend upon the degrees of availability of lexical items in the mental lexicon and/or proper functioning of the externalization system in the patients with LKS.

2.1.3. Behavioral Profile

Aside from the linguistic characteristics mentioned in the previous section, children with LKS will present associated behavioral disturbances as co-morbidity (see e.g. Landau & Kleffner 1957; Rapin 1995; Tuchman 1997; Pearl et al. 2001; Tharpe et al. 1991), as enumerated in (1):

- (1) *Co-morbidity in LKS:*
 - a. hyperkinesis (= hyperactivity)
 - b. attention deficit
 - c. rage outbursts (= tantrums)
 - d. aggressiveness
 - e. autistic-like behaviors such as stereotypies (= persistent repetition of an act)
 - f. apparently poor 'social communication' skills
 - g. withdrawal
 - h. clumsiness of fine hand/finger movement (e.g., messy eating)

Such behavioral problems as in (1a-h) are, however, (at least partly) related to the existence of epilepsy (clinical or sub-clinical) in children with LKS (on this point, see Gordon 1990; Deonna 1991; Tharpe et al. 1991; Tuchman 1997). Deonna & Roulet-Perez (2010) actually refer to the possibility, though they do not ascertain, that the 'autistic' behavior is a reaction to the severe receptive language deficit, or an additional developmental comorbidity or the result of an epileptic activity involving not only language but also 'social brain' circuits.

In fact, Stefanatos (2011: 964) notes that LKS has come to be recognized as belonging to the so-called "epileptic encephalopathies, in which a deterioration of cognitive, sensory, and/or motor functions results from epileptic activity" (Nabbout & Dulac 2003) and that epileptiform discharges may have deleterious effects on psychological development in some developmental disorders such as ASD (Ballaban-Gil & Tuchman 2000). Stefanatos (2011: 976) also states that "epileptiform abnormalities are often bilaterally synchronous and have disruptive influences on the function of perisylvian cortex in both hemispheres, even if effects are often asymmetric" (see also the remark by O'Hare 2008 in section 2.3 below). He further states that "functional disruption of language cortex in perisylvian regions of temporal lobes might also impede nonlinguistic functions localized in the same areas" (p. 976). Thus, given that children with LKS suffer from expressive language disorder, it can be easily imagined that some motor-related regions of the brain that are relevant to both fine hand/finger movement and articulation/externalization of I-language are affected by LKS. Hence, (1h) can be regarded as resulting from fine motor/praxic difficulties. In fact, it has been suggested in the literature that the opercular syndrome of oromotor dysfunction involving EEG abnormalities is related with LKS (Shafrir & Prensky 1995; Tachikawa et al. 2001; Desal et al. 2013).

As such, it is further expected that all the behavioral problems in (1a–h) would be alleviated or cease to exist along with the disappearance of LKS-related epilepsy/epileptiform EEG abnormalities by adulthood (for discussion of a case report that seems to suggest this possibility, see Ansink et al. 1989).

To sum up, 'autistic' behavioral disturbances such as (1a–h) observed in LKS could take over the clinical manifestation (Campos & de Guevara 2007: 94) and result in key diagnostic dilemmas in clinical practice (Stefanatos 2011). More specifically, early onset of LKS before the solid establishment of the first language, accompanied by various behavioral disturbances as in (1a–h), causes difficulties with clinical diagnosis (Uldall et al. 2000), leading to failure in correctly differentiating patients with LKS especially from those with ASD/AR. In the next section, we will compare LKS with other clinical cases of interest and differentiate the former from the latter.¹²

2.2. Comparison between LKS and Other Clinical Cases

First, we will discuss LKS and ordinary child aphasia in terms of presence or absence of brain lesions. Then, we will compare LKS with *benign childhood epilepsy with centrotemporal splikes* (BECTS) and *continuous spike-wave during sleep* (CSWS) for better understanding of LKS from the perspectives of EEG patterns and other characteristics. Finally, we will highlight crucial differences between (early) LKS and ASD, or more specifically AR, which is extremely important in not only capturing the true nature of (early) LKS but also reducing clinical confusion between the two due to some apparently overlapping features (see e.g. Campos & de Guevara 2007; Penn et al. 1990; Stefanatos 2011; Uldall et al. 2000).¹³

2.2.1. Comparison of LKS and Ordinary Child Aphasia from the Perspective of Brain Lesions

In discussing the particular properties of LKS, it is useful to compare it with ordinary child aphasia. Relevant differences between the two can be summarized as follows (see Pearl et al. 2001 and references therein for more details):

¹² Tuchman (1997) discusses not only LKS but also what he calls 'disintegrative epileptiform regression' and 'autistic epileptiform regression'. As Rapin (1995) points out, whether or not disintegrative epileptiform regression really constitutes a distinct separate entity from autistic epileptiform regression remains to be seen, so we will not address the dichotomy in question in this paper.

¹³ See Rice (2016) for illuminating comparison among specific language impairment (SLI), ASD, attention-deficit/hyperactivity disorder (ADHD), and other conditions. In our comparison, we will not address the clinical condition of SLI because it is typically independent of epilepsy (Ooi 2011:125) and thus in principle readily differentiated from LKS. See Billard et al. (2009) for some discussion on SLI versus LKS. Furthermore, the contrast between LKS and ADHD is relatively clear. Though children with ADHD do not have any particular problems in non-verbal intelligence (Sumi 2015), in interpersonal social communication and pragmatic knowledge including theory of mind (Temple 1997), they are hyperactive, inattentive, and impulsive (Rice 2016), apparently on a par with children with LKS. However, LKS and ADHD are crucially differentiated in that LKS presents as the state of global aphasia, as stated above, but ADHD does not involve any developmental difficulties in linguistic comprehension and production (Redmond 2016). Therefore, since ADHD *per se* as a clinical condition does not involve any language disorder (Redmond 2016), we will not include it as part of our comparative discussion in the text.

(2) Ordinary Child Aphasia:

- a. The underlying pathology is some organic lesions (localized or diffuse) in the brain.
- b. Epileptic brain activity is *not* observed.
- c. The general tendency of the prognosis is 'the earlier the onset of the language disorder is, the better its prognosis becomes'.
- d. The language disorder occurs after the core linguistic knowledge has been acquired by a child.
- e. The aphasic symptoms include receptive aphasia (Wernicke's aphasia), expressive aphasia (Broca's aphasia), anomic aphasia, conduction aphasia, and transcortical aphasia on a par with the case of adult aphasia, depending on which region(s) of the brain has/have been affected.
- f. The recovery from the aphasic state is made possible via new formation of a neural network in the hemisphere where the lesion has been incurred or in the other hemisphere.
- g. Only the language function is affected and the other cognitive functions remain basically intact.
- (3) *LKS*:
 - a. The underlying pathology is not yet definitely identified, but it is not related to any organic lesions (localized or diffuse) in the brain.
 - b. Epileptic brain activity is clearly observed.
 - c. The general tendency of the prognosis is 'the earlier the onset of the language disorder is, the worse its prognosis becomes'.
 - d. The language disorder occurs either when the core linguistic knowledge has not yet been acquired completely by a child or after it has been acquired by a child.
 - e. The aphasic symptom is 'verbal auditory agnosia' usually along with reduction of expressive speech eventually to mutism, displaying virtually the state of 'global aphasia'.
 - f. The recovery from the aphasic state is *not* readily made possible via new formation of a neural network in either hemisphere, presumably, as long as there exist abnormal epileptic discharges generalized over both the hemispheres.
 - g. Not only the language function but also other cognitive and/or motor functions can be affected (Stefanatos 2011), displaying a particular 'co-morbidity', which is the very reason why children with LKS are likely to be clinically misdiagnosed as having autism.

The most crucial differences between ordinary child aphasia and LKS are the presence or absence of brain lesions and epileptic discharges in the brain. Just as in the case of adult aphasia, ordinary child aphasia involves some sort of organical brain lesions due to traumas, tumors, or cerebrovascular damages, and does not normally implicate epilepsy. In contrast, as already mentioned in section 2.1.1, children with LKS exhibit particular EEG abnormalities, displaying no organical brain lesions with computed tomography and magnetic resonance imaging scans.

Moreover, unlike aphasia incurred in adulthood, ordinary child aphasia will generally be overcome if it strikes the child early enough in life (Lenneberg 1967, 1969). Considering the case of recovery from aphasia during preteen years, Lenneberg (1969: 639) suggests that such a phenomenon "may partly be regarded as a reinstatement of activities that had never been lost". Curiously enough, however, LKS differs from ordinary child aphasia in that the above-mentioned generalization by Lenneberg does not hold. That is, in LKS, a younger age of the onset of the language disorder is generally related to a gloomy prognosis for recovery from the state of aphasia (see Bishop 1985 and references therein). Thus, the following different patterns emerge for ordinary child aphasia and LKS as the second major difference, as already mentioned in (2c) and (3c), respectively:

- (4) Different Patterns of Prognosis in Ordinary Child Aphasia and LKS:
 - a. Ordinary child aphasia (= (2c))
 - The earlier the onset of the disorder is, the better the prognosis will be. b. LKS = (3c)

The earlier the onset of the disorder is, the worse the prognosis will be.

The pattern of ordinary child aphasia in (4a) seems to be quite expected in the light of plasticity of the child brain in connection with Lenneberg's (1967) critical period hypothesis (see section 3.1 for discussion). In (4a), if the onset of the language disorder is earlier, relevant language functions would be relocated or compensated for by the use of other parts of the brain to the extent that the child is still within the critical period. This means that in the case of (4a) the child could overcome the aphasic state by appealing to plasticity of the neural network under development in the brain before full maturity of the neural network is attained.

The question therefore arises: Why does LKS behave differently from ordinary child aphasia (4b)? One possibility that immediately comes to mind is that, unlike ordinary child aphasia, LKS displays EEG abnormalities (Denes et al. 1986), due to epileptiform discharges typically with spike activity over the temporal (and/or parietal) regions (Deonna 1991). As Gordon (1997) clearly states, the main problem of LKS lies in the presence of epileptiform activity, or more precisely, the presence of CSWS discharges during slow-wave sleep, as reflected in the abnormal EEG. In the next section, we will compare LKS with other clinical conditions from the perspectives of EEG abnormalities and other characteristics.

2.2.2. Comparison of LKS, BECTS, and CSWS from the Perspectives of EEG Patterns and Other Characteristics

In the first place, recall from section 2.1.3 that LKS is a particular clinical instance of a newly defined class of *epileptic encephalopathies*, in which "a deterioration of cognitive, sensory, and/or motor functions results from epileptic activity" (Stefa-

natos 2011: 964; see also Nabbout & Dulac 2003). Hirsch et al.'s (2006: 244–245) review of neurophysiological and neuroimaging studies of LKS also summarizes the recent view on LKS by saying "LKS is an acquired aphasia secondary to an epileptogenic disturbance affecting a cortical area involved in verbal processing". Accordingly, as discussed in section 2.1.3, the apparent 'language disorder' and 'developmental disorder' in LKS are secondarily derived epiphenomena.

Although the ultimate etiology/etiologies of the paroxysmal EEG abnormalities in LKS *per se* still remain unclear, recall that the EEG abnormalities will usually disappear by puberty in LKS (Massa et al. 2000; Ramanathan et al. 2012). Thus, in principle, LKS is a curable disease to the extent that the EEG abnormallities can be removed and therefore the acquired aphasia (verbal auditory agnosia and loss of expressive speech), accompanied by behavioral disturbances and possibly clinical seizures, are ultimately derived from the presence of paroxysmal EEG abnormalities, as illustrated in Figure 1:



Figure 1: The causal relations in LKS.

The two clinical cases of BECTS and CSWS are to be differentiated from LKS: BECTS shares with LKS the general EEG patterns and severity but not the location of EEG abnormalities; CSWS, on the other hand, shares with LKS the general EEG patterns but not the location and the severity as well as the frequency of EEG abnormalities.¹⁴

Deonna & Roulet-Perez (2010) state that the generally accepted view is that "LKS constitutes one severe end of the continuum of cognitive manifestations that can be observed in idiopathic (genetic) focal epilepsies of childhood which may start quite early in development, the benign end being represented by Rolandic epilepsy" (where Rolandic epilepsy is another term referring to BECTS). Based on the acknowledgement that (the aphasia in) LKS is of epileptic origin and that it occupies the rare and severe end of a spectrum in idiopathic focal epilepsies of childhood with the more frequent typical BECTS at the other end (Deonna & Roulet-Perez 2010), LKS is to be compared with BECTS.

Deonna & Roulet-Perez (2010: 748) present the similarities between BECTS and LKS as follows (with some inconsequential modifications in wording in (5)):

¹⁴ One caveat is in order here: The term CSWS is, strictly speaking, ambiguous between 'CSWS as a particular electrographic pattern' and 'CSWS as a clinical syndrome' on a par with electrical status epilepticus during sleep. Van Hirtum-Das et al. (2006) use 'electrical status epilepticus during sleep' and CSWS for referring to the particular electrographic pattern and the clinical syndrome, respectively. However, in the following discussion, CSWS is used in either sense, depending on the content.

(5) *Similarities between BECTS and LKS:*

- a. Cases of BECTS can develop verbal auditory agnosia typical of LKS.
- b. Cases with LKS and remission have later onset of Rolandic seizures.
- c. Cases of BECTS who develop persistent oromotor deficits (anterior opercular syndromes) later remit like LKS.
- d. Cases of BECTS with subtle acquired reversible language disturbances (oral and written) often have preexisting auditory-verbal and written language deficits (= 'mild forms of LKS').
- e. Seizure semiology and course of epilepsy in BECTS and LKS are similar (= benign).
- f. EEG findings: Focal sharp waves, increased by sleep, disappear with age in BECTS and LKS.
- g. There are families described with one sibling having BECTS and the other LKS.

On the other hand, CSWS is one of the two epileptic syndromes that are associated with the EEG pattern of electrical status epilepticus during slow wave sleep, an electroencephalographic pattern in which the epileptiform discharges increase during sleep (Patry et al. 1971), the other being LKS (Tuchman 2009). There are differences in the frequency and severity of epilepsy between patients with CSWS and LKS, with children with CSWS having more severe and frequent and difficult-to-treat seizures than those with LKS (Jayakar & Seshia 1991; Smith & Hoeppner 2003).

Furthermore, BECTS exhibits minor developmental cognitive and behavioral problems, and some children with BECTS undergo deterioration in these domains (usually temporary), which are called 'atypical' forms of the syndrome. The severity and types of deterioration correlate with the site and spread of epileptic spikes within the perisylvian region, and CSWS frequently occurs during the period of the epileptic disorder. Some of these children have more severe preexisting communicative and language developmental disorder. If early stagnation or regression occurs in these domains, presumably it can be assumed to reflect epileptic activity in the networks outside the perisylvian region, that is, those involved in social cognition and emotions.

Table 1 depicts the main differences among LKS, BECTS, and CSWS. Note that the term CSWS in the first row in the right-most column is CSWS as a clinical syndrome rather than a particular electrographic pattern (see the caveat in fn. 14):

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	LKS	BECTS	CSWS
EEG features	• focal or multifocal epileptiform discharges consistently enhanced during sleep; CSWS occurs in 80% of cases (Mikati et al. 2010)	 focal epileptiform abnormalities (Levisohn 2004) or focal sharp wave increased by sleep (Deonna & Roulte-Perez 2010) CSWS occurs in occasional cases (Mikati et al. 2010) a spike-and-wave index greater than 85% is not observed (Tassinari et al. 2000) 	 in the waking state, focal and/or multifocal, and/or generalized diffuse spike wave activity (Mikati et al. 2010) during sleep, continuous bilateral and diffuse slow spike wave activity through all or most (>85%) of the slow sleep stages (in all cases) (Mikati et al. 2010)
Location of EEG Abnormalities	superior temporal regions (Honbolygó et al. 2005)	centro-temporal regions (Tassinari et al. 2000)	fronto-central regions (Stefanatos 2011)
Linguistic Condition (difficulties in comprehension/ production)	 severe disturbance of auditory language com- prehension (verbal auditory agnosia) (Stefanatos 2011) substantial disruption of expressive language (Stefanatos 2011) 	 milder (Nevill 1999), though verbal auditory agnosia is possible (Deonna & Roulte-Perez 2010) regression is not normally verbal auditory agnosia (Mikati et al. 2011) 	 expressive aphasia (Ekinci et al. 2012) difficulties with lexical and syntactic skills (Ekinci et al. 2012) language comprehension generally spared (Ekinci et al. 2012)
Non-linguistic Conditions	• non-verbal IQ and other cognitive functi- ons can be affected with behavioral prob- lems (attentional defi- cits, impulsivity, dis- tractibility, hyper- activity, aggressive- ness) (Deonna & Roulte-Perez 2010; Stefanatos 2011)	• most patients keep normal global intellectual efficiency, but some may suffer from oromotor dysfunction, neuropsy- chological deficits, or attention deficits with learning disorders (Mikati et al. 2010)	• widespread behavioral regression (decreased IQ, apraxia, memory loss, deficits of spatial and temporal orienta- tion, psychiatric dis- turbances) (Stefanatos 2011)
Prognosis	• 50% of patients re- cover fully, while the remaining 50% recover partially or suffer from permanent aphasia (Mikati et al. 2010)	• most patients have good long-term outcome (Mikati et al. 2010)	• in adulthood, 50% of patients suffer from speech abnormalities and behavioral problems (Mikati et al. 2010)

Table 1: Comparison among LKS, BECTS, and CSWS.

2.2.3. Comparison of (Early and Ordinary) LKS and AR from the Perspectives of Language Disturbances and Other Characteristics

Although the exact current demographic data on the prevalence of each of the two clinical syndromes of LKS and AR are not available, and the figure on the prevalence rate of LKS is unclear at this point, ballpark figures on the basis of the relevant literature are listed in Table 2:

	LKS ¹⁵		AR
	Early	Ordinary	
Occurrence Rate in Population	• 10% before 3 years of age (Bishop 1985)	• unclear	 one third of children with ASD (Trevathan 2004) ~30% of children with ASD (Tuchman 1997)
Linguistic Condition (difficulties in comprehension/ production)	• severe (= global aphasia) (Landau & Kleffner 1957; Stefanatos et al. 2002)		• severe (Mantovani 2000)
Cognitive deficit	• non-verbal IQ and other cogni- tive functions can be affected (Deonna & Roulte-Perez 2010; Stefanatos 2011)		• severe (Mantovani 2000)
Difficulties in Pragmatics/Social Communication	• no (Temple 199	97)	• severe (Nass & Devinsky 1999; Stefanatos et al. 2002)
Behavioral Characteristics: • Hyperactive • Inattentive • Impulsive	Tuchman (1997) Yes Yes Yes		Rice (2016) Yes Yes
EEG abnormalities	 always present CSWS in bitem in most active ph Roulte-Perez 201 	: (Deona 2000) aporal or diffuse ase (Deonna & 0)	 not significantly frequent (Tuchman 1997; Deonna & Roulte-Perez 2010) only 20% (Tuchman 2009) epileptiform discharges in the centro-temporal regions (Tuchman 1997) significant correlation with children without clinical seizures (Mantovani 2000)
EEG patterns	• focal epileptifo abnormalities are BECTS (Levisohr	rm e similar to n 2004)	• no differences in locali- zation (centrotemporal or other) of EEG discharges seen in children with epi- lepsy (Tuchman & Rapin 1997; Levisohn 2004)
Seizures	 70% (20% do not seizures) (Neville simple or composiziones and/or a seizures Rolandic seizure LKS and remission Roulte-Perez 201 	ot have clinical e 1999) plex partial atypical absence res possible with on (Deonna & 0)	• 31% (Kobayashi & Murata 1998; Trevathan 2004)

Table 2: Comparison between (early and ordinary) LKS and AR.

¹⁵ More than 160 cases of LKS have been reported from 1957 to 1990 (Paquier et al. 1992), but the prevalence is unclear (Pearl et al. 2001). In a recent study based on a questionnaire sent to all Japanese hospitals (3,004 hospitals as of March 2009), Kaga et al. (2014) conducted the first epidemiological estimation of LKS in Japan and found that the incidence of children with LKS aged 5 to 14 years is about 1 in a million (978,000) and the prevalence of children with LKS aged 5 to 19 and under medical care is 1 in 302,147 to 407,420 in Japan.

The comparison between LKS and ASD/AR seems to be the 'trickiest' and at the same time the most crucial. The two clinical cases may not be so easy to tease apart, because both children with LKS and those with ASD/AR have similar characteristic behaviors of being hyperactive, inattentive, and impulsive (Tuchman 1997; Rice 2016) and because LKS could affect the non-verbal intelligence on a par with the case of ASD (Deonna & Roulet-Perez 2010 and Stefanatos 2011; see also Great Ormond Street Hospital 2010 and Kimata et al. 2014). Thus, a majority of children with LKS (70–80%) exhibit clinically significant behavioral disturbances, and the combination of the profound communication disorder and severe behavioral abnormalities can approximate to the typical characteristics of non-high-functioning ASD (Ansink et al. 1989; Denes et al. 1986; Roulet-Perez et al. 1991; Roulet-Perez 1995; Stefanatos et al. 2002).

Especially since children with AR develop the impairments of autism after initial normal development (Mantovani 2000), AR attracts particular interest due to overlapping clinical and EEG features with LKS. Among children with ASD, at least 30% develop normally or nearly normally during the first year or two of life before developmental skills regress (Mantovani 2000). According to Mantovani (2000), their regression is not limited to language but also includes dramatic deterioration of social interaction and cognitive abilities, which usually begins between 18 and 24 months of age acutely or insidiously. The pathophysiology remains unknown, but electrophysiological disruption of normal brain development could be a contributing cause of AR (Mantovani 2000), in light of the fact that autistic children without clinical seizures have a significant correlation between AR and EEG abnormalities (Tuchman & Rapin 1997). Given the similarities between LKS and AR, we can suspect that a subgroup of the children diagnosed with AR, especially, those with epileptiform EEG abnormalities, could actually have suffered from early LKS.

In fact, Deonna & Roulet-Perez (2010) also suspect that "some children with an autism spectrum disorder, especially those who have a history of regression, which always involves language, and who have epileptiform EEG abnormalities, could actually have suffered an early form of LKS" (p. 746). They continue: "In several children finally diagnosed as early LKS, autism had been the initial diagnosis, but on closer look, the language deficit was clearly predominant" (p. 749). Moreover, Stefanatos (2011) has criticized the fact that the traditional clinical descriptions and boundaries of LKS have remained largely unchanged since their original formulation and suggested greater cross-disciplinary communication to enhance better diagnostic evaluation. Thus, clearer distinction between early LKS and AR becomes necessary.

The most crucial landmark is the differing rate of the presence of EEG abnormalities between LKS and AR. Patients with LKS always have EEG abnormalities with CSWS, while the rate of AR patients having EEG abnormalities is not significantly high. McVicar et al. (2005) have examined whole-night EEG records of 149 children with language regression and found that those with isolated language regression had a higher frequency of epileptiform abnormalities and seizures than children with both language and autistic (i.e., social and behavioral) regression (see also Deonna & Roulet-Perez 2010). Language regression (with or without autistic features) associated with epilepsy and paroxysmal EEG abnormalities may represent early LKS in light of the fact that children with a history of autistic regression did not have significantly higher rate of EEG abnormalities than those who did not have autistic regression (Tuchman & Rapin 1997 and Baird et al. 2006; see also Deonna & Roulet-Perez 2010). Thus, EEG abnormalities are likely to be part of the underlying pathophysiology for LKS, whereas these are much less clear in the group with AR.

As for EEG patterns, although centrotemporal spikes in autistic children without language regression, independent of the presence of epilepsy, are prominent, no differences in localization of EEG discharges are seen in children with AR and epilepsy; whereas focal epileptiform abnormalities with CSWS, similar to BECTS, are obvious in LKS (Tuchman & Rapin 1997; Levisohn 2004). In other words, CSWS with autistic regression is a rare occurrence (Tuchman 2009). Moreover, as explained earlier, EEG abnormalities as well as seizures in LKS are likely to disappear between the ages of 8 and 13 years (Massa et al. 2000), which can be another clinical marker for LKS.

Secondly, another important landmark differentiating LKS from AR is pragmatic or social function. Mantovani (2000) identifies the pragmatic or social function as the most important differing feature because children with LKS retain their social awareness, use of gestures, and cognitive abilities measured on standardized tests of non-verbal skills. Deonna & Roulet-Perez (2010) also point out that, while LKS involves absent verbal communication, withdrawal, and stereotypies, lack of play and lack of understanding of social situations are clearly not in the forefront of LKS. Typically, children with ASD in general have severe difficulties in interpersonal social communication, due to abnormal development of pragmatic function, including theory of mind (Baron-Cohen 1995, 1998; Temple 1997; Pearl et al. 2001; Matsui 2010).¹⁶ Bishop (2000) also specifies difficulties of pragmatically appropriate use of language as additional impairments of autistic children in addition to their difficulties in mastering syntax and semantics. On the other hand, LKS-affected children, who develop proper attachment to their parents and caregivers, do not have particular problems in interpersonal social communication and can develop pragmatic knowledge, including theory of mind (Temple 1997). Mikati et al. (2010) clearly state that "problems in reciprocal social relatedness and limited stereotypical forms of interests and behaviors that are associated with autism are not manifested in LKS patients" (pp. 259-260). As Deonna & Roulet-Perez (2010) explain, "if the epileptic process is restricted to the perisylvian cortex like in LKS, specific features of developing verbal language are expected to be lost, but not global social interaction like seen in children with primary autism who regress" (p. 748). Since the reciprocal social relatedness in social interaction is related to pragmatic function, its intactness is a clear clinical marker for LKS.

The third landmark is the differences in language restoration patterns between LKS and AR. Nearly three quarters of LKS-affected children (spontane-

¹⁶ Somewhat contradictory views are expressed in the literature, though. See, among others, Tager-Flusberg & Joseph (2005) and Tager-Flusberg (2007) for the view that "autism involves delays and deficits not only in the development of a theory of mind but also in additional aspects of social affective information processing that extend beyond the traditional boundaries of theory of mind" (Tager-Flusberg 2007: 311).

ously) restore language skills completely or partially by adolescence (Mikati et al. 2010), whereas AR patients usually retain severe language deficits (Tuchman 1997). As Deonna & Roulet-Perez (2010) claim, it is true that "the proof that these children really suffered from an early form of LKS can only be brought convincingly if they improve significantly in correlation with the suppression of the EEG discharges or if they show definite relapses and remission in their language and other communicative abilities, a course which is not seen in a developmental condition" (p. 749) (see also Deonna & Roulet-Perez 2005). Nevertheless, the fact remains that approximately three quarters of LKS patients (spontaneously) restore language skills completely or partially by adolescence as the EEG abnormalities diminish and disappear (Mikati et al. 2010), which can serve as yet another clinical marker for LKS.

In summary, we believe that the most confusing case of comparison is between early LKS and AR, because both cases apparently involve grave language deficits for both comprehension and production. However, as pointed out above, by closely examining whether or not the relevant child has a particular pattern of EEG abnormalities (CSWS), has already developed an appropriate ability for interpersonal social communication with proper pragmatic knowledge, and can restore language skills with the disappearance of the characteristic EEG abnormalities, in theory, it seems to be possible to differentiate children with early LKS from those with AR.

2.3. Significance of LKS for Linguistic Investigation

Recall from fn. 5 that a child will acquire the core linguistic competence by around 3 years of age in the normal course of first language acquisition (Pinker 1994; O'Grady 2005). Recall also from section 2.1.1 that 80% of LKS have the onset ranging from 3 to 8 years of age, but the earliest onset of LKS falls on 18 months (Uldall et al. 2000). With those facts in mind in addressing LKS in the context of biolinguistics, we would like to propose to divide LKS into two gross sub-types. We refer to the early onset LKS as *early LKS* and all other cases of LKS as *ordinary LKS*, as defined in (6) on the basis of the differences of the onset of the language disorder in relation to the degrees of the state of I-language acquisition/growth at the time of its onset, with the first approximation dividing line being specified as 3 years of age, as already briefly mentioned in fn. 5:

- (6) Two Sub-types of LKS:
 - a. Early LKS

Early LKS has the onset before 3 years of age, when the I-language of the affected child has not yet acquired the core linguistic competence sufficiently.

b. *Ordinary LKS* Ordinary LKS refers to all other cases of LKS.

In this paper, we will focus on early LKS rather than ordinary LKS, which can be more easily diagnosed with the obvious establishment and disappearance of the first language. In fact, the term 'early LKS' is not novel, as Deonna & Roulet-Perez (2010) use the term basically in the same sense, although they do not mention the notion of I-language. Actually, 12%–14% of children with LKS undergo language regression before three years of age (Bishop 1985; Dugas 1991; Tuchman 1997) and even a case of LKS with its onset at 18 months has been reported in the literature, as mentioned in the previous discussion.

Since LKS is not caused by any lesions of anatomically identifiable specific substrate in the brain, unlike adult aphasia or ordinary child aphasia, nor has any particular gene been linked to it so far (Benítez-Burraco 2013 and references cited therein),¹⁷ investigation into LKS in the context of biolinguistics has significant virtues. Particularly, early LKS is extremely important from two perspectives. One is clinical improvement, as mentioned above, in terms of preventing misdiagnosis of LKS with ASD or AR, since early LKS with the onset before the solid establishment of the first language, accompanied by behavioral disturbances, is hard to distinguish it from these other developmental disorders (Uldall et al. 2000). If the onset of LKS in children were to be around 18 months, as in the case of early LKS, their first language acquisition and development of other cognitive and motor skill functions would still be at early and immature stages. Under these circumstances, it is highly likely that quite a lot of children with early LKS would be misdiagnosed as ASD or AR with severe retardation because of the overlapping co-morbidity, and would not be treated properly.

The other is linguistic investigation and analysis into the nature of human language and first language acquisition in connection with the critical period, modularity of mind, and modularity of the faculty of language (I-language). To the extent that LKS is not directly caused by any identifiable specific gene defects (but see the caveat in fn. 18), we can also assume that the genetic endowment (whatever it may be) responsible for emergence of UG remains virtually intact in patients with LKS, based on the fact that 50% of the patients recover fully and 50% of the remaining patients recover partially (Mikati et al. 2010) after a certain period of time.¹⁸ Rather, given the lack of any identifiable organic lesions in the brain, we can naturally assume that at least some neuronal-level mechanism(s) in the brain, but not the lack or deficits of I-language, would be responsible for the language disorder observed in LKS, as suggested by the following remark:

Neurophysiological techniques such as magneto-encephalography can also now help explain why children [with LKS] have limited potential to relocate the devastated language area as there is bilateral involvement of the cortex. It appears that the likely 'pacemaker' for the electrical disruption of the language arises from the intrasylvian cortex but spreads to the contralateral sylvian cortex. (O'Hare 2008: 724)

¹⁷ Although a particular genetic cause for LKS has not been identified so far, a number of recent studies have suggested that *GRIN2A* (16p13.2) mutations may underlie familial and sporadic cases of LKS (see Conroy et al. 2014 and references therein). We are grateful to a reviewer for pointing out this fact.

¹⁸ While the patient with ordinary LKS would be highly likely to recover from the state of aphasia in a relatively short period of time, the patient with early LKS would either recover from such a state after a relatively long period of time or not recover from it. This description is based on the observation in Bishop (1985), which does not express absolute correlations but just tendencies (see Deonna et al. 1977 for the varied prognosis of LKS depending on factors other than the onset of the disorder).

If this is the case, as long as epileptic electrical disruption of the relevant neural network of the language areas continues bilaterally in the brain, which interferes with plasticity of the brain functioning for language development, the state of aphasia observed in LKS would not cease to exist. Landau & Kleffner (1957) themselves do not specify what "brain tissue largely concerned with linguistic communication" and "the functional ablation of these areas for normal linguistic behavior" refer to, so identifying the relevant brain areas for language and the mechanisms as well as the culprit of the EEG abnormalities is clinically of great importance. If the EEG abnormalities of LKS patients can be controlled, it is highly likely that language might re-emerge or be restored (see Figure 1). In the following section, we will closely examine the phenomena of LKS in terms of Lenneberg's critical period hypothesis for first language acquisition, Chomsky's first language acquisition model, and his views on modularity.

3. Some Biolinguistic Considerations

3.1. The Critical Period Hypothesis for First Language Acquisition

The notion of a 'critical period' for (first) language acquisition was entertained by Penfield & Roberts (1959) (see also Lenneberg 1960) and was clearly formulated by Lenneberg (1967) (see also Lenneberg 1969), considering a variety of cases of child language acquisition (both normal and handicapped).¹⁹ Lenneberg (1967) hypothesizes that the critical period for first language acquisition corresponds to the time span from around 2 years of age to around 12 or 13 years of age, and that during this period children can acquire their mother tongue on a biologically determined course of language development, given appropriate linguistic input from their environment.²⁰

¹⁹ The critical period hypothesis has been discussed extensively and revised dramatically in the literature over the past five decades (see e.g. Weber-Fox & Neville 1996; Locke 1997; Hyltenstam & Abrahamsson 2003; Knudsen 2004; Michel & Tyler 2005; Meisel 2013; Balari & Lorenzo 2015). The notion of 'sensitive period(s)' has come to be used instead of the critical period in order to reflect the relative plasticity of our brain handling first/second language acquisition rather than a sudden halt, even after the end of Lenneberg's (1967) original specification of such a period.

Furthermore, unlike a single critical period in Lenneberg (1967), multiple different sensitive periods are assumed to exist in relation to various 'components' of language such as phonetics, phonology, morphology, syntax, semantics, and so forth, or several clusters of 'sensitive phases' in such multiple sensitive periods are postulated to account for the development of different subcomponents of grammar. While we fully acknowledge the significance of these various refinements of the critical period hypothesis, we would like to invoke Lenneberg's (1967) original version of the critical period hypothesis in the following discussion on LKS for a certain reason to be clarified later.

It is also to be noted that the exact onset and end of the critical period are controversial in the literature. Thus, the onset of the critical period may well be much earlier than two years of age (see e.g. Mayberry & Lock 2003; Dettman et al. 2016), and it may end much earlier or later than 12–13 years of age, say, somewhere between the ages of 6–7 and 16–17 (see DeKeyser 2000 and references therein for the latter). Although we will keep to Lenneberg's original specification of the onset of the critical period as 2 years of age in the following discussion, it would be more appropriate to set an onset, depending on systems in I-language, say, at the perinatal or even the prenatal period, particularly with respect to the development of the sound system (see, e.g., Werker 1989; Kuhl 1993).

Lenneberg's critical period is related to the putative steady state of Ilanguage attained by the relevant neuronal circuitry within the brain. In fact, with regard to the critical period, Lenneberg (1969) also remarks that "it is interesting that the critical period coincides with the time at which the human brain attains its final state of maturity in terms of structure, function, and biochemistry (electroencephalographic patterns slightly lag behind, but become stabilized by about 16 years). Apparently the maturation of the brain marks the end of regulation and locks certain functions into place" (p. 639).²¹

It is to be noted that, as already mentioned, since LKS affects both hemispheres due to secondary generalization of a focal epilepsy, lateralization of the language function in the brain does not result in the employment of the contralateral brain regions for the language function, unlike in the case of ordinary child aphasia (see the remark by O'Hare 2008 in section 2.3 above). Therefore, linguistic input would be practically unavailable to the child with LKS to the extent that verbal auditory agnosia due to the EEG abnormalities exists in the child. However, if linguistic input somehow were to become available to the child again along with the disappearance of the EEG abnormalities during the critical period, re-start of acquisition of the first language and re-emergence of language would be possible in principle.

Morrell et al. (1995) put forth a hypothesis that the presence of epileptiform activity within the relevant circuits for language in LKS may hinder pruning of inappropriate cells and axons for the optimal network of language, and that those circuits may become permanent if the critical period has passed. Accordingly, it can be assumed that the full-fledged acquisition/growth of Ilanguage in patients with LKS would become virtually impossible or extremely hard to achieve, unless the epileptiform activity as reflected in the EEG abnormalities would be removed before the critical period ends.

At this point, it is in order to correctly understand the original version of the critical period hypothesis put forth by Lenneberg (1967) in connection with our proposal in this section. First of all, Lenneberg's critical period is only concerned with first language acquisition and he does not say anything clearly about second/foreign language acquisition. Furthermore, although the term has been commonly used in the broad notion of 'first language acquisition' in the literature, which encompasses linguistic input and output, Lenneberg's original

The following discussion is not affected much as long as the onset of the critical period is before 3 years of age, which is the age for differentiating between early LKS and ordinary LKS. We are grateful to a reviewer for raising our attention to recent research on cochlear implanting in children (Dettman et al. 2016) and on deaf signers (Mayberry & Lock 2003) in connection with the critical period hypothesis.

²¹ For a recent study on the maturation of components of event-related potentials as measured with EEG and event-related fields as measured with MEG in connection with auditory processing, see Ruhnau et al. (2011). They demonstrate that a mature N1 can be observed in children of 9 to 10 years of age on a par with the one in adults and reveal that the source of N1m in children and adults is mainly located in primary auditory cortex on the basis of source localization of the MEG data. Their result is in support of Ponton et al.'s (2002) findings based on dipole source modeling that brain areas underlying early auditory processes are mature in children at around 9 to 10 years of age. We are grateful to a reviewer for bringing our attention to Ruhnau et al. (2011) in relation to the maturation of the brain and auditory processing.

version of the critical period for first language acquisition only applies to linguistic input. It crucially claims that linguistic output/externalization, say, by articulation is *not* subject to such a critical period (see Lenneberg 1967: 158). As such, even if a child is suffering from childhood aphasia, it is predicted that, in principle, there should be a case where *externalization* of I-language could happen *after* the critical period, once the deficit in the neural system for articulatory motor skills of externalization is removed or somehow disappear—on the condition that acquisition of the mental lexicon and language-particular morphophonology, syntax, and semantics should become possible in time for the completion of the critical period.

Thus, Lenneberg's critical period hypothesis is of great significance in considering the case of early LKS, in which the re-start of I-language acquisition would be rendered possible if linguistic input became available within the critical period. Since the development of the system of articulatory motor skills is not subject to the critical period, according to Lenneberg (1967), the child with early LKS could become capable of producing speech even after the critical period ends in accordance with gradual redevelopment of such an externalizing sensorimotor (SM) system. In a nutshell, Lenneberg's critical period is only concerned with the linguistic input, so the linguistic output is outside of its domain.

Consequently, the pattern examples of the two sub-types of LKS, ordinary LKS and early LKS, can be schematically illustrated as follows in Figure 2:



Figure 2: Pattern examples of ordinary LKS, early LKS, and the critical period.

Nonetheless, there is a serious issue concerning the end of the critical period and the time of termination of EEG abnormalities. As stated in Massa et al. (2000: 89), EEG abnormalities as well as seizures in LKS patients could disappear between the ages of 8 and 13 years (mean of 10 years), after being controlled by, say, anti-epileptic drugs and/or corticosteroids. Suppose the EEG abnormalities alleviate and disappear by around 14 years (considering margins of error): Then, there is a temporal gap (1–2 years) between the end of the critical period (12/13 years of age) and the end of the EEG abnormalities. If the intake of linguistic input for language development becomes possible after controlling the EEG abnormalities at around 14 years of age, is it too late for language acquisition since it is over the critical period?

It seems, however, that EEG could improve gradually, not suddenly, by around 14 years of age (Massa et al. 2000; Robinson et al. 2001; Deonna & Roulet-Perez 2010). Thus, it is quite natural to assume that verbal auditory input would become possible gradually well before 14 years of age and the quality of linguistic input would concurrently improve during the process of gradual amelioration of the EEG status in LKS. In any case, one cannot stress enough the importance of offering the child with LKS the opportunities to secure linguistic input within the critical period.

3.2. Primary Linguistic Data (PLD) for First Language Acquisition and LKS

In the tradition of generative grammar, the relevant process of first language acquisition has been abstractly characterized as follows (see Chomsky 1967 for an earlier and Chomsky 2004a, among others, for a more recent version):²²



Figure 3: Generative model of language acquisition.

On this model of first language acquisition, the universal properties of syntax and semantics (and morpho-phonology) of I-language are biologically given, or more appropriately determined, and are not learned ontogenetically and only the language-particular aspects of linguistic knowledge pertaining to the *primary linguistic data* (PLD) must be learned in the course of first language acquisition.²³ Therefore, Lenneberg's critical period hypothesis should only apply to the acquisition of lexical items along with the language-particular dimensions of syntax, semantics, and morpho-phonology of I-language on the basis of the PLD.²⁴

²² The content of LAD used to be regarded as virtually UG as a genetic endowment, but the role of UG has been radically reduced to the bare minimum while the role of interface conditions and that of a 'third factor' has been emphasized in the context of the Minimalist Program (see Chomsky 2005). Here, we are only concerned with the general conception of Chomsky's first language acquisition model, without delving into the debate on the content of LAD, including UG. Although we believe the line of proposals on the content of LAD in Boeckx & Leivada (2014) and Boeckx & Theofanopoulou (2014) is biolinguistically on the right track, we will use the original term LAD with this caveat in mind. Furthermore, the 'instantaneous model of language acquisition' conceived in the tradition of generative grammar, as illustrated in Figure 3, is an idealized model, abstracting away from actual stages of language development or growth in children, as emphasized in Lorenzo & Longa (2009), who propose a new model of language acquisition from a developmentalist point of view in the framework of the Minimalist Program. Although we fully recognize the importance of interface conditions and third factor principles (Chomsky 2005) along with the minimized role assumed by UG and the role of individual linguistic experiences, we will keep to the label LAD without going into such an elaborated model of first language acquisition in this paper (see also Locke 1997; Longa & Lorenzo 2008), since our main point in this section is on the role of PLD in connection with LKS.

²³ See also Guasti (2002) for detailed explication of various aspects of language acquisition in the framework of generative grammar.

²⁴ Note that, although not mentioned here, pragmatics/pragmatic knowledge should constitute part of the system of interpretation together with semantics/semantic knowledge (see

Therefore, if there is a situation where the PLD were to be unavailable for the language acquisition device (LAD) in a child, acquisition of lexical items would become impossible and as a result the child would not be able to expand the domain of words (and other linguistic expressions). Furthermore, the universal aspects of syntax and semantics (and morpho-phonology) of I-language would remain at least potentially intact.²⁵ On the other hand, if the PLD should become available again somehow within the critical period, re-start of acquisition or growth of I-language, including the mental lexicon, would become possible, even if the child would be in a situation where he/she could not speak his/her first language while understanding it. Thus, if the critical period hypothesis is on the right track, in principle, a child with LKS could re-start acquiring his/her Ilanguage to the extent that the PLD becomes available again as linguistic input to the LAD in the sense of Chomsky's model of first language acquisition somewhere within the critical period, even in the case of 'covert language acquisition', or language acquisition without involving any expressive speech.²⁶ More specifically, if the EEG abnormalities in LKS were to be gradually suppressed within the critical period, it is expected that the quality of the PLD for the LAD should become better, leading to re-starting of I-language acquisition in time before the end of the critical period.

Furthermore, if the externalization/articulation in the SM system, which is not subject to the constraint of Lenneberg's (1967) critical period, could be restored in LKS somehow (see our concrete proposal toward this goal in section 4.2), even a child with early LKS could re-start producing speech at some point with a surprising speed of language development, compared with the one of normal language development, after regaining an ability to comprehend speech, because of the existence of potentiality of I-language even without its externalization. This would give the impression that a 'linguistic big bang' could occur in a child with early LKS. Accordingly, if such a linguistic big bang should happen, the case of early LKS would dramatically demonstrate the validity of Lenneberg's version of the critical period hypothesis.²⁷

e.g. Chomsky 1980/2005 for the concept of pragmatic competence). However, pragmatics, by nature, encompasses 'non-linguistic contexts' such as intentions of others independently of PLD. Given that pragmatics, including theory of mind, can be dissociated from I-language, as observed in ASD and LKS (see the discussion in sections 2.2.3 and 3.3.3), it develops as a separate system in the mind. Since we will be only concerned with I-language and PLD *per se* in discussing LKS in this paper, we will not include pragmatics here.

²⁵ If both lexical items and syntactic structures are equally generated by Merge, as Merge- α in the anti-lexicalist approach (Fujita & Matsumoto 2005; Fujita 2014; Boeckx 2015; see also Marantz 1997; Borer 2005.), Merge should be potentially ready for acquisition of lexical items even in the face of unavailability of the PLD in LKS (see also Nasukawa 2015 for a Merge approach to the lexical structure of morphemes in intra-morphemic phonology). This might explain why a 'linguistic big bang' could occur in LKS (once a sufficient amount of PLD becomes available again due to (gradual) amelioration of EEG abnormalities) (see the discussion below).

²⁶ Lenneberg (1962) reports an interesting case in which an eight-year-old boy who had a congenital language disorder developed language comprehension ability without ability to speak, arguing that this kind of case argues against the view that speech production is crucial to the development of speech comprehension.

²⁷ Deonna et al. (2009) argue that learning a sign language will not delay or prevent oral language recovery in children with LKS but possibly even facilitate the recovery process by

The image of language development of the normal child and that of the early LKS child could be roughly illustrated as follows in Figure 4 (note that these are just images, not exact graphs showing actual language development in the two groups of children):



Figure 4: Images of language development in the normal child and recovery of expressive language in the early LKS child.

While normal children will develop their first language steadily within the critical period on the basis of the biologically determined course, children with early LKS would first begin developing their first language normally but suddenly start regressing at a point indicated by X before 3 years of age, possibly before the critical period starts. From that point on, some degree of lexical acquisition, if it ever exists, might occur on the basis of the PLD of poor quality. Then, at some point in time within the critical period, epileptic abnormal brain activity will be suppressed and the quality of the PLD will become better, boosting up the process of first language acquisition again. Finally, 'normalization' of the neural circuitry in the SM system for externalization of I-language should happen at some point in time either within the critical period, as shown by Y¹, or after the end of the critical period, as shown by Y², respectively (it is to be noted that the period from X to Y¹/Y² is a 'virtually silent period' and the PLD would become available again sometime before the critical period ends).

In this way, as mentioned earlier, children with early LKS would be able to experience something like a linguistic big bang. As a matter of fact, Uldall et al. (2000) observe that their patient with early LKS (with onset at 18 months) sped up language acquisition in his 'catch-up periods' in such a way that he acquired vocabulary that would have normally taken one whole year in just 3 months after the age of 5 years. Uldall et al. (2000) remark that "the normal spurt of vocabu-

stimulating the 'functionally connected core language networks', resulting in being bilingual. This clearly indicates that, even if children with LKS are in the state of verbal auditory agnosia and do not produce any utterances, the neural circuitry of I-language and its externalization system potentially remain in the brain, albeit with some deficiency in externalization.

lary usually seen at the age of 17–19 months seemed to have been blocked until it was 'released' by the prednisone course at the age of 5 years" (p. 85). In sum, as long as I-language is established before the critical period ends, externalization of I-language is not affected by the critical period, and thus it would become possible even later in life, in principle.

3.3. Modularity and LKS

We regard I-language itself—or more strictly, the FL²⁸—as composed of independent but interacting sub-systems, or sub-modules (see Chomsky 1980/2050, 1981, 1984, 1986, 1995, among others; for more recent views on FL, see also Hauser et al. 2002; Chomsky 2016; Berwick & Chomsky 2016). Specifically, we take for granted the following basic design of FL that has been assumed as standard in the current Minimalist Program:



Figure 5: Basic design of FL.

Given the nature of LKS that we have discussed in the previous sections, our focus in theorizing the language-related mechanisms behind LKS is the SM system and the 'mapping' between the syntactic computational and the SM systems, including the phonological system. In this connection, recall from section 2.1.1 that Landau & Kleffner (1957) originally proposed a 'functional ablation' view on LKS: "[P]ersistent convulsive discharge in brain tissue largely concerned with linguistic communication results in the functional ablation of these areas for normal linguistic behavior" (p. 529). Then the linguistically significant question is: What does the phrase 'these areas' in the above quote refer to? The literature in the past generally mentions the temporal(-parietal) and perisylvian cortices as relevant areas responsible for the language disorder in LKS, *viz.* verbal auditory agnosia and loss of expressive speech.

The main purpose of this subsection is to zero in on these linguistically relevant areas of the brain, putting forth a concrete hypothesis on the LKS-affected linguistic function and its related cortical areas involved in verbal auditory agnosia and loss of expressive speech in LKS. Since Chomsky himself does not articulate the content of the SM system in neurophysiological terms, we would like to consider the general architecture of language in LKS in the context of speech processing, drawing on a recent study on the cortical organization of speech processing in Hickok & Poeppel (2007).²⁹

²⁸ For an alternative to the traditional FL, see Balari & Lorenzo's (2015) new concept of language as a 'gradient' proposed in a dynamic developmental perspective.

²⁹ See also Friederici (2011) for a comprehensive detailed discussion on the structural and functional neural network in the brain underlying sentence processing.

3.3.1. Hickok & Poeppel's (2007) Dual-Stream Model of Speech Processing

Hickok & Poeppel (2007) put forth the *dual-stream model of speech processing*, as roughly illustrated in Figure 6, on the basis of a wide range of empirical observations such as basic perceptual processes, aspects of speech development and speech production, linguistic and psycholinguistic facts, verbal working memory, task-related effects, sensorimotor integration circuits, and neuropsychological facts (e.g., patterns of sparing and loss in aphasia). It is to be noted that the numbers from 1 to 7 in Figure 6 are not included in the original but are assigned by us for expository purposes, and that they do not indicate temporal ordering or sequencing of processing. In Figure 6, based on our interpretation of Hickok & Poeppel (2007), we inserted a blue dotted enclosure and a black dotted enclosure to indicate the portion dedicated only to speech production and the one shared by speech comprehension and production, respectively, which are not included in their original chart.

In order to help the reader to visually grasp the approximate anatomical locations of the dual-stream model components and their interconnections, a rough illustration of the left-hemisphere of the brain is provided in Figure 7 with the same colors used for the corresponding relevant components in Figure 6. In the following discussion, we will not be concerned with the conceptual network and its interconnections with the lexical interface and the articulatory network.



Figure 6: The dual-stream model of speech processing, based on Hickok & Poeppel's (2007) figure 1a with some simplification and adaptation. Though the original 'input from other sensory modalities' is not depicted here due to space constraints, the sensorimotor interface component is supplied with input from other sensory modalities.



Figure 7: The relevant brain areas in the dual-stream model of speech processing, based on Hickok & Poeppel's (2007) figure 1b with some simplification and adaptation. Unlike in the original, only the left hemisphere is depicted, and the dorsal stream and the ventral stream are highlighted by the blue connection and the pink connection, respectively.

Now, let us briefly go over the whole process of language comprehension in this model. First of all, the earliest stage of cortical speech processing involves some form of spectrotemporal analysis of acoustic signals, or auditory phonetic analysis of sequences of speech sounds, which is carried out in the auditory cortices bilaterally in the supratemporal plane, i.e., in the superior temporal gyrus (STG) (see e.g. Zatorre & Belin 2001 for details on spectrotemporal processing in the human auditory cortex). Then, the result of the spectrotemporal analysis is transmitted to the bilateral phonological network, accompanied by the feedback from the latter to the former, in the middle to posterior portions of the superior temporal sulcus (STS) (= 1), which is responsible for carrying out phonologicallevel processes and creating phonological representations.

Subsequent to the phonological system, the information flow diverges into two broad streams. The dorsal stream, which is strongly left-hemisphere dominant, maps phonological representations onto articulatory motor representations in the sensorimotor interface at the Sylvian-parietal-temporal (Spt) area located within the planum temporale (PT) (= 3), with the feedback from the sensorimotor interface to the phonological network as well. Furthermore, the articulatory motor representations are handed over to the articulatory network in the posterior inferior frontal gyrus (pIFG) involving Broca's region,³⁰ the premotor cortex (PM), and the anterior insula (= 4), again accompanied by the feedback from the articulatory network to the sensorimotor interface. Note, incidentally, that the spectrotemporal analysis component and the sensorimotor interface could be directly interrelated as indicated by the two-way arrow (= 2).

³⁰ See Yusa (2012, 2016) and references therein, including Grodzinsky & Amunts (2006), for detailed discussion on the fine-grained architecture of Broca's region (BA 44, 45). In this paper, we will not delve into this issue while acknowledging its theoretical importance ultimately in connection with LKS as well in the biolinguistic context.

In contrast, in the ventral stream, which is largely bilaterally organized with a weak left-hemisphere bias, phonological representations are associated with lexical conceptual representations in the lexical interface (= 5), which is with weak left-hemisphere bias, in the posterior middle temporal gyrus (pMTG) and the posterior inferior temporal sulcus (pITS), with the feedback from the lexical interface to the phonological network. Then, an array of lexical conceptual representations (linked with corresponding phonological representations) are handed over to the combinatorial network (= 6), which is assumed to be left-dominant, to generate post-lexical conceptual and semantic representations (with corresponding phonological representations), in the anterior middle temporal gyrus (aMTG) and the anterior inferior temporal sulcus (aITS), accompanied by the feedback from the combinatorial network to the lexical interface, and the interaction between the combinatorial network and the articulatory network as well.

In Hickok & Poeppel's (2007) dual-stream model of speech processing, within the whole process of speech comprehension, *speech perception* of pre-lexical stages (such as segmental/phonemic identification and supra-segmental identifycation like syllabification) are to a greater extent handled by the dorsal stream, while *speech recognition*, including processing of lexical/post-lexical stages (such as word identification and hierarchical syntactic structure identification), relies more on the ventral stream.³¹ In section 4.2, we will make use of the term *verbal auditory comprehension* in discussing several recovery patterns of language disorder in LKS. It is to be kept in mind that the term verbal auditory comprehension in the sense of Hickok & Poeppel (2007), because LKS typically incurs *verbal auditory agnosia*, which refers to a situation where not only sublexical-level but also lexical-level and phrasal-level processing is disrupted in a severe period of the disorder.

Although Hickok & Poeppel (2007) themselves do not explicitly describe the concrete processes of speech production unlike for speech comprehension in the dual-stream model of speech processing,³² we assume that at least the initiation of speech production does not involve the spectrotemporal analysis component, whereas the subsequent processing of speech production will employ the spectrotemporal analysis component along with the phonological network so that the speaker can monitor his/her own speech. In the case of speech comprehension, the interactions between the articulatory network and the sensorimotor interface and between the articulatory network and the combinatorial network as indicated by 4 and 7 may not be required (see the case of Lenneberg 1962 in fn. 27), but in the case of speech production those interactions are absolutely

³¹ Hickok & Poeppel (2007: 394) define the three terms *speech processing, speech perception,* and *speech recognition* as follows: (i) "speech processing refers to any task involving aurally presented speech"; (ii) "speech perception refers to sublexical tasks (such as syllable identification)"; and (iii) "speech recognition (auditory comprehension) refers to the set of computations that transform acoustic signals into a representation that makes contact with the mental lexicon".

³² Hickok (2012) proposes a hierarchical state feedback control (HSFC) model of speech production. Since the purpose of this section is to consider verbal auditory agnosia and loss of expressive speech from the perspective of the dual-stream model of speech processing, we will not incorporate Hickok's (2012) model of speech production in the following discussion, leaving the task to another occasion.

necessary. Given these assumptions, it seems natural to suppose that verbal auditory comprehension of sentences, which involves accessing to hierarchically structured expressions, must comprise the components of spectrotemporal analysis, phonological network, sensorimotor interface, lexical interface, and combinatorial network along with the interactions indicated by 1, 2, 3, 5, and 6. In the case of verbal production (speech production) of sentences, it seems to be natural to assume that, in addition to those components and interactions, the articulatory network is also involved via interactions with the sensorimotor interface and the combinatorial network, as indicated by 4 and 7, respectively.

We also presume that basically the same asymmetries between the dorsal stream and the ventral stream hold in the case of speech production as well with all the various interactions/feedbacks illustrated in Figures 6 and 7: (i) the dorsal stream is strongly left-hemisphere dominant, while the ventral stream is largely bilaterally organized, with a weak left-hemisphere bias; (ii) the dorsal stream is mainly for the processing of pre-lexical units such as phonemes and syllables, whereas the ventral stream is to a greater extent for the processing of lexical/ post-lexical units such as words and phrase structures.

3.3.2. Input and Output Problems in LKS

We would like to propose that LKS is a language disorder that involves two major problems regarding the FL, which would be ultimately ascribed to some deficiencies in the SM system, as depicted in Figure 8:



Figure 8: Language disorder in LKS caused by deficiencies in SM system.

The first problem is with acquisition of lexical items (the 'input problem') and the other with the externalization of I-language, say, by articulation (the 'output problem'). Let us first consider the input problem of LKS.

At first, it is of vital importance to identify the core deficiencies underlying the input problem of LKS. In view of the linguistic profile of LKS discussed in section 2.1.2 and Stefanatos's (1993) insight into LKS as "an apperceptive disturbance in which there is primary impairment of processes subserving the auditory analysis of acoustical features [amplitude modulation (AM) or frequency modulation (FM)] necessary for speech perception" (p. 412), we propose to analyze LKS as affecting the system for spectrotemporal analysis located bilaterally in the dorsal superior temporal gyrus (STG) (and possibly the routes connecting the system for spectrotemporal analysis and other relevant systems).^{33,34} Recall from section 2 that children with LKS suffer from spike-wave discharges predominating over the superior temporal regions activated by sleep and secondarily generalized to both hemispheres. Given this state, it is quite natural to imagine that such abnormal brain wave activity will disrupt proper working of the system for spectrotemporal analysis bilaterally.

Note that in Hickok & Poeppel's (2007) model, the dorsal STG for spectrotemporal analysis, the posterior half of the superior temporal sulcus (STS) for phonological processing, and the parietal-temporal Spt for sensorimotor interface processing are interconnected with each other bidirectionally (see Figures 6 and 7). Crucially, this implies that if the system for spectrotemporal analysis were impaired in LKS, it would be expected to yield deleterious effects on both the ventral stream and the dorsal stream, as clinically observed as verbal auditory agnosia and loss of expressive speech in LKS.

More specifically, if acoustic signals of sequences of speech sounds cannot be properly analyzed spectrotemporally in the dorsal STG (bilaterally), the phonetic sound sequences cannot be correctly linked with appropriate abstract phonological units, even if the phonological system in the mid-post STS *per se* remains intact. As a result, the supposed lexical items cannot be formed/identified at the lexical interface in the pMTG and pITS, presumably due to the lack of appropriate pairing of <P, S> (where P stands for a phonological representation including specification of distinctive features, and S for a semantic representation).^{35,36} Consequently, there would be no proper input of lexical items for the combinatorial network in the aMTG and aITS to form/identify hierarchically structured expressions (i.e., phrases and sentences). Hence, the 'input problem' of LKS, or the state of verbal auditory agnosia in LKS, emerges.

As such, if no correct *P* is available to the child with LKS, normal acquisition of lexical items would not be possible as long as the child with LKS is suffering from the state of verbal auditory agnosia. However, given the fact that comprehension will be regained in due course in accordance with the amelioration of the EEG abnormalities in LKS (Massa et al. 2000) (after anti-epileptic medication), the input problem of LKS will more or less disappear eventually.

³³ The PET results in Zatorre & Belin (2001) indicate that "(i) the core auditory cortex in both hemispheres responded to temporal variation, while the anterior superior temporal areas bilaterally responded to the spectral variation; and (ii) responses to the temporal features were weighted towards the left, while responses to the spectral features were weighted towards the right" (p. 946).

³⁴ Tsuru & Hoeppner (2007) suggest the possibility that deficits in Wernicke's area (= post-STG) and the supramarginal gyrus are involved in LKS on the basis of Iwata (1996). Their suggestion is not exactly the same with our proposal, but seems to partly overlap with it.

³⁵ Phonological features (e.g., [+voiced]) and semantic features (e.g., [+artificial]) of each lexical item will become part of a phonological representation and a semantic representation, respectively. See Chomsky (1965, 1995 *et seq.*) for discussion on different kinds of features in lexical items.

³⁶ In the framework of Distributed Morphology, *P* (phonological features) will be inserted later in the derivation in the post-syntactic Morphology component (e.g., Halle & Marantz 1993). Even if this is the case, the fact remains that the two feature bundles (*P* and *S*) have to be 'lumped together' somehow to guarantee Saussurean arbitrariness in a coherent lexical item. See Harley (2014) for recent developments of the framework, in which indices are employed as a device for this purpose.

Next, let us turn to the output problem of LKS. If acoustic signals of sequences of speech sounds cannot be properly analyzed spectrotemporally in the dorsal STG, the correct information on the phonetic sound sequences (and the correct phonological analysis of them in the phonological network) cannot be transmitted to the sensorimotor interface at the parietal-temporal Spt, which in turn would lead to failure in transmitting appropriate relevant sensorimotor information to the articulatory network in the pIFG, PM, and anterior insula for articulation/externalization of the expected phonetic sound sequences corresponding to the 'intended' hierarchically structured expressions supplied by the combinatorial network in the aMTG and aITS. Hence, the 'output problem' or the state of loss of expressive speech in LKS appears.³⁷ Consider Figure 9:



Figure 9: 'Domino effect' in LKS in the dual-stream model of speech processing. The deficiencies of the system of spectrotemporal analysis are indicated by a large, relatively thick cross, and the 'direct disruption' between the component of spectrotemporal analysis and that of phonological network or that of sensorimotor interface is depicted by small, relatively thick crosses, while the 'indirect disruption' between the other relevant systems is represented by small, relatively thin crosses.

The figure summarizes the 'domino effect' behind the 'input problem' and the 'output problem' in LKS that we discussed in the framework of Hickok &

³⁷ Pulvermüller et al. (2006) demonstrate, using event-related fMRI, that speech perception activates motor circuits responsible for corresponding speech production, without any speech production. If this is the case, it is plausible to assume that children with LKS who have become capable of comprehending speech to some extent, due to the improvement of the system of spectrotemporal analysis, might be able to activate the phonological network and the sensorimotor interface, even without any overt speech production.

Poeppel's (2007) dual-stream model of speech processing (although we will not discuss the higher-order frontal networks, note that (part of) the networks may be affected by the characteristic epileptic discharges particularly in the brain of the children with LKS suffering from non-linguistic cognitive dysfunction). In proposing the dual-stream model of speech processing, Hickok & Poeppel (2007) make an interesting claim that the dorsal auditory-motor circuitry offers the basic neural mechanisms for phonological short-term memory. Given the domino effect in LKS depicted in Figure 9, it is expected that a child with LKS would suffer from phonological short-term memory disturbances due to the deficiencies related to spectrotemporal analysis in the STG. This prediction seems to be borne out. Majerus et al. (2003) report that there is a correlation between the quality of phonological working memory and the degree of activity in the STG (PET data) in their patients with LKS with varying prognosis.

If the reasoning above is basically on the right track, we would reach the following hypothesis about LKS (both early and ordinary) in (7):

(7) Hypothesis on LKS:

LKS only affects the neuronal-level mechanism(s) in the SM system for spectrotemporal analysis of acoustic signals of sequences of speech sounds, which will in turn result in failures to acquire further lexical items and to externalize I-language in the wake of the domino effect upon the dorsal stream and the ventral stream, although the potentiality of phonological, syntactic and semantic components in I-language *per se* remains virtually intact.

Accordingly, if our hypothesis in (7) is correct, the apparent 'disconnection' (Tsuru & Hoeppner 2007) in LKS should result from the dysfunction of the spectrotemporal analysis component in the SM system and the disruption of its relevant interconnections with other components due to the deleterious domino effect, as illustrated in Figure 9.

Finally, Berwick et al. (2013) emphasize that "regarding the neural mechanisms of human language, research should focus on distinguishing neural networks supporting the externalization of language from those engaged in core syntactic computations, such as 'merge'" (p. 96). The hypothesis in (7) is in line with this suggestion; so, if it is on the right track, LKS seems to be conducive to research in such a direction. Furthermore, it is to be recalled that, although children with LKS are highly likely to be incapable of producing speech, they will become capable of comprehending speech once the relevant neuronal-level mechanism(s) in the SM system start(s) to function properly. This point is important in understanding children with LKS in the context of the hypothesis in (7).

3.3.3. Modularity of Mind

Another fundamental assumption adopted in this paper is 'modularity of mind' (see e.g. Chomsky 1980/2005, 1981, 1984, 1986, 1995). From this point of view, I-language functions as an independent system, interacting with other modules such as the vision system, the number system, the memory system, the pragmatic

system (including theory of mind), the system of general knowledge, the sensorimotor system, and the thought system among others in the mind.³⁸ In connection with Chomsky's view of modularity of mind, a caveat seems to be in order. He clearly states that the faculty of language (FL) is "a subcomponent of (mostly) the brain that is dedicated specifically to language" (Chomsky 2004b: 104), but he also clearly defines the subcomponent as "a system, that is, its elements might be recruited from, or used for, other functions" (p.124). Accordingly, Chomsky's version of modularity of mind does not presuppose the existence of what Marcus (2006) calls *'sui generis* modularity' and is compatible with Marcus' description of *'descent with modification* modularity' (see also Marcus et al. 2013).³⁹ In fact, the modularity of mind is empirically supported by a variety of clinical symptoms of dissociations among cognitive sub-systems (e.g., Curtiss 1977, 1981; Yamada 1990; Smith & Tsimpli 1991, 1995; see also Jenkins 2000 for a concise review).^{40,41}

As mentioned in section 2.2, children with ASD/AR differ significantly from children with LKS with regard to development of theory of mind. Generally, children with LKS can develop theory of mind as part of their pragmatic competence and proper attachment to their parents and caregivers; whereas, children with ASD/AR characteristically cannot or have difficulties to develop them (for LKS, see Pearl et al. 2001; for ASD, see Baron-Cohen 1995; Matsui 2010; Baron-Cohen et al. 2013). Thus, the contrast between LKS and ASD/AR suggests a dissociation between the module of I-language and the module of theory of mind (pragmatics) in a much clearer fashion.

³⁸ See Pinker (1994) and Jackendoff (1996), among others, for discussion on the independence of the thought system from I-language.

³⁹ Marcus (2006) points out that recent neuroimaging results seem to support this view of modularity (for relevant evidence, see Crosson 1992; Lieberman 2002; Poeppel & Hickok 2004). Although this view is not explicitly stated by Lenneberg (1967), his conception of language and cognition in the context of biolinguistics is also to be considered as a precursor and is in line with Chomsky's view of modularity of mind. See Boeckx & Longa (2011) for recent discussion on the correct interpretation of Lenneberg (1967); see also Fujita (2016) for an interesting proposal on modularity of mind and FL, which is in line with Marcus (2006).

⁴⁰ Fodor (1983) also proposes his view of modularity of mind, which differs from Chomsky's. Unlike Chomsky, for Fodor, modules are 'informationally encapsulated' without directly interacting with each other and the 'language module' is regarded as only an input system. This view of modularity of mind, to which Marcus (2006) refers as 'sui generis modularity', clashes with the clinical findings: Generally, complete dissociation is very rare and cooccurrence of multiple cognitive deficiencies quite common, as argued by Marcus (2006; see also Marcus 2004). At the same time, it is to be noted that any non-modular domain-general view of the mind is also at variance with clinical cases that show symptoms of dissociation (even if not a complete one) among cognitive systems in the first place.

⁴¹ Karmiloff-Smith (2009, 2010) argues for what she calls 'neuroconstructivism', which rejects the notion of innate, genetically pre-determined modules in the mind, taking issue with the Fodorian modularity and claiming that human intelligence, including language, is an emergent property over developmental time as a result of dynamic and multidirectional interactions between genes, brain, cognition, behavior, and environment. It is to be noted that, unlike Fodor's notion of modularity, Chomsky's notion of modularity is *not* incompatible with Karmiloff-Smith's neuroconstructivism, especially in the context of the Minimalist Program, which deemphasizes innately specified domain-particular genetic endowment while emphasizing the interactions of environment and the 'third factor' (including developmental paths), giving rise to the Chomskyan system of modularity (Chomsky 2005); for discussion of the non-gene-centric nature of the Minimalist Program in the context of evo-devo, see Benítez-Burraco & Longa (2010).

This suggestion is quite significant for considering modularity of mind in connection with the apparent co-morbidity in LKS. It opens up the possibility that all relevant modules of the mind in the child with LKS develop as different systems, while they are simultaneously affected by spreading of the LKS-related epileptic discharges to various brain regions involved in functioning of these modules. Deonna (2000) also remarks that the loss of language in LKS does not necessarily mean a sign of global mental deterioration (dementia). This view can naturally account for the fact that some children with LKS suffer from only language disorder, while the other cognitive functions remain relatively intact, even though they may look apparently severely mentally handicapped due to the lack of verbal production.

Furthermore, if Jackendoff (1996) is right in claiming that 'inner speech' (i.e., the phonological output of I-language in the mind) aids us to articulate our thought by providing a 'handle' for attention, the dysfunction of the phonological network in LKS as a result of the 'domino effect' in Figure 9 suggests that the child with LKS would not have access to propositionally complex articulated thought associated with appropriate phonological forms, presumably until the recovery of the system of spectrotemporal analysis and the proper working of the mechanism(s) for phonological processing in the phonological network. This might account for the co-morbidity of deteriorated cognitive function of thinking among children with early LKS.

4. Broader Implications

4.1. Implications for Biolinguistic Research

First of all, identifying a group of children with early LKS would bring a benefit to investigation into the nature of human language in the field of biolinguistics. Note that, unlike in the case of ordinary LKS, children with early LKS stop acquiring their first language in the middle of its acquisition due to unavailability of linguistic input derived from malfunctioning of the SM system (see Figure 8). However, if the availability of linguistic input should come back some time before the end of the critical period, thanks to the success of epilepsy control and amelioration of the EEG abnormalities, for instance, one can theoretically expect the children to experience a 'linguistic big bang', with a modular reinstatement of the properly functioning SM system of I-language. Namely, children with early LKS would suddenly display an ability to produce syntactically complex sentences via Merge in their first language. Thus, this kind of linguistic big bang would reveal that the core computations of syntax and semantics are virtually innately determined, as assumed in the current theorizing of the Minimalist Program (see e.g. Chomsky 2004b, 2005, 2010, 2016 and Berwick & Chomsky 2016).

Furthermore, a linguistic big bang would demonstrate that, if linguistic input should become available (again) within the critical period in the sense of Lenneberg, externalization of I-language would still be possible even after the end of the critical period (see Figure 4). Thus, we can assume that, in theory, as long as linguistic input becomes possible within the critical period, language development would occur later even in children with early LKS. However, in order to realize this theory-based conjecture, we have to deal with the problem of neural dysfunction in the SM system that hampers externalization of I-language, making smooth speech difficult in LKS (see also Tsuru & Hoeppner's 2007 'disconnection' view of LKS). To do this, we would like to suggest the use of transcranial direct current stimulation (Nitsche & Paulus 2000) as one of the possible non-invasive medical interventions using external devices, a subject we turn to in the next subsection.

4.2. Implications for Medical Intervention/Treatment/Research

4.2.1. tDCS Treatment

First of all, recall from section 2 that there are three different patterns in the recoverability prognoses of LKS: Approximately 50% of patients recover fully, while the remaining 50% recover partially or suffer from permanent aphasia/dysphasia (Mikati et al. 2010). Given this situation, it is imperative to consider effective ways of medical intervention on behalf of the remaining LKS-affected patients with partial or no recovery of (expressive) language ability.

Transcranial direct current stimulation (tDCS) is a non-invasive stimulation technique for inducing polarity-dependent focal changes in cortical excitability, modulating spontaneous neuronal network activity; anodal stimulation increases and cathodal stimulation decreases the excitability of the cortical areas underneath the active electrode (see Brunoni et al. 2012 and references therein). Thus, the former has an excitatory effect, while the latter has an inhibitory effect. This neuromodulation technique has been clinically employed for treatment of neuropsychiatric disorders such as major depressive disorder, chronic and acute pain, or drug addiction, as well as for rehabilitation of stroke, including stroke-induced aphasia, among others (see Brunoni et al. 2012; Fiori et al. 2011, and references therein).⁴²

Also, tDCS has been applied to patients with LKS in an attempt to improve their clinical conditions. Although Varga et al. (2011) failed to demonstrate the efficacy of cathodal tDCS with an inhibitory effect in reducing the epileptiform activity in children, including children with LKS (age at tDCS: 6; 1 and 7; 2), they have at least shown that this non-invasive neuromodulation technique can be safely applied to children with epilepsy (see Varga et al. 2011 for details). On the other hand, Faria et al. (2012) successfully demonstrate that cathodal tDCS is not only safe but also possesses "enough cortical polarization power to modulate epileptic activity focally" (p. 424) in patients with epilepsy, including a patient with LKS (age at tDCS: 7;0), for whom approximately 50% reduction of the paroxysmal activity was observed.

One difference between Varga et al. (2011) and Faria et al. (2012) is that tDCS was applied to patients who were awake in the former and asleep in the

⁴² Interestingly, Fiori et al. (2011) demonstrate that application of anodic tDCS (20 min, 1 mA) over Wernicke's area of patients with stroke-induced aphasia significantly improves word retrieval in the aphasics with a long-term effect on recovery of their anomic disturbances.

latter. Faria et al.'s (2012) success of tDCS application to LKS patients can be justified, because LKS patients usually have EEG abnormalities during sleep. Other differences between the two methods were a more precise localization of the epileptogenic foci, a more focal tDCS application, and quantified epileptiform EEG discharges during and immediately after tDCS when applied to patients who were asleep. These results show that epileptiform EEG abnormalities in LKS can be technically reduced by tDCS if it is applied to patients with LKS whilst they are asleep, and with a precise localization of the foci and a sufficient focal stimulation supported by simultaneous EEG recording. To the extent that Faria et al.'s (2012) approach is on the right track, EEG abnormalities in patients with LKS can be controlled to a significant degree by tDCS.

Notice that, even though LKS-affected children's epileptic clinical seizures can be readily suppressed by anti-epileptic medication, typically they still have EEG abnormalities until around 15 years of age (Ramanathan et al. 2012). However, as attested by Varga et al. (2011) and Faria et al. (2012), among others, tDCS may be safely applied to the affected areas of the brain before a patient's EEG has become normalized. This may also solve the problem of the time lag between the end of the critical period (say, 12–13 years of age) and the termination of EEG abnormalities (15 years of age) for the sake of providing linguistic input within the critical period for fully establishing I-language in time.

Given the safety and efficacy of tDCS for LKS, we would like to suggest that this neuromodulation technology be focally applied in a careful manner not only for targeting the epileptogenic origin to alleviate EEG abnormalities but also for targeting Hickok & Poeppel's (2007) 'linguistic neuropathways', including the ventral stream and the dorsal stream in the brain, in the hope of ameliorating the deficiencies in the SM system and directly resolving both the input problem and the output problem of LKS shown in Figure 8. In doing so, of course, application of tDCS should be as careful as possible, and the correct identification of the target areas of the brain is to be done as precisely as possible by neuro-imaging techniques such as EEG (Faria et al. 2012), MEG (Sobel et al. 2000), PET (Kang et al. 2006), and SPECT (O'Regan et al. 1998). Therefore, if EEG abnormalities of LKS patients can disappear by puberty (Massa et al. 2000; Ramanathan et al. 2012), it may be ideal to apply tDCS when the EEG abnormalities are controlled to some extent and when the focus of the epileptiform discharges can be detected more precisely.

4.2.2. tDCS Application to Various Language Recovery Patterns in LKS

Let us now consider theoretically how tDCS could contribute to linguistic improvement in children with LKS. To start with, in connection with Figure 9, we can make the following speculations for the theoretically conceivable three patterns of recoverability from LKS: full, partial, and no recovery. In considering this issue, it is imperative to define what these recovery patterns refer to.

Notice that the term 'recovery' comprises two components: recovery of verbal auditory comprehension and recovery of verbal production. Accordingly, we have to define each category of the three patterns of recovery in LKS in a more refined way in terms of the two components. We will summarize logically possible patterns of linguistic recovery in LKS on the basis of three degrees of recovery in the ability of verbal auditory comprehension and verbal production, along with the recommended loci for tDCS application (which we will discuss later) in Table 3.

	Verbal auditory	Verbal	Recommended Loci for
	comprehension	production	tDCS Application
Full recovery	✓	1	n.a.
Partial recovery (I)	??	1	STA,1, 2
Partial recovery (II)	1	??	AN, 4, 7
Partial recovery (III)	??	??	STA, PN, SMI, LI, CN,
			AN, 1, 2, 3, 4, 5, 6, 7
Partial recovery (IV)	Φ	??	STA, PN, SMI, LI, CN,
			AN, 1, 2, 3, 4, 5, 6, 7
Partial recovery (V)	1	Φ	AN, 4, 7
Partial recovery (VI)	??	Φ	STA, PN, SMI, LI, CN,
			AN, 1, 2, 3, 4, 5, 6, 7
No recovery	Φ	Φ	STA, PN, SMI, LI, CN,
			AN, 1, 2, 3, 4, 5, 6, 7
Partial recovery (VII)	Φ	1	n.a.

Key: STA = spectrotemporal analysis, PN = phonological network, SMI = sensorimotor interface, AN = articulatory network, LI = lexical interface, CN = combinatorial network, and numbers 1 to 7 correspond to the numbers for the interconnections in Figures 6 and 9.

Table 3: Logical possibilities of linguistic recovery patterns in LKS and tDCS application loci. \checkmark , ??, and φ stand for virtually complete recovery, incomplete/deficient recovery, and virtually no/extremely poor recovery, respectively.

First, the case of full recovery, shaded in blue, corresponds to a situation in which both verbal auditory comprehension and verbal production have recovered virtually completely (for this kind of case, see Landau & Kleffner 1957; Worster-Drought 1971; Deonna et al. 1977; Mantovani & Landau 1980; Dugas et al. 1991; Paquier et al. 1992; Kaga 1999). In this case, the system of spectrotemporal analysis can be assumed to have regained its proper function, and as a result, appropriate phonological representations can be formed in the phonological network system. The phonological representations can then be transduced to motor instructions in the sensorimotor interface system, which transmits the motor instructions to the articulatory network system, and this works in cooperation with the combinatorial network system for externalization, via the dorsal-stream pathway. In the ventral-stream pathway, then, the phonological representations can be associated with the proper semantic representations in the lexical interface system, and the formed lexical items will be sent to the combinatorial network system for constructing phrases and sentences, which will be externalized through the articulatory network system. Note that it must be assumed that no particular damage as a result of the domino effect is found in any of the components of the dorsal stream and the ventral stream in this case. Thus, obviously, no application of tDCS is necessary here.

The case of partial recovery (I), also shaded in blue, looks like full recovery superficially on verbal production-based prognosis but can only be categorized as partial recovery under our criteria: The system of spectrotemporal analysis has not recovered 100%, and the still defective but sufficient information could flow into both the dorsal stream and the ventral stream, which have not suffered any damage from the domino effect. So, I-language has been externalized verbally in a fluent manner, possibly with some degree of mis-articulation due to the deficiency of spectrotemporal analysis. This case, which is clearly reported in Paquier et al. (1992) and Kaga (1999), may imply that although the quality and quantity of verbal auditory input is not perfect, verbal externalization could be possible as long as I-language is established without any domino effect damage on the dorsal and the ventral stream; thus it is speculated that a modicum of input might be enough to trigger functioning of I-language. The two cases in blue account for ca. 50% of LKS patients, according to Mikati et al. (2010). In the partial recovery pattern (I), bilateral application of tDCS to the dorsal STG and the connecting routes (indicated by 1 and 2) between the dorsal STG and the mid-post STS and between the dorsal STG and the parietal-temporal Spt, respectively, is recommended to improve the function of spectrotemporal analysis and its interconnections with the two systems, as specified in Table 3 (see Figure 9 for reference).

The next three cases (II), (III), and (IV), shown in orange in Table 3, are partial recovery on verbal production-based prognosis, which accounts for 25 % of LKS patients, based on Mikati et al.'s (2010) data. In the case of partial recovery (II), verbal auditory comprehension has become virtually normal, while verbal production has still remained defective (see Mantovani & Landau 1980), presumably because of the domino effect on at least the articulatory network system in Figure 9. In (II), the virtually normal verbal auditory comprehension seems to suggest that all the components and interconnections other than the articulatory network and its interconnections (4 and 7) with the sensorimotor interface and the combinatorial network have recovered and are functioning properly. Hence, tDCS should be applied to pIFG, PM, anterior insula, and the connecting routes 4 and 7, as indicated in Table 3 (see Figure 9 for reference).

Although precise identification of the cause of such damage from the domino effect in the partial recovery pattern in (II) awaits further investigation, with respect to the dorsal stream at least, it seems reasonable to imagine the following as one possibility. If the articulatory network is not employed for a relatively long period of time in LKS, due to persistent dysfunction of the interconnection between the sensorimotor interface and the articulatory network, the strength of the neural connection between the two systems would become weakened in the LKS patient, leading to difficulties in recovering expressive speech.

Another partial recovery pattern (III), on the other hand, constitutes a case where both verbal auditory comprehension and verbal production have stayed defective (for this kind of case, see Worster-Drought 1971; Deonna et al. 1977; Mantovani & Landau 1980; Ansink et al. 1989; Dugas et al. 1991; Paquier et al. 1992; Penn et al. 1990; Kaga 1999; Kimata et al. 2014). Such a state of affairs implies that both the dorsal-stream and the ventral-stream pathways have sustained some damage from the domino effect triggered by the disruption of the spectrotemporal analysis system. Therefore, tDCS should be applied to the cortical areas related to all the relevant components and interconnections to improve verbal auditory comprehension and verbal production, as specified in Table 3.

Furthermore, the partial recovery pattern in (IV) (see Worster-Drought 1971; Deonna et al. 1977; Dugas et al. 1991) might strike us as a bit odd. Since the system of spectrotemporal analysis has stayed defective in this case, new spectrotemporal analysis of streams of sounds should be extremely difficult or virtually impossible. However, suppose that the phonological network system and both the dorsal stream and the ventral stream were to be free from any serious damage from the domino effect in Figure 9. Suppose also that, before the onset of LKS, some degree of first language acquisition has been carried out, with a certain amount of lexical items being stored in the mental lexicon. Then verbal externalization of I-language should be partially possible, albeit with some degree of defective articulation due to the deficiency of the system of spectrotemporal analysis. This should be, at any rate, a rare case, probably not easily seen among ordinary LKS children. With respect to tDCS application in this case, similarly to the case in (III), the cortical areas responsible for all the relevant functions and interconnections must be properly targeted to ameliorate verbal auditory comprehension and verbal production, as recommended in Table 3.

As for 'apparent no recovery' on verbal production-based prognosis, indicated in red, two partial recovery cases in (V) and (VI) are included in addition to no recovery. First of all, in the case of no recovery (for this kind of case, see Worster-Drought 1971; Deonna et al. 1977; Dugas et al. 1991), presumably due to the severity of the damage to the system of spectrotemporal analysis, appropriate auditory phonetic information cannot be linked with phonological representations in the phonological network system. As a result, neither the dorsal-stream pathway nor the ventral-stream pathway would be able to function due to the lack of input of proper information.

Note, however, that the case of no recovery in Table 3 should not be taken as suggesting 'no I-language'. To the extent that other modalities such as visual linguistic input in a sign language are available within the critical period to the LKS child with no recovery of verbal auditory comprehension and verbal production, the child could still acquire a sign language as his/her mother tongue (see e.g. Bishop 1982; Deonna 2000; Roulet-Perez et al. 2001; Deonna et al. 2009 for discussion on the effectiveness of use of sign language learning in LKS). Note, incidentally, that the fact that LKS patients can acquire a sign language with the proficiency that equals that of an individual with congenital deafness (Roulet-Perez et al. 2001) clearly shows that "higher-order linguistic representational processes are relatively spared in LKS" (Stefanatos 2011: 969). In addition, theoretically, there remains a possibility that application of tDCS is still effective even in the case of no recovery. If the cortical areas related to all the relevant components and interconnections are targeted, as indicated in Table 3, both the functions of verbal auditory comprehension and verbal production in LKSaffected children might be ameliorated in this category.

The partial recovery pattern in (V) is often mistaken for no recovery because of the lack of verbal production. But in fact it is a case in which verbal auditory comprehension has virtually recovered completely, indicating that the system of spectrotemporal analysis has been sufficiently reinstated and all the relevant components and interconnections in the dorsal stream and the ventral stream have recovered enough and are functioning properly, except for the articulatory network and its interconnections with the sensorimotor interface and the combinatorial network (4 and 7). As such, on a par with the partial recovery pattern in (II), tDCS should be applied to pIFG, PM, anterior insula, and the connecting routes 4 and 7, as shown in Table 3 (see Figure 9 for reference).

In the partial recovery case of (VI) (see Landau & Kleffner 1957), in which verbal auditory comprehension has recovered incompletely/deficiently and verbal production has remained virtually nil due to the incomplete recovery of the system of spectrotemporal analysis and some serious damage from the domino effect at least on the dorsal stream, verbal externalization of I-language will be impossible. Unlike the pattern in (V) but similarly to the patterns in (III) and (IV), tDCS must be applied to the cortical regions in charge of all the relevant functions and interconnections properly to improve both functions of verbal auditory comprehension and verbal production, as specified in Table 3.

Note, incidentally, that the partial recovery patterns in (V) and (VI) as well as no recovery may likely lead to simple 'no recovery' prognosis, which might in turn lead to misdiagnosis of LKS patients in the red zone in Table 3 as having ASD/AR, and as a result, impede proper medical treatment of them.

The final case of partial recovery pattern (VII), shown in purple in Table 3, is not attested as LKS but corresponds, so to speak, to 'pure Wernicke's aphasia'. In this case, verbal auditory comprehension is supposed to have remained virtually nil, while verbal production is supposed to have recovered virtually completely. The non-existence of this recovery pattern in LKS seems to suggest that the output problem cannot be resolved, at least in theory, unless the input problem can be resolved to some extent.

In addition to tDCS application to the language-related brain regions, if the neuromodulation technique could be equally successfully applied to the relevant brain regions responsible for the co-morbidity listed in (1) and other related cognitive dysfunctions, such non-linguistic disturbances could be alleviated as well. Thus, it might be applied to the pre-motor/motor cortex for improvement of fine motor skills and the perisylvian cortex including the STG, STS, and insula for amelioration of an array of 'autistic behavioral disturbances' (see Stefanatos 2011 and references therein for the point that deficits in the perisylvian cortex are responsible for such autistic behaviors). Given that tDCS was invented and has been widely employed in treating various motor and cognitive disorders, this move for treatment of LKS seems to be quite natural (see, e.g., Hummel & Cohen 2006 for application of tDCS to rehabilitation of stroke patients).⁴³

⁴³ Bludau et al. (2014) show that the human frontopolar cortex is made up of two cytoarchitectonically and functionally distinct areas called lateral frontopolar area 1 (Fp1) and medial frontopolar area 2 (Fp2) and that Fp1 is involved in cognition, working memory and perception while Fp2 is responsible for affective processing and social cognition. If the EEG abnormalities in LKS also affect the frontopolar cortex, deficiencies in these functions would be expected, and thus possibly these areas in the frontopolar cortex might be considered as relevant targets for application of tDCS in some cases of LKS and ASD/AR as well.
4.2.3. 'Risk Markers' of LKS

Just as important as selection of effective medical interventions for LKS patients is to identify correctly potential LKS patients among the vast ASD-diagnosed population (Tharpe et al. 1991) and differentiate them especially from AR patients. In order to avoid misdiagnoses, we should pay careful attention to the following 'risk markers'.

First, it is to be recalled that epileptic seizures (clinical or subclinical) in patients with LKS can be characteristically quite readily controlled with a single anti-epileptic medication such as benzodiazepines, in contrast to other cases of epileptic seizures in children or adults, which often require the use of more than one kind of anti-epileptic medication (Pearl et al. 2001). Thus, this criterion can be the first risk marker for LKS. If the children in question fit into this character-ization, they should be suspected of having LKS as a first approximation.

The second risk marker for LKS is concerned with the presence of the EEG abnormalities with CSWS over the temporal (or perisylvian) regions. The occurrence of CSWS during non-REM sleep and its location over the brain regions can be essential for diagnosis. Although the disappearance of EEG abnormalities of LKS-affected children requires us to wait until puberty, as already mentioned, the EEG abnormalities will generally disappear by/around 15 years of age (Ramanathan et al. 2012), while children with ASD do not necessarily suffer from epileptiform EEG abnormalities, which can be infrequent and intermittent, if any (McVicar 2005).

Finally, although this is rather a psychiatric criterion, as discussed in section 2, one prominent characteristic of children with LKS is that they can develop pragmatic ability including theory of mind and can enter into interpersonal social communication without serious problems, in contrast to children with ASD/AR. As such, if a child in question has this characteristic, he/she should be counted as a possible candidate for LKS rather than ASD/AR. Thus, it is recommended to take EEG of all children with language regression during the entire time that they are asleep, including non-REM sleep, as conducted in McVicar et al. (2005), to discover potential LKS patients, who can be somewhat different from typical ASD/AR children in terms of pragmatic competence.

4.3. Implications for Developmental and Educational Therapy

In discussing problems with behavior therapy, which aims to 'train' children with developmental disorders, Konishi (2011) remarks that, although behavior therapy may be helpful to some degree toward severely autistic children who lack speech, caution must be exercised in using such a therapy toward children with Asperger's syndrome and those with developmental disorders who have come to acquire language. He points out that such a mechanical training in behavior therapy will cause too much burden on the children and their parents/ caregivers and have emotionally negative impact on the children. We believe that the same holds with respect to children with LKS who have regained verbal auditory comprehension without (sufficient) verbal production.

Given that they have functioning I-language without externalization, they should be put in a natural environment where their parents, caregivers, therapists, and peers communicate with them by using natural languages rather than artificial communication systems such as artificial gestures or pictures used in developmental therapy. Note that some children with LKS can normally regain the ability of language comprehension (but not usually the ability of language production) in due course under anti-epileptic medication. This clearly indicates that they have I-language without externalizing it. Therefore, to increase language input, natural language is better suited for stimulating children with LKS, which would help boost their language comprehension.

However, we should pay attention to the tendency that children with LKS would not have access to propositionally complex forms of thought associated with appropriate phonological forms, before the recovery of the mechanisms for spectrotemporal analysis and phonological processing (see section 3.3.3). Therefore, the use of short, simple sentences with clear phonetic articulation in natural language contexts is recommended when addressing the children with LKS.

It is also to be noted that, as discussed in section 2, children with LKS are capable of developing and maintaining pragmatic cognitive functions, unlike the quintessential case of ASD/AR, and can socially communicate with others appropriately, even if non-verbally, by reading the minds of others without any problems. Given this nature of LKS, it is important to create environments or design educational settings where children with LKS can interact closely and form emotional bonds with their parents, caregivers, educators, peers, and therapists. The children can then maximize their pragmatic cognitive ability by using their natural language. Given that it normally takes approximately four years for theory of mind to fully develop in children (Wellman et al. 2001), parents and caregivers of a child with early LKS might give up trying to foster communicative interactions by appealing to the child's own pragmatic ability, including theory of mind, under the misjudgment or misdiagnosis of their child as ASD/ AR. The parents and caregivers might misunderstand the child's behavioral disturbances, verbal auditory agnosia, and loss of expressive speech caused by EEG abnormalities as merely 'autistic' symptoms.

Moreover, the preserved pragmatic ability and willingness to communicate in LKS-affected children could possibly contribute to the restoration of their output abilities. Deonna (2000) warns that a prolonged disruption of the activity of auditory cortex can permanently impair some components of auditory functioning, and this could be applied to reproducing speech acts as well. Since LKS-affected children have longer absence of output experiences, they may give up externalizing I-language in spite of their potential abilities, unless they have a strong desire to listen to and communicate with others including parents and caregivers, demonstrating a 'dysbulia of speech' (Stefanatos 2011: 140). With ample developmental connection with others and willingness to communicate, the final stage of intake of verbal auditory input to connect with sensorimotor skills for articulation would accelerate and stimulate the emergence of speech production. Otherwise, LKS-affected children without recognition of the meaning of language and communication would finally be doomed to mutism. With a belief in LKS-affected children's hidden abilities of comprehending linguistic input and with a hope of their being able to externalize I-language, parents and caregivers should continue to engage the children in natural daily conversations and show them the joy of communicating with others.

Finally, children with LKS show fluctuations with respect to the degree of linguistic and cognitive recovery, which often frustrates them and their parents/ caregivers. Accordingly, it is also vital for them to be raised and provided with therapy in a stress-free setting. Unfortunately, there is no established special therapy currently available for children with LKS (see Jansing 2007 and references therein).⁴⁴ Accordingly, there is no special educational institution designed for them either (see e.g. Penn et al. 1990). Thus, it is urgently hoped for linguists, doctors, therapists, educators, and parents/caregivers of children with LKS to collaborate closely in creating a better educational condition in the near future (see Gordon 1990).

5. Concluding Remarks

This paper has examined the so-called Landau–Kleffner syndrome (Landau & Kleffner 1957), particularly from the perspective of I-language and the critical period hypothesis. We argued that this childhood language disorder provides further empirical foundations to the critical period for first language acquisition and modularity of mind as well as modularity of FL, while elucidating the linguistic mechanisms behind the language disorder in LKS by invoking the framework of Hickok & Poeppel's (2007) dual-stream model of speech processing. It was also claimed that the concept of what we called *early LKS* holds a key to differentiating children with LKS from those with ASD/AR.

From a medical perspective, we first emphasized the importance of discovering potential LKS-affected children from the vast ASD-diagnosed population by paying close attention to the three 'risk markers': (i) whether or not epileptic seizures (clinical or subclinical) in the patient can be readily controlled by a single anti-epileptic medication; (ii) whether or not the EEG abnormalities with CSWS exist over the temporal (or perisylvian) regions during non-REM sleep and can be normalized by around 15 years of age; and (iii) whether or not the patient can develop pragmatic knowledge, including theory of mind, to the extent that he/she can engage in interpersonal social communication, even non-verbally.

Much more careful scrutiny is urgently called for in diagnosing such children with early language disorder and other cognitive dysfunctions. Especially, the number of autistic children has been dramatically increasing for the last few decades (see Sumi 2015 and references therein), so it can be presumed that children with early LKS are included in the large population. This implies that more early-LKS patients might exist than are being reported, given the possibility

⁴⁴ But see Hurley & Hurley (2009), who report a case study of auditory remediation for a patient with LKS, which employs two distinct auditory training programs (Fast ForWord[®] and dichotic interaural intensity difference (DIID) training). They argue that the improvement of the patient's auditory system as a result of the two training programs suggests "the plasticity of the central auditory nervous system" and provide "a viable auditory remediation therapy" for LKS patients. See Hurley & Hurley (2009) for details.

of mixing the loss of the early-stage language development in LKS with the congenital lack of language development in addition to developmental cognitive and co-morbidity problems seen in other disorders like ASD/AR. Unfortunately, the necessity for revision of the original definition of LKS has not been well understood and shared by all medical specialists (see Stefanatos 2011). If any LKScharacteristic EEG abnormalities can be detected correctly at an early stage and (potential) epilepsy can be controlled with appropriate anti-epileptic medicine, clinical interventions would become possible to regain the language development.

Furthermore, from a linguistic viewpoint, we first analyzed the mechanisms behind the verbal auditory agnosia and loss of expressive speech in LKS on the basis of Hickok & Poeppel's (2007) dual-stream model of speech processing, and then emphasized the importance of eliminating the EEG abnormalities with the use of appropriate anti-epileptic medication and the intake of vitamin substance to improve the function of mitochondria in neurons (see fn. 8) in order to facilitate language input internally and establish I-language before the critical period ends. With I-language establishment in time in terms of the critical period hypothesis, language restoration becomes possible theoretically as long as linguistic input has been processed properly before the end of the critical period. In addition, in order to solve the input problem on lexical acquisition and output problem on I-language externalization of LKS patients, as a promising protocol for medical intervention, we suggested the possible loci for application of tDCS to seven recovery patterns of LKS patients as external medical intervention, as summarized in Table 3, based on Hickok & Poeppel's (2007) dual-stream model of speech processing. We also claimed that the EEG abnormalities are the culprit of LKS and that the language disorder and concomitant developmental cognitive and behavioral disturbances are secondary epiphenomena, suggesting that the restoration of the language function as well as other cognitive and sensorimotor functions would be possible by resolving the neural dysfunction and disruption among the relevant brain regions with proper application of tDCS. In sum, as explained above, using both internal and external medical intervention is highly recommended to treat LKS patients.

In addition, it is extremely important to discover children with early LKS, and closely observe and analyze the patterns of language and other cognitive development after they have recovered from LKS and re-started externalizing I-language. This would lead to providing further empirical evidence for Lenneberg's critical period hypothesis for first language acquisition and for Chomsky's modularity of mind and modularity of FL, as discussed in section 3. As our final speculation, let us touch upon LKS in connection with the issue of evo-devo on human language based on our assumption of early-LKS patients' possible 'linguistic big bang' in first language acquisition. Chomsky (2010) speculates that the human language capacity evolved as a result of some genetic mutation, which led to some neural re-wiring of the brain around 50,000 years ago in Africa and that externalization of I-language took place at some point subsequent to the evolutionary event. Even though it is surely impossible to pin down the cause of externalization of I-language at the moment, LKS seems to suggest one possible scenario. Recall that we characterized LKS as a case where externalization of I-

language is hampered by neural dysfunction caused by epileptiform abnormal electrical discharges as reflected in the EEG abnormalities. Suppose that some Homo sapiens individual who had I-language without its externalization was attacked by a series of epileptic seizures (clinical or subclinical) for some reason, which led to neurally connecting unconnected parts of the brain, resulting in externalization of I-language.⁴⁵ If this speculation is not widely off the mark, a patient with LKS might well be regarded, so to speak, as a 'living fossil' or more correctly a 'living proof' of reflecting the state of I-language in our ancestors before its externalization in the evo-devo context. Although this is a mere speculation, it might be compatible with Chomsky's (2010) view that the I-language externalization problem "may not have involved an evolutionary change—that is, genomic change" (p.61).

Last but not least, we would like to emphasize the importance of investigating LKS from both 'bottom-up' and 'top-down' perspectives in a collaborative and systematic way, so that we can discover the real cause(s) of the clinical symptoms and gain more understanding of the underlying mechanisms behind language and other cognitive functions in the brain. On one hand, the bottom-up approach to LKS has been extensively attempted in the field of medicine, accumulating relevant data on LKS from patients, as has been cited in this paper. On the other hand, the top-down approach to LKS has not been seriously undertaken thus far, and this is exactly where the field of biolinguistics can play a pivotal role and make a great contribution. They can provide a theoretical model of language and related cognition in light of biology and linguistics. It is our sincere hope that the present study will serve to facilitate further collaboration among professionals, including linguists, biologists, cognitive neuroscientists, medical doctors, developmental therapists, educators, parents/caregivers, and so forth in discovering more children with (early) LKS and zeroing in on the ultimate cause(s) and cure for the disease.

Landau concludes his remark with the following hope:

Just as Schilder's disease has become a more intellectually gratifying illness called *adrenoleukodystrophy*, Frank Kleffner and I hope that an organized research effort may spare the next generation of pediatric neurologists from the useless chore of recalling our names.

(Landau 1992: 353)

It is also our desire that 'Landau–Kleffner's dream' will come true in the near future, with the top-down and bottom-up approaches converging on a concerted enterprise and endeavor for this grand dream.

⁴⁵ For discussion of the effects of epilepsy on neuronal circuits in the brain, see e.g. Holmes (1991), Holmes & Ben-Ari (2001), Lynch et al. (1996). See also Benítez-Burraco & Murphy (2016) for discussion of the oscillopathic nature of language deficits in ASD. Although we will leave investigation into the oscillopathic nature of language and cognitive deficits in LKS to another occasion, we believe that detailed oscillopathic comparative study between ASD/AR and LKS from the perspective in Benítez-Burraco & Murphy (2016) will shed new light on the evo-devo issue and discovery of new protocols for ASD/AR and LKS as well.

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\star BRIEFS \star

Why Nurture Is Natural Too

Samuel David Epstein

Both within and outside generative linguistic circles, it is often claimed that at least two factors determine organismic development, hence determine language development in humans. First, an innate capacity, perhaps species-specific as well, that allows humans (but not e.g. cats) to acquire linguistic systems such as the one you are now using to transduce 'retinal images' to meanings. The second factor is, of course, the environmental input. Thus, we have the standard dichotomy 'nature vs. nurture'. The influence of the environment is amply demonstrated, for example, through naturalistic experimentation indicating that a normal child raised in Japan acquires 'Japanese', but one raised in the Philippines develops 'Tagalog'. Hence, the central role of the environment in language development.

However, it is important to remember-as has been noted before, but perhaps it remains underappreciated—that it is precisely the organism's biology (nature) that determines what experience, in any domain, can consist of (see Chomsky 2009 (originally 1966) for discussion (and resurrection) of the Rationalist roots of the idea, especially pages 103–105, concerning Cudworth and Humboldt; more recently, see e.g. Gould & Marler 1987, Jackendoff 1994, Lust 2006, Lewontin 2008, and Gallistel 2010). To clarify, a bee, for example, can perform its waggle dance for me a million times, but that 'experience', given my biological endowment, does not allow me to transduce the visual images of such waggling into a mental representation (knowledge) of the distance and direction to a food source. This is precisely what it does mean to a bee witnessing the exact same environmental event/waggle dance. Ultrasonic acoustic disturbances might be experience for my dog, but not for me. Thus, the 'environment' in this sense is not in fact the second factor, but rather, nurture is constituted of those aspects of the ill-defined 'environment' (which of course irrelevantly includes a K-mart store down the street from my house) that can in principle influence the developmental trajectory of one or more organs of a member of a particular species, given its innate endowment.

This manuscript was originally drafted in 2006 and has been used in my classroom teaching ever since. A number of people found it to be clarificatory and urged me to make it more widely available than in just my classes. I thank *Biolinguistics* for making this possible and especially two reviewers for helpful comments. Many thanks also to Kleanthes Grohmann, the editor, for his patience, valuable suggestions, and support. I am also indebted to Noam Chomsky. Without his support of this manuscript, it would never have made it outside the classroom. For extensive and invaluable discussion of the ideas expressed here I am very grateful to Elaine McNulty. Thanks also to Hisatsugu Kitahara, Rick Lewis, Jim McGilvray, and T. Daniel Seely for very helpful discussion. All errors are mine.



In the biolinguistic domain, the logic is no different. The apparent fact that exposure to some finite threshold amount of 'Tagalog' acoustic disturbances in contexts (originating from outside the organism, in the 'environment') can cause any normal human infant to develop knowledge of 'Tagalog' is a property of human infants. Of course, even here as I seek to clarify, it is misleading but unfortunately terminologically unavoidable that I characterize the acoustic disturbance inputs as 'Tagalog' and the knowledge system internalized, as also 'Tagalog', inviting the mis-inference that the acoustic input and the state attained (knowledge) are identical, a mis-inference often invited by claiming (even in some generative literature) that "the child is exposed to the language, or to sentences of the language". The corresponding fact that exposure to a finite number of 'Japanese' acoustic disturbances can cause knowledge of 'Japanese' to develop in a human, is similarly a hypothesis about properties of human infants (indicating one respect in which they (we) differ from all known objects in the universe). Thus the standard statement that on the one hand, innate properties of the organism and, on the other, the environment, determine organismic development, is profoundly misleading. It suggests that those environmental factors that can influence the development of particular types of organisms are definable, non-biologically-as the behaviorists sought, but of course failed, to define 'stimulus' as an organism-external construct. We can't know what the relevant develop-mental stimuli are or aren't, without knowing the properties of the organism. Indeed, debates have raged, and continue to rage (I think unnecessarily) regard-ing this very nature-nurture dichotomy. Within the field of Linguistics, broadly construed, this is instantiated by the ongoing and contentious poverty of the stimulus 'debate' (where, perhaps importantly, 'stimulus' is an illusory and failed behaviorist concept, precisely due to its purely externalist definition). But of course, organism external 'stimuli' cannot possibly suffice to explain any aspects of the developed adult state of any organism. In fact, all aspects of an organism's development involve the organism, including the capacity of the organism to develop differently depending on the 'experience' the organism undergoes, or more precisely constructs, given its anatomical properties. It is a (conditionally stated) biological property of a normal human infant that, if exposed to these noises (or for sign language, certain perceived hand shapes in motion in fact, just photons hitting the retina), then the organism develops one way cognitively. If exposed to others (or none), its cognitive linguistic develop-ment follows another course. Other noises (e.g. jet planes) or perceived motion of limbs (e.g. watching the hands of a performing violinist) have no effect on this particular (i.e. linguistic) aspect of development. That very (slight) develop-mental indeterminacy on the one hand and (infinite) rigidity on the other-and their precise ranges-are defining properties of the organism, in the sense that they cannot be stated independently of the organism. The exact same variant exposure to 'Tagalog' vs. 'Japanese' finite acoustic disturbances has no corres-ponding effects on the development of a cat, as far as we know. So, in this case, the 'environment' is held constant, but the developmental trajectory of the two organisms differs. This then must be due to innate organismic differences in capacities enabling the conversion of experience into growth. The input to the language knower (acoustic disturbances) and the state attained (knowledge of

language) are vastly different, just as the nutritional input given to a tadpole and the frog anatomy it develops are not to be conflated (in this case or in any account of biological development).

Conversely, if the organism is held constant (two human infants) and the exposure is varied (a finite number of 'Tagalog' vs. 'Japanese' acoustic disturbances hitting the eardrum), then any differences in the development of the two infants must be due—not to 'the environment' as is usually confusingly stated—but to a species-level property by which these variant exposures are mapped to those particular developmental trajectories resulting in particular anatomical (including mental) states. In this sense, 'language variation' (in humans) is, contra much standard locution, innate (biologically constrained), as was instantiated clearly in, for example, the Government and Binding/Principles and Parameters Theory of Chomsky (1981), wherein the parameters (with unspecified values) were of course part of the innate endowment, delimiting the possible range of variation that could in principle be attained. That is, it is a defining property of the species that the possible class of variant developmental trajectories is determinable by variant experiences of a particular type. Again, experience is constructed by the organism's innate properties, and is very different from 'the environment' or the behaviorist notion of 'stimulus'. As Kleanthes Grohmann (p.c.) points out, the use of the (organism-independent, externalist) term 'data' in 'primary linguistic data' (Chomsky 1965) may also be misunderstood, as the exact same external data has differential effects on different organisms given their internal constitution (see among others Lightfoot 1989 and much subsequent work). As Descartes importantly noted, regarding the environmental input:

Nothing reaches our mind from external objects through the sense organs except certain corporeal motions [...] But neither the motions themselves nor the figures arising from them are conceived by us exactly as they occur in the sense organs [...] Hence it follows that the very ideas [e.g. phonemes, syntactic categories, meanings, laws, rules, representations, constraints, in fact, all postulates proposed by linguists, none of which occur in the environmental input—SDE] of the motions themselves and of the figures are innate in us. (Descartes 1648/1985: 303–304)

Simply put, the 'environmental input' (for e.g. spoken language) is some finite number of acoustic disturbances, while the cognitive state attained (linguistic knowledge of e.g. syntax, semantics, phonology, morphology, and their interactions) is not acoustic nor does the knowledge system developed by the language learner display finite generative capacity.

Contrary to the implication of the standard nature vs. nurture dichotomy, 'nurture' is then itself definable only in terms of nature, and 'human language variation' is a species property or capacity frequently characterized, inaccurately as: 'that which is not innate'.

As a final note, even though Chomsky himself played a, or more likely, the central role in illuminating this very crucial distinction between 'environment' (or the behaviorist notion of 'stimulus') on the one hand and organismic experience on the other, even his writing does not invariably make explicit the profoundly important and subtle differences he reveals. Thus, for example,

Chomsky (2005: 1) writes that three factors determine human language development: "genetic endowment (the topic of Universal Grammar), experience, and principles that are language- or even organism-independent". But expressed this way, experience—or more precisely, that which can be experienced, as determined by an organism's anatomical (including cognitive) constitution, as opposed to that which is experienced by a particular organism (as determined by historical contingency, Chomsky's clear intent here)—is not entirely transparent.

Thus in addition to distinguishing the externalist notions of 'environment/ stimulus' from the internalist concept 'experience', Chomsky's revolution importantly embraces two distinct (perhaps confusable) but very closely related interpretations of 'experience':

- (1) That which is experienc*able* given an organism's constitution (see e.g. at least as early as Chomsky 1966 as well as Chomsky 1975).
- (2) That which a particular organism actually happens to experience in its particular lifetime.

The latter is determined by a combination of (i) what an organism can possibly experience as determined by its biological constitution and (ii) historical contingency. Thus the fact that I experienced tokens of the (not invariant) acoustic disturbance 'cat' as containing three ordered phonemes, each a bundle of distinctive features, with the initial one mapped to its aspirated allophonic variant, was made possible by my innate language capacities (universal phonology/phonetics), while the fact that I was exposed to these particular acoustic disturbances and not to, say, multiple (acoustically distinct) occurrences of *gato* was an accident of where I happened to grow up.

What I happen to in fact experience is thus necessarily a proper subset of what I can experience, and thus to (at least, ordinally) distinguish the first factor (genetic endowment) from a second factor defined as 'experience' may lead (human) readers to a confusing (linguistic) experience, the avoidance of which is naturally worth nurturing. Finally, certain aspects of experience are presumably due to third factor properties of the organism as well, and it is an empirical issue to distinguish which aspects of experience are constructed by uniquely linguistic capacities from those constructed by more general laws, or by some interaction of the two. But, if indeed there are a trinity of factors, as seems unavoidable, then not only is the 'vs.' in 'nature vs. nurture' a false opposition, but its binarity is singularly unnatural.

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\star FORUM \star

Notice

At the end of a busy year, I would like thank everyone involved in creating the 10th volume of *Biolinguistics*. After a slight drop in submissions, the journal really picked up in 2016. And we are currently busy at work to create a very special *special issue* for next year's volume 11, in 2017, the 50th anniversary of the publication of Eric H. Lenneberg's *Biological Foundations of Language* (New York: Wiley, 1967). Details on this special issue and submission procedures can be found here:

http://www.biolinguistics.eu/index.php/biolinguistics/announcement/view/61

We have also created improved social media distribution channels, something we will increasingly make use of, thanks to Patrick C. Trettenbrein, who also provided fast and efficient IT solutions that crept up along the way. If you're on Facebook, do not miss out on the *Biolinguistics* Journal page:

https://www.facebook.com/biolinguistics

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