# THE BIOLOGY OF LANGUAGE UNDER A MINIMALIST LENS: PROMISES, ACHIEVEMENTS, AND LIMITS

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# THE BIOLOGY OF LANGUAGE UNDER A MINIMALIST LENS: PROMISES, ACHIEVEMENTS, AND LIMITS

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# Editorial: The Biology of Language Under a Minimalist Lens: Promises, Achievements, and Limits

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**Editorial on the Research Topic**

**The Biology of Language Under a Minimalist Lens: Promises, Achievements, and Limits**

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Language can be approached from a variety of perspectives, e.g., philosophical, social, historical, psychological, biological, or physical, and it has been investigated from those perspectives throughout the history of language study. Among them, the generative enterprise was launched by Noam Chomsky in the 1950s (Chomsky, 1975), identifying language as a biological object of study. While the biological nature of language was clearly illustrated in Lenneberg's (1967) seminal work, linguistic theorizing including generative grammar has been too "linguistics-specific" to marry biology. However, with the advent of the minimalist program (MP) for linguistic theory advocated by Chomsky (1993), the view toward the architecture of language has drastically changed in the field. In MP, the core of language as a mind/brain-internal system is regarded as a computational mechanism that generates hierarchically structured expressions to link them to the sensorimotor (SM) and conceptual-intentional (C-I) systems. The computational mechanism is a syntactic combinatorial operation called Merge, which recursively combines lexical items as conceptual atoms or already constructed syntactic objects to yield new syntactic objects. Thanks to such radical simplification of the architecture of language in theory, MP has paved the way toward exploring how to link language with biology in the context of biolinguistics (Jenkins, 2000), even though there are still significant challenges for the linking (Poeppel and Embick, 2005; Poeppel, 2012).

Almost 30 years have passed since the appearance of MP in Chomsky (1993) and a lot of research has been carried out both within the linguistics proper and its related fields thus far, and we think it is about time to evaluate whether and/or to what extent the study of the biology of language has been furthered and deepened in the context of the minimalist program, critically examining its promises, achievements and limits from a multitude of angles. In keeping to this goal of our Research Topic in the current volume, the contributors focus on aspects related to one or more of the following broad themes in the study of the biology of language under a minimalist lens: (i) how (knowledge of) human language is to be characterized; (ii) how (knowledge of) human language develops (ontogeny of language); (iii) how (knowledge of) human language is put to use; (iv) how human language is implemented in the brain; (v) how human language evolved (phylogeny of language) (the questions raised in e.g., Chomsky, 1986; Jenkins, 2000, among others).

With respect to the nature of knowledge of human language, Haspelmath takes issue with the traditional view in generative grammar that the building blocks of languages (features, categories, and architectures) are part of an innate blueprint for human language, arguing that they are to be derived from convergent cultural evolution, which is in fact more in line with the minimalist tenet of attributing as few domain-specific elements as possible to what he calls *human linguisticality*, or the biological capacity for language. He also emphasizes the importance of exploring human linguisticality from the perspective of Greenbergian approach to comparison given the structural uniqueness of languages with respect to lexicon, phonology, and morphosyntax. Furthermore, Progovac points out the need for sorting out what to keep and what to discard from among the fundamental assumptions in the current version of the minimalist program. Adopting a gradualist approach to the evolution of syntax, she argues that while binarity and syntactic hierarchy of projections are stable and useful postulates for biolinguistic considerations, the claim that Merge *per se* yields infinite recursion subsuming Move is harmful from the standpoint of both linguistic analysis and language evolution considerations. In addition, Gil and Shen address the relation between cognition and grammar by focusing on three different phenomenological domains (compositional semantics, metaphors and schematological hybrids), arguing that there are two kinds of cognitive structures, symmetric and asymmetric cognition, and that the latter is derived from the former with the introduction of asymmetric thematic-role assignment in grammar. They also claim that the distinction between symmetric non-grammatical and asymmetric grammatical cognition manifests itself in phylogeny, ontogeny, and the architecture of human cognition.

Concerning the ontogeny of human language, addressing first language acquisition in the context of minimalism, Goodluck and Kazanina make a case for the superiority of drawing on Merge and interface conditions/constraints such as working memory capacity in accounting for the contrast between children and adults with respect to word order and phrase structures, pronominal structures and long-distance dependencies. In their opinion, among the advantages of this view is that the theory of child language acquisition does not have to account for the unlearning of an incorrect grammar on the way to adult language.

With regard to how (knowledge of) language is put to use, addressing the issue of code-mixing in both neuro-typical and neuro-atypical speakers/signers, Aboh argues that code-mixing receives a natural explanation by interaction between an innate cognitive process of what he calls *recombination* as an instance of general Merge and executive functions in the brain which are responsible for vocabulary insertion. It is claimed that recombination allows language learners to select relevant linguistic features from heterogeneous inputs to yield new syntactic objects for code-mixing in hybrid grammars.

Concerning the issue of how (knowledge of) language is implemented in the brain, based on a fMRI study on sentence processing of nested and cross-serial dependencies, Tanaka et al. argue that their new concept of "Merge-generability," i.e., whether the structural basis for a given dependency is provided by Merge, holds a key to a better understanding of the nature of human language characterized by strong generative capacity (Chomsky, 1965). They demonstrate the prominent localized activation in the left frontal cortex as well as the left middle temporal gyrus and angular gyrus in response to Merge-generable dependencies, providing evidence for the specialization of these brain regions for syntactic processing. Furthermore, based on event-related potential (ERP) studies, Gallagher tests, and offers evidence for, the minimalist program (MP) prediction that organisms that possess the faculty of language (FL) cognitively process "language-like systems" in a qualitatively distinct fashion, defining language-like systems in terms of recursion criteria. He points out that processing language-like systems with recursion such as certain domains of mathematics and music will crucially elicit the common language-related ERPs [the left-anterior negativity (LAN), N400, and P600] on a par with language.

Finally, regarding how (knowledge of) human language evolved in our species, there has been a debate over the saltationist vs. gradualist view of phylogeny of language. From a perspective of paleoanthropology, Tattersall espouses the non-gradualist/punctuationist view of language evolution in support of the position advocated in the minimalist program (e.g., Bolhuis et al., 2014). He argues that modern symbolic human behavior patterns and cognition emerged suddenly in a short period of time, whereas he casts doubt on the claim that externalization of I-language came after internalization of it in the hominin evolution of language. On the other hand, in favor of the gradualist view of language evolution, Corballis takes issue with the fundamental tenet of the minimalist program that unbounded generativity of I-language is due to Merge, which is unique to our species, *Homo sapiens*. Instead, he argues that such a property of I-language derives from our ability of mental travel in time and space, or more broadly our ability of imagination, which is also unbounded and recursive in generativity and is shared with non-human animals that move, although the degree of power has been expanded in our species. Miyagawa and Clarke put forth yet another version of gradualist or incremental approach to the emergence of an infinite, recursive combinatorial operation of Merge. They argue that apparent simple cases of compositionality as observed in non-human primate call combinations of the Old World monkeys are implemented by means of what they call "a dual-compartment frame" rather than Merge and suggest that the dual-compartment frame may have served as an input to Merge in the evolution of human language. Also in line with the gradualism, while addressing the issue of the evolvability of words in the framework of the minimalist program, Clark considers what needed to evolve for the emergence of words in human language, pointing out that, how lexical items and the lexicon evolved is especially poorly understood. In proposing what properties lexical items have and what determines these properties, he claims that the pointers and packaging approach to the structure of lexical entries (Glanzberg, 2018) can prove to be illuminating in exploring the evolution of words in our species. From a broader perspective, addressing current minimalist biolinguistic and usage-based approaches as the two main theoretical frameworks for the evolution of language, Pleyer and Hartmann point out that, unlike the traditional views in each approach, recent developments in each of the two approaches have seen more convergences than differences. They argue that the two approaches are getting closer in terms of four contentious issues: modularity/domain-specificity, innateness/development, biological/cultural evolution, and knowledge of language/its description. Lastly, in connection with the issue of phylogeny of human language as it is concerned with historical language change in cultural evolution, Ceolin et al. statistically demonstrate that less visible taxonomic traits such as syntactic parameters modeled within the generative biolinguistic framework provide insights into deep-time language history as a new tool of phylogenetic linguistics, contrary to long-standing assumptions in the field.

Needless to say, more interdisciplinary research is called for to pin down the biological nature of language, and it is hoped that our Research Topic in this volume will provide a stimulating trigger for more active collaborative research in the various fields relevant for the biology of language, going beyond the current minimalist program into the future.

## AUTHOR CONTRIBUTIONS

AB-B, KF, KH and LP conceived, wrote, and approved the manuscript. All authors contributed to the article and approved the submitted version.

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# The Minimalist Program and the Origin of Language: A View From Paleoanthropology

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In arguing that articulate language is underpinned by an algorithmically simple neural operation, the Minimalist Program (MP) retrodicts that language emerged in a short-term event. Because spoken language leaves no physical traces, its ancient use must be inferred from archeological proxies. These strongly suggest that modern symbolic human behavior patterns – and, by extension, cognition – emerged both abruptly and late in time (subsequent to the appearance of *Homo sapiens* as an anatomical entity some 200 thousand years kyr ago). Because the evidence is compelling that language is an integral component of modern symbolic thought, the archeological evidence clearly supports the basic tenet of the MP. But the associated proposition, that language was externalized in an independent event that followed its initial appearance as a conduit to internal thought, is much more debatable.

**Keywords: evolution, paleoanthropology, origins, exaptation, language and thought**



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## INTRODUCTION

Spoken language is famously ephemeral. In the absence of preserved writing systems language leaves no direct trace in any material record, so that its putative employment by hominids at virtually any point in human prehistory has to be inferred from indirect proxy evidence. One might hope that the fossil record of early humans would be helpful here; but in the event, this turns out to be a problematic line of inquiry. There is obviously a relationship of some kind between the morphology of the upper vocal tract (roofed by the skull base) and the physical ability to produce the sounds used in the articulate speech through which we express language; but the nature of that relationship remains highly controversial (Lieberman, 2012; Fitch et al., 2016). What is more, while we may safely conclude that any fossil hominid displaying the distinctively modern human retracted-face splanchnocranial anatomy had possessed the potential for speech production, it is far from evident that the potential for speech necessarily implies a concomitant possession of language. For these reasons, putative proxies for speech and language use are more usefully furnished not by fossils, but by the archeological record, our only first-order archive of ancient human behaviors. Frequently, though, archeological evidence offers us no more than shadowy or indirect traces of the full complexity of past human behaviors. And in consequence it is particularly important that any conclusions we draw from it about when and how our human precursors acquired language should align appropriately with the broader contexts in which we might reasonably expect this unique human property to have arisen. Those key contexts include both what we know of evolutionary pattern in general, and what we know of the intrinsic properties of language itself.

In an ideal world, contextual considerations of both kinds would have acted as constraining influences on our perceptions of when and how language evolved, and on the kinds of proxy evidence for it that might be considered satisfactory. But in practice they seem to have done little to limit the variety of language proxies that different observers have been willing to accept; and the resulting lack of agreement has quickly polarized, leaving very little middle ground between the possible extremes. On the one hand, there are those who believe that language is so complex and multifaceted that it can only have emerged over a very long period, under the guiding hand of natural selection. This would have occurred, by implication almost inevitably, as complex societies and sophisticated vocal communication gradually co-evolved. On the other side are those who think that language merely involved a tweak to prior systems of vocal communication and mental information processing, and that the transition from non-linguistic to linguistic was rapidly accomplished, in a single bound.

In the first camp are those aligned with Stephen Pinker and Paul Bloom, who roundly declared a quarter-century ago that "every detail of grammatical competence . . . must have conferred a reproductive advantage on its speakers . . . and there must be enough time and genomic space separating our species from non-linguistic primate ancestors" (Pinker and Bloom, 1990: 745). In the other camp are those who broadly agree with Derek Bickerton that "true language, via the emergence of syntax, was a catastrophic event, occurring within the first few generations of *Homo sapiens*" (Bickerton, 1995: 69). Of late, Lieberman (2013, 2015) has been a particularly energetic advocate of the former view, whereas Bolhuis et al. (2014, 2015) have equally vigorously defended the latter one. In terms of the absolute time-scale involved in language acquisition, some authorities (e.g., Uomini and Meyer, 2013) would equate the neural processes underpinning language with those underlying Acheulean stone-working techniques, thereby extending the rudiments of language back to almost two million years ago. In contrast, those accepting the spirit of Bickerton's declaration (including this author: see Tattersall, 2012) would look for the abrupt acquisition of full-blown language at some time under 200 thousand years (kyr) ago, when the first modern humans appeared.

The Minimalist Program (MP: Chomsky, 1993, 1995) sees language as underpinned by an algorithmically simple interface between sensorimotor and conceptual-intentional systems that were co-opted from pre-existing functions or potentials. The MP thus has clear and immediate relevance to the long-running dispute over language origins, being very comfortably compatible with – indeed, predicting – the notion that language as we recognize it today originated suddenly, at some definable point in the human past. By itself, the MP does not predict the timing of this event; but its emphasis on algorithmic simplicity coexists uneasily, at best, with the idea that language is simply too rich and too complex to have been achieved quickly and that it must therefore have evolved gradually and incrementally over the eons. Accordingly, in the absence of any clearly articulated alternative, independent demonstration that language was acquired in a short-term event may be taken as support for the MP's tenets.

## THE MATERIAL RECORD

The merits of the two major opposing viewpoints continue to be debated among linguists and others on a variety of intrinsic grounds; but from a paleoanthropological perspective the choice between the longer and shorter timescales, or between the gradualist and punctuationist models of origin, will most obviously be resolved by extrinsic archeological evidence. Most proponents of gradualism rely on evidence for behavioral "complexity," in one form or another, as proxy for linguistic status. Complex behaviors such as grinding ochre, the production of lithic utensils (at varying stages of sophistication), and the non-functional modification of objects, have all been taken at one time or another as behaviors sufficiently complex to imply that their practitioners had language. The problem here, though, is that there are evidently many different ways in which to be an intelligent hominid with complex behaviors, not all of them necessarily involving linguistic skills. What is more, most of the purely functional behaviors that we associate with the Paleolithic simply do not appear to have mapped directly on to the unique modern cognitive mode with which we can firmly associate language (Tattersall, 2012). In seeking indicators of modern cognitive status, we thus need to look beyond strictly technological and economic activities in the material record and instead to focus on evidence for the kinds of behaviors that are uniquely governed by the modern human style of information processing to which we can reasonably correlate language.

The most fundamental distinguishing property of modern human cognition lies in its "symbolic" nature, the term deriving from the fact that – just as in language – the individual's external environment and internal mental states are deconstructed by the thought process into a vocabulary of discrete symbols that can be recombined, according to rules, to make statements about the world not only as it is directly perceived by the senses, but as it *might* be. The human symbolic capacity, in other words, imposes an arbitrary discreteness on what is otherwise a perceptually continuous world, allowing the entities thereby distinguished to be both mentally manipulated and conceptually extended. And because the elements of symbolic thought map closely onto the vocabularies of words that we use as linguistic building-blocks, it is highly probable that we are justified in using anything we can legitimately regard as a routine material expression of symbolic mental operations as a proxy for the hominid possession of language. This view fits very well with the perspective of the clinical and theoretical linguist Wolfram Hinzen, who has recently argued very persuasively that language and thought are not "two independent domains of inquiry," (Hinzen, 2012: 640), and has more specifically espoused the notion that thought is inherently grammatical. In consequence, only where we have evidence for symbolic thought can we confidently conclude we have evidence for language.

One category of objects that might legitimately be regarded as proxies for modern cognition, and hence for language, is the overtly symbolic: representational images, for example, or plaques bearing engraved signs. But since spoken language is a community possession, we also need evidence that objects which might individually be seen in this light were actually integrated into a larger symbolic tradition: evidence that is best furnished by the existence of multiple examples within the same archeological context. The production of symbolic objects is, moreover, only one offshoot of the modern cognitive capacity. Combined with high technological skills, the routine ability to imagine that the world might be other than it currently is should reasonably be expected to express itself in a distinctive pattern of innovation in the archeological record. After all, cognitively modern human beings have radically altered the face of the planet in a geological eyeblink, so that at the start of the process of acquisition a detectable inflection in the material record would reasonably be expected.

From the very beginnings of the archeological record, technological innovation was invariably followed by an extended period of stasis lasting from hundreds of thousands of years to over a million (Tattersall, 1998). But at around 100 kyr ago, a hundred millennia after the appearance in Africa of anatomically modern *Homo sapiens* (McDougall et al., 2005), a pattern of additive change was clearly beginning to assert itself within the cultural period known to African archeologists as the Middle Stone Age (MSA). Ochre was being mixed into pigments (Henshilwood et al., 2011); and marine shells, pierced for stringing into bodily ornaments and often bearing traces of pigment, occur at several sites (e.g., Bouzouggar et al., 2007; d'Errico et al., 2009). By around 80 kyr we find multiple geometrically engraved plaques at Blombos Cave in South Africa (Henshilwood et al., 2002, 2009), a site which has also yielded evidence for sophisticated multi-stage material-hardening technology (Mourre et al., 2010) – one of very few Paleolithic technologies that almost certainly mandated symbolic planning abilities. The nearby Pinnacle Point caves also have evidence for fire-hardening by 72 kyr or even earlier (Brown et al., 2009), and they also furnish indications of complex forward planning in the exploitation of marine resources (Marean, 2014). Hard on the heels of these developments, around 70 kyr ago, modern humans expanded beyond the confines of Africa and rapidly took over the Old World, driving all resident hominid competition to extinction by about 40 kyr ago (see Tattersall, 2012), a point at which we also see the initiation of a long and extraordinary tradition of cave art and other symbolic activities, not only in Europe but also in Sulawesi (Aubert et al., 2014) and Borneo (Aubert et al., 2018). In a remarkably short time, change replaced stasis as the default mode in the archeological record: rather than adapting old tools to new uses when environmental exigency demanded, humans were inventing new ones. A revolution in the relationship of humans to the world around them had been accomplished, in a mere few tens of thousands of years.

As the late Pleistocene began, *Homo sapiens* was far from the only species of *Homo* around; and the best-known of its congeners were undoubtedly clever and resourceful. So perhaps it is unsurprising that one of them would have occasionally produced an object of a kind that a symbolic hominid might also have made: a mollusk shell some 500 kyr-old with zig-zag-engraving, putatively the work of *Homo erectus* (Joordens et al., 2014); eagle talons notched for stringing by early *Homo neanderthalensis* (Radovčić et al., 2015); a deep hash engraving probably made by late Neanderthals (Rodríguez-Vidal et al., 2014); some paint on Spanish cave walls that arguably predated Cro-Magnon arrival (contrast Hoffmann et al., 2018 with Slimak et al., 2018). But it is important to appreciate that all such expressions are floating points, and that there is no wider archeological context suggesting that symbolic reasoning of the modern human kind was an established characteristic of any Neanderthal society. The Neanderthals left behind them a record suggesting that they were without doubt intelligent and resourceful. But there are evidently many ways to be a clever hominid; and, despite a few straws in the wind (e.g., Rodríguez-Vidal et al., 2014; Radovčić et al., 2015), this record does not suggest that the symbolic manipulation of information that is best equated with language was a routine component of the Neanderthal cognitive repertoire (Tattersall, 2012). Indeed, the overwhelming message of the extensive Neanderthal archeological record is that these sophisticated and large-brained hominids related to their environments, and to each other, in a very different way from the Cro-Magnons who replaced them. Smart they and their non-modern contemporaries unquestionably were; but there is evidently more than one way in which to be a highly intelligent hominid, and only in the case of *Homo sapiens* do we have clear evidence of a cognitive revolution in the late Pleistocene. The most convincing evidence for this is furnished by the undisputable fact that, once anatomically modern humans began to show evidence for a radically new behavioral pattern, they rapidly left their natal continent and took over the entire Old World, substantially replacing resident hominids wherever they went – *Homo erectus* in Asia, *Homo neanderthalensis* in Europe – and everywhere substituted a cultural pattern of restless and continual change for the ancestral pattern of technological uniformity interspersed with rare innovations.

So how did this extraordinary transition occur, involving as it did a qualitative leap and not simply an incremental cognitive improvement of the kind that probably accompanied earlier advances? Well, because there can be little doubt that the switch from intuitive to symbolic cognition was extremely rapid, the simplest proximate explanation appears to be that the radical developmental reorganization that gave rise some 200 kyr ago to the highly distinctive *Homo sapiens* skeletal anatomy had also, exaptively, produced what Boeckx and Benitez-Burraco (2014) have termed a "language-ready brain," one possessing the internal connections required to make the complex associations that are involved both in language and symbolic thought. This new brain evidently continued to function in the ancestral intuitive manner for some 100 kyr, until its enhanced associative potential was recruited for symbolic thought by what was necessarily a behavioral stimulus – much as ancestral birds only tardily recruited their feathers for flight. Most probably the stimulus concerned involved a spontaneous attribution of meaning to specific vocal sounds, initiating a mental feedback process between sound and meaning. This created a cascade of associations, governed by rules, that in turn eventuated in language and structured thought (Tattersall, 2012, 2017). But whatever the exact mechanism may have been, we know it initiated a rapid transition; and the simultaneous origin of language and symbolic thought suggested here not only conveniently obviates any chicken-and-egg arguments, but also makes it much easier to understand the intimate relationship between the two that Hinzen (2012) noted. Interestingly, the new symbolic cognitive algorithm seems to have proven more energetically frugal than its intuitive predecessor in which cognitive complexity almost certainly scaled with brain size, since the human lineage subsequently witnessed a significant reduction in neural volume (Tattersall, 2018).

Placing the acquisition of language within the tenure of *Homo sapiens* as an anatomically distinctive entity has another very significant advantage. For years, researchers from Laitman et al. (1979) to Fitch et al. (2016) have lustily argued over the relevance of hyoid and cranial base morphologies to the ability to produce the sounds necessary for articulate speech: a debate that is rendered entirely superfluous if, as suggested here, the modern vocal tract anatomy was in fact already in place before it was co-opted for the production of speech. The same, of course, would also apply to arguments over the relevance of other putatively speech-associated structures such as Broca's cap (see Falk, 2014). The neural and cranial morphologies necessary for speech production were there first – as, indeed, they had to be.

## THE MINIMALIST PROGRAM

The MP describes a research strategy based on the proposition that, as a "finite computation system yielding an infinity of expressions" (Berwick and Chomsky, 2016: 1), language depends on a simpler mental algorithm than many had expected. In doing so, it pares universal grammar down to the minimum essentials necessary to meet the conceptual and phonological requirements of the human beings who, uniquely, use it (Boeckx, 2006). The MP thus has implications for the evolutionary roots of human language, predicting that it had a single origin in time as the result of a simple algorithmic flip, rather than emerging gradually over the eons. This is entirely consonant with the archeological evidence discussed above, which strongly suggests that modern language-based cognition emerged not only suddenly, but also late in time, subsequent to the emergence of anatomically recognizable *Homo sapiens*.

In their most recent articulation of the MP, Berwick and Chomsky (2016) acknowledge this. But they go on to argue not only that Merge, the underpinning operation that combines objects into new syntactic units, was acquired by hominids in Africa around 80 kyr ago, but that the resulting internalized "language of thought" was "*at some later stage* . . . connected to the sensorimotor system" (2016: 87; italics added) to produce spoken language as a means of communication. As the product of an avowedly minimalist approach, this elaborate two-stage process – internalization first, externalization later – seems oddly unparsimonious. And it also robs us of any explanation for why "the minor biological change that provided the operation Merge" should have become fixed, or in what context the new system might have become co-opted for externalized expression. It hardly seems enough to remark simply that this latter complex task "could have been solved in many ways and at different times" (Berwick and Chomsky, 2016: 87). In contrast, we know that it is entirely possible for modern human beings with language-ready brains to extemporaneously begin attaching meaning to symbol (Senghas et al., 2005), resulting in the emergence of a structured language readily capable of rapid subsequent refinement. In the case just cited the currency of the new language was visual signs; but vocal symbols are clearly even more effective in this role since they are not limited to line-of-sight. In conjunction with the necessary possession of an exaptively language-ready brain, it is this associative aptitude of our species that makes the spontaneous invention of spoken language, at some point around 100 kyr ago, by far the most credible putative driver of symbolic thought and modern cognition.

## AUTHOR CONTRIBUTIONS

IT wrote the article.

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OPINION
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# Minimalism in the Light of Biology: What to Retain and What to Discard?

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**Keywords: minimalism, language evolution, move, subjacency, recursion**

This volume, and in general this moment in the history of science, is calling for us linguists, and especially those of us who have worked in Minimalism, to characterize what it is that our approach has discovered, that we want to embrace and move forward with, and what it is that we need to discard. There is plenty in both categories, and it is precisely the considerations of biology (e.g., language evolution) that can help us weed out the burdensome, damaging aspects of this approach. Too often we linguists look down upon the study of language evolution as some kind of marginal topic that need not concern "true" linguists, and we prefer to just wait until geneticists, biologists, and neuroscientists figure it all out. And yet, it is only linguists who can put forward specific, linguistically informed hypotheses that can be subjected to interdisciplinary testing. The emphasis here is on specific, falsifiable hypotheses, rather than some vague assertions that cannot be subjected to falsification. It is true that many such specific hypotheses will be proven wrong, but after all, the nature of the scientific process is simply to narrow down the range of possibilities.

My focus here is on a few influential assumptions/postulates in Minimalism that are particularly harmful in establishing meaningful links between language and biology, and which, both on this ground, and based on more careful linguistic considerations, should be abandoned. I will also point to certain postulates that are worth keeping and moving forward with, based on their usefulness for biological considerations. Needless to say, this short Opinion piece is not a comprehensive review of Minimalism, but is rather meant to provoke a substantive discussion about how to better constrain this framework, and how to, at the same time, make it better compatible with gradualist evolutionary considerations.

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## OMNI-POTENT, INFINITE MERGE

Consider the recent claims, primarily in the context of language evolution research, that syntax reduces to Merge (e.g., Berwick and Chomsky, 2011, 2016), where Merge has been granted almost mythical powers, distracting from the fact that Merge is really just a term meaning "combine." It is true that we can always pack into such terms whatever we want, e.g., that it has to be binary; that it is recursive; that it subsumes Move. But these are separate and separable properties of human syntax, and need not be seen as the part and parcel of Merge at all. Packing virtually all we know about syntax into Merge is only there to create an illusion that syntax is one undecomposable, unnegotiable block, which evolved as a result of one single sudden evolutionary event, as per Berwick and Chomsky's saltationist view. The binary nature of syntactic structure building (e.g., Kayne, 1984), as well as the small clause foundation of every sentence (section Binarity and Hierarchy of Projections), are stable postulates, in fact discoveries, which predate Minimalism, as well as carry over into Minimalism. Because they are also useful for evolutionary considerations, they are postulates to keep and move forward with. On the other hand, the claims that Merge by itself yields infinite recursion, and that it subsumes Move, are problematic both from the standpoint of linguistic analysis, and language evolution considerations. I discuss Move in section Subjacency, and infinite recursion in section The Notion of Free Infinite Recursion. Section Syntactic Uniformity Across Languages and Constructions discusses the idea of syntactic uniformity across languages.

## SUBJACENCY

In Minimalism, Move is typically seen as a default state of grammar (in fact, an inseparable property of Merge itself), in the sense that it applies freely and repeatedly, as long as there are features to check. With that assumption, one of the central goals of syntactic theorizing has been to provide an elegant characterization of Subjacency, the principle supposed to explain why Move is nonetheless prohibited from some syntactic constructions, dubbed islands. The expectation is that there exists some deep, abstract property which captures islandhood effects in a unified and elegant fashion (but see e.g., Cinque, 1978; Postal, 1997; Boeckx and Grohmann, 2007; Boeckx, 2008; Sprouse and Hornstein, 2013 for an exploration of alternative views).

Typically, Move is possible only out of (a subset of) complements/objects, while the constructions that prohibit Move are many and various, including adjuncts, conjuncts, subjects, complex noun phrases, *wh*-clauses (for a long list of additional islands, see Postal, 1997, 1998). Crucially, constructions which prohibit Move (islands) do not form a natural class, while those that allow Move do form a natural class (Progovac, 2009, 2015). It is thus not surprising that, despite the sustained effort for half a century (since Ross, 1967), to date there has been no unified or principled account of islandhood (Belletti and Rizzi, 2000 report an interview with Chomsky, in which he concludes that much). The classic accounts are Huang (1982); Lasnik and Saito (1984); Chomsky (1986), but there have been many more attempts, including the so-called phases in Minimalism (Chomsky, 2001).

If islands do not form a natural class (i.e., have no thread in common), then there cannot possibly exist an insightful unified account of islandhood. Accordingly, our efforts need to be re-oriented from searching for a common thread for all islandhood to searching for an explanation for what accommodates Move in non-islands, and why islands exist at all. This shift in direction would argue against the reduction of Move to (internal) Merge, given that (external) Merge is not affected by islandhood, but Move is. There is in fact a good evolutionary rationale for why islandhood (i.e., lack of Move) should be the default (evolutionarily primary) state of grammar (Progovac, 2009, 2015), while there is no good explanation for why evolution would deliver a principle such as Subjacency, against the background of free and powerful Move (e.g., Lightfoot, 1991). It is significant that the elusiveness of Subjacency has been used to argue that syntax could not have evolved gradually: one does not see why evolution would target a grammar with Subjacency, when its contribution to grammar is not clear, let alone its contribution to survival. According to Lightfoot (1991), "subjacency has many virtues, but … it could not have increased the chances of having fruitful sex." Subjacency thus poses (unsolvable) problems not only for syntactic theory, but also for language evolution! These are two important reasons to abandon Subjacency, and the concomitant assumptions.

This search for an abstract principle accounting for all islandhood is analogous to biologists seeking a unified, deep biological explanation for why so many species do *not* have wings. However, instead of assuming that every living being is supposed to have wings by default, biologists consider that having wings is an evolutionary innovation, against the backdrop of the primary state of winglessness. Applying this logic to syntax, one would need to posit that there existed a modest proto-syntax stage without wings (i.e., without Move, recursion, and many other niceties of syntax), and that Move was a later innovation, enabled by the rise of hierarchical syntax (Progovac, 2009, 2015). As is well motivated in syntactic theory, Move typically requires hierarchical syntax and c-command.

## THE NOTION OF FREE INFINITE RECURSION

There are many constructions across languages that are not (infinitely) recursive, i.e., do not allow multiple embeddings of one category within another category of the same type, even though they are presumably put together by Merge[1]. These include recursive embedding of clauses (CPs) within other clauses, or possessive noun phrases (NPs/DPs) within other noun phrases, in some languages, as well as recursive composition of noun-noun compounds in some languages. There are even rigid syntactic creations (often small clauses) across languages, including English, that are syntactic isolates in the sense that they do not merge/combine with any category, and not just with categories of the same type. These are all discussed and exemplified in Progovac (2015, and references there), adducing evidence that recursion, Merge, and Move are decomposable into primitives and simpler constructs. What leads to recursive possibilities in some constructions, in some languages, is a combination of factors, including not only Merge, but also specialized functional projections and categories such as complementizers, which develop/evolve through gradual grammaticalization processes (e.g., Heine and Kuteva, 2007). In other words, the reason why languages (in some constructions) show recursion (and potential infinity) need not come from some cognitive twist in the brain that suddenly emerged in humans, but rather from a complex interaction of (grammatical) factors, some of which are not available in all constructions, in all languages.[2]

## SYNTACTIC UNIFORMITY ACROSS LANGUAGES AND CONSTRUCTIONS

Finally, this brings up yet another undesirable postulate, promoted by some, but certainly not all syntacticians, that

[1]This is basically the classical characterization of recursion in linguistics, but see e.g. Kinsella (2009), Tomalin (2011), Progovac (2015), who point to immense confusion and inconsistency in the use of the term recursion in syntactic literature; see also Watumull et al. (2014) for offering a clarification of the use of the term, questioning the relevance of embedding. In our eagerness to become highly theoretical (and not easily proven wrong), have we sacrificed the precision in using and defining terms? This is surely one of those aspects that must be fixed.

[2]It is often stated that it does not matter whether languages actually exhibit recursion in this or that construction, or at all, as long as we humans are all cognitively equipped with recursion (e.g. Watumull et al., 2014). This can't be very helpful. If we had never come across a language that showed any recursive capabilities in this sense, would we still maintain that recursion is a crucial property of language?

the syntax of every construction is syntactically uniform across all languages. Whatever functional projections and categories have been postulated for English sentences (e.g., vP, TP, CP, DP, DegP) must also be posited in equivalent constructions/translations in all the other languages. How one translates these languages into English is how one can analyze them syntactically. When something looks different from the English situation, one can simply posit some null category or another, ironing out the differences. While in some cases one may be justified in positing a null category, this blanket declaration of uniformity takes away the tools necessary for deciding when this is justified, and when not, giving rise to a host of unfalsifiable claims. Such sweeping claims are also harmful for biological considerations, because it is exactly the variability, the contrasts and comparisons among different constructions, that reveal the evolutionary primitives of syntax (e.g., Progovac, 2015, 2016), which can also be used to probe language variation and language representation in the brain (e.g., Progovac et al., 2018a,b).

## BINARITY AND HIERARCHY OF PROJECTIONS

At the same time, the basic analysis of the sentence in this framework (Minimalism and predecessors), in English and related languages, is quite insightful and useful for both linguistic and biological evolutionary considerations. Every sentence in this framework is analyzed as having as its bottom layer a Verb Phrase (VP) or Small Clause (SC), essentially a mini sentence, upon which other layers can be constructed, in a binary fashion, including: vP, another (transitive) layer of VP; TP, Tense Phrase; and CP, Complementizer Phrase.

$$CP > TP > vP > SC/VP \tag{1}$$

Binary branching and the small clause foundation are amongst the most insightful and stable postulates in this theoretical framework (e.g., Burzio, 1981; Stowell, 1983; Kitagawa, 1985, 1986; Koopman and Sportiche, 1991; Chomsky, 1995; Adger, 2003; Citko, 2011). Significantly, these two postulates also provide a particularly useful method for reconstructing the initial evolutionary stage of human grammars, i.e., an intransitive small clause stage, equivalent to the inner VP/SC layer in (1) (Progovac, 2015, 2019). They are also useful in characterizing syntactic variation across languages and constructions, considering this inner layer as the common denominator, or foundation, upon which languages can build further syntactic layers. As such, these postulates are worth keeping and moving forward with.

In conclusion, while there is plenty in Minimalism and predecessors that is empirically and theoretically solid, as well as compatible with gradualist evolution of syntax, this approach would benefit enormously by returning to its more modest but falsifiable claims, aimed at discovering and analyzing the rich landscape of syntactic variation, variability being a key ingredient of selection and evolution.

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The author confirms being the sole contributor of this work and has approved it for publication.

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# Minimalism and Evolution

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Minimalism proposes that universal grammar (UG) is a characteristic of human thought, also known as I-language, whose main component is the operation Merge, providing for the generative and recursive properties of human thought and language. The complexity and diversity of human languages arises from a process of externalization, whereby internal thoughts are communicated and shared. A fundamental tenet of the Minimalism Program is that UG is uniquely human, emerging well after the evolution of our species, *Homo sapiens*. I argue instead that the essence of I-language lies in the ability to think about the non-present, as in mentally traveling in time and space, which has a long evolutionary history among animals that move. What may be special but perhaps still not unique to humans is the capacity to communicate our mental travels, as in the core linguistic property of displacement. Mental time travel, or more broadly imagination, is unbounded, and it is this that underlies the generativity of linguistic expression.

**Keywords: gesture, imagination, language, mental time travel, minimalism, theory of mind, universal grammar**

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## INTRODUCTION

The sheer complexity of human languages creates severe difficulties for the understanding of how it evolved. Shortly after the publication of Darwin's (1859) famous treatise *On the Origin of Species*, the philologist Müller (1880) was quick to note language as the main obstacle to Darwin's theory: "… the one great barrier between brute and man is language. Man speaks, and no brute has ever uttered a word. Language is our Rubicon, and no brute will dare cross it (p. 403)." Much more recently, Christiansen and Kirby (2003) introduced an edited collection of articles on language evolution with a chapter entitled "Language Evolution: The Hardest Problem in Science?"

The most prominent linguist of modern times, Noam Chomsky, has also been skeptical of natural selection as an explanation of how language emerged, proposing instead that language emerged in a single step in our own species, *Homo sapiens*, within the past 100,000 years, well after that species itself emerged (e.g., Chomsky, 2010). The advent of language may therefore seem a miracle of Biblical proportions rather than a product of natural selection. Chomsky's views on language have nevertheless become simpler since the publication of *Syntactic Structures* (Chomsky, 1957). In *The Minimalist Program* (Chomsky, 2015b), the essence of language is effectively reduced to the single operation Merge, the basis of what he calls I-language, the internal process that allows elements to be merged recursively to build structures of any desired degree of complexity. Berwick and Chomsky (2016) suggest that this simplified theory helps resolve the evolutionary problem: they write that "… narrowly focusing the phenotype in this way greatly eases the explanatory burden for evolutionary theory—we simply don't have as much to explain, reducing the Darwinian paradox" (p. 11).

Chomsky (2015a) writes that I-language is a system of discrete infinity, through a computational process yielding an unbounded array of hierarchically structured expressions. It has two interfaces with other systems, a conceptual-intentional (CI) system and a sensory-motor (SM) system; the SM system effectively links it with motor outputs for expression, through either speech or sign language. I-language is then fundamentally a property of human thought, and is only incidental to language as communication. This further eases the burden of explaining the complexity of language, because much of that complexity arises in the translation from thought to expression, or what Chomsky calls *externalization*. As Chomsky (2015b) put it: "It is a familiar fact (*sic*) that that the complexity and variety of language appears to be localized overwhelmingly—and perhaps completely—in externalization (p. xi)." I-language itself is of primary interest, because it not only unites the 6,000 languages of the world, providing a universal grammar (UG), but also applies to human thought itself, accounting for unbounded nature of both thought and expressive language.

In spite of these moves toward a simpler account seemingly more compatible with evolutionary theory, Chomsky and colleagues continue to insist that I-language, or UG, is unique to humans. In their treatise "Why only Us?" Berwick and Chomsky (2016) write of the Minimalist Program that "there is no room in this picture for any precursor to language" (p. 71). Part of the argument for the late emergence of UG rests on archaeological evidence for symbolic thought within the past 100,000 years, including the fashioning of bodily ornamentation from shells, beads, or animal teeth, the emergence of sophisticated cave art, and a sudden advance in the level of technology (e.g., Hoffecker, 2005; Mellars, 2005). Tattersall (2012) emphasizes the seemingly miraculous transformation in human thinking:

> Our ancestors made an almost unimaginable transition from a non-symbolic, non-linguistic way of processing information and communicating information about the world to the symbolic and linguistic condition we enjoy today. It is a qualitative leap in cognitive state unparalleled in history. Indeed, as I've said, the only reason we have for believing that such a leap could ever have been made, is that it *was* made. And it seems to have been made well *after* the acquisition by our species of its distinctive modern form (p. 199).

But do such miracles really happen?

## TOWARD A GRADUALIST ACCOUNT

According to Darwin (1859), any complex system must be formed by "numerous, successive, slight modifications (p. 158)," and that any exception would refute his theory. If I-language (or UG) did indeed emerge in a single step, it may appear to provide the exception that Darwin feared. Some theorists have suggested that evolutionary mechanisms compatible with evolution might be found in more recent developments, like exaptations, spandrels, punctuated evolution, or evo-devo, but there is still serious doubt as to whether a complex system such as language could have evolved fully-fledged in a single step (Pinker and Bloom, 1990).

There remains some ambiguity as to whether the concept of Merge is sufficiently simple to constitute a "slight modification," as Berwick and Chomsky imply, or whether the cognitive shift is "a qualitative leap unparalleled in history," as Tattersall claims, in which case the evolutionary challenge remains. Either way, there seems no strong reason to suppose that it emerged in a single step.

In what follows, I suggest that the essence of I-language exists in what has been termed "mental time travel" (Tulving, 1985; Suddendorf and Corballis, 1997, 2007), and underlies the linguistic property of *displacement*, defined by Hockett (1960) as the ability "to talk about things that are remote in space or time (or both) from where the talking is going on." Bickerton (2014) has suggested that displacement provides "the road into language" (p. 93). Displacement is not mental time travel itself, but is rather the *externalization* of mental time travel. In the view developed here, then, the generativity of language comes not from some human-specific concept of UG, but from our mental time travels, or more generally from imagination, as explained below.

### Mental Time Travel

The concept of mental time travel arose from Tulving's work on episodic memory, the capacity to re-experience personal events. Tulving's (2002) view on the emergence of episodic memory echoes Chomsky's account of the late arrival of UG itself:

> Many non-human animals, especially mammals and birds, possess well-developed knowledge-of-the-world (declarative, or semantic, memory) systems and are capable of acquiring vast amounts of flexibly expressible information. Early humans were like these animals, but at some point in human evolution, possibly rather recently, episodic memory emerged as an "embellishment" of the semantic memory system (p. 7).

The notion of episodic memory, though, may be extended to the experience of imagined future episodes; that is, we can travel mentally both backward and forward in time (Suddendorf and Corballis, 1997, 2007), with the suggestion that mental time travel in general is unique to humans. Further, our displaced thoughts also go well-beyond the imagining of past or possible future events to events that are purely imaginary. Imagination itself may be defined as "the act or power of forming a mental *image* of something not present to the senses or never before wholly perceived in reality" (Merriam-Webster on-line Dictionary)[1]. Imaginative thoughts carry the generativity and recursiveness exemplified in our reconstructions of the past, in mental anticipations of the future, and perhaps most commonly in the fabrication of stories (Boyd, 2009; McBride, 2014) that need not be specifically located in time ("Once upon a time."). Indeed it is stories, whether in the form of fiction, soap operas, tales around the campfire, or gossip, that prompted Niles (2010) to rename our species *Homo narrans*—the storytellers.

If mental time travel is indeed unique to humans, then this might help further explain why language itself is unique to humans. This tidy picture perhaps explains much that is distinctive to our species, but still leaves the question of how such far-reaching and complex activities could have evolved in such a short period of time, and in a single momentous step.

[1]Merriam-Webster Dictionary, online at https://www.merriam-webster.com/dictionary/imagination

## Is Mental Time Travel Really Unique to Humans?

Claims that episodic memory (Tulving, 2002) and mental time travel more generally (Suddendorf and Corballis, 1997, 2007) are unique to humans were soon challenged. First off the mark were Clayton and Dickinson (1998), who provided evidence that scrub jays not only recalled where and when they had cached items of food, but also re-cached food in apparent anticipation that a bird watching the original caching might later steal the food. Similar behavioral claims for mental time travel have been offered for a wide variety of non-human species, including chickadees (Feeney et al., 2009), great apes (Martin-Ordas et al., 2010; Beran et al., 2012; Janmaat et al., 2014), meadow voles (Ferkin et al., 2008), rats (Bird et al., 2003; Wilson et al., 2013), ravens (Kabadayi and Osvath, 2017), scrub jays (Clayton et al., 2003), and even cuttlefish (Jozet-Alves et al., 2013). In one recent study, rats remembered many different episodes over intervals of up to 45 min without any evidence of decline in performance (Panoz-Brown et al., 2016).

This body of evidence is now substantial, although sometimes explicable in terms of processes other than mental time travel, such as trial and error learning or simple association (Suddendorf and Corballis, 2010). Additional evidence, though, comes from neurophysiology, leading me to change my opinion and argue that mental time travel probably goes far back in the evolution of animals that move around in space (Corballis, 2013; but see Suddendorf, 2013).

## Role of the Hippocampus

It has long been known that the hippocampus is critical to human declarative memory, including semantic memory for general facts as well-episodic memory for specific events. Patients with bilateral loss of hippocampal function are well-known to suffer severe loss of episodic memory for past events, as well as an inability to form new memories (Corkin, 2002, 2013; Tulving, 2002; Wearing, 2005). Brain imaging confirms that the hippocampus is active both when people recall past episodes and when they imagine future ones (Martin et al., 2011), and also when they simply construct imaginary scenes (Hassabis et al., 2007). Although critical to the construction of imagined events, the hippocampus is probably part of a larger network; for example, impairment of the ability to imagine personal past or future events has also been linked to damage of the ventromedial prefrontal cortex (Bertossi et al., 2016). Maguire et al. (2016) suggest that the particular role of the hippocampus may lie in what has been termed *scene construction*, the drawing together of dispersed information for conscious inspection, while McCormick et al. (2018) suggest that hippocampal function goes beyond mental time travel to mind-wandering more generally, and lies at "the heart of mental life" (p. 2745).

Neurophysiological recordings from the rat hippocampus suggest remarkably similar functions. It has long been known that cells in the rat hippocampus, known as "place cells," record the animal's current location in space (O'Keefe and Nadel, 1978). While this suggested different roles for the hippocampus in humans and rodents, subsequent research has revealed increasing convergence. Place cells not only record current location, but may fire in sequence after an animal has been removed from the particular environment to which they corresponded, indicating memory for an earlier episode. Such sequences correspond to trajectories in the earlier environment, and have been described as "replays," although in many cases they did not correspond to trajectories actually taken, as though the animal was imagining future trajectories or simply mentally exploring. Reviewing the evidence, Moser et al. (2015) write that "the replay phenomenon may support 'mental time travel' … through the spatial map, both forward and backward in time (p. 6)." And this evidence comes from the rat, contrary to Tulving's suggestion that mental time travel is uniquely human.

Again, many other brain regions seem to echo these trajectories (Hoffman and McNaughton, 2002), driven by the hippocampal sequences. Place cells respond not only to specific locations, but tag non-spatial features of past event even in the rat, such as odors (Igarashi et al., 2014), touch sensations (Young et al., 1994), and the timing of events. Hippocampus activity is modulated by activity in the neighboring entorhinal cortex, where so-called grid cells code locations corresponding to spatial features such as spatial scale and orientation, and other cells code shape and color, proximity to borders, and the direction in which the head is facing (Diehl et al., 2017). These cells operate in modular fashion, creating an enormous number of combinations reflecting the possible spatial contexts in which an animal might find itself. Moser et al. (2015) liken this to "an alphabet in which all words of a language can be generated by combining only 30 letters or less" (p. 11). The system is fundamentally generative.

Such properties seem to extend to imagined locations and trajectories as well as those recording the present. Drawing on both human fMRI evidence and neurophysiological recordings in rodents, Deuker et al. (2016) write of "an event based map of memory space in the hippocampus," scaled with "the remembered proximity of events in space and time" (p. 1). In one study, the rat hippocampus constructed 11 different maps of 11 different rooms in which it had previously been placed (Alme et al., 2014), suggesting the capacity to conjure different settings. In humans, this may underlie the capacity to hold stories in context. Milivojevic et al. (2018) show from brain imaging how people maintain separate episodic context for stories, even when the stories, shown as videos, are interwoven in time. Hippocampal function is both generative and recursive, as in the capacity to alter spatial scale, and zoom—effectively embedding finer-scaled representations into more global ones. Mental time travel itself is recursive, in that we can call routines representing past, future, or purely imaginary sequences of events and insert them into the present—and even insert scenes into scenes, as when we recall an event when we remembered another event. Even episodic memory itself is generative, a construction rather than an exact rendering of the past. As Neisser (2008) once put it, "Remembering is not like playing back a tape or looking at a picture; it is more like telling a story (p. 88)." Because of the vast number of objects, actions and qualities we know, and our ability to combine them into different combinations as remembered or imagined scenes, and locate them in time and space, imagination itself is essentially unbounded.

So-called declarative memory, made up of both episodic and semantic memory, is widely understood to be dependent on hippocampal function (e.g., Squire, 2004), and the term "declarative" itself betrays the close relation between memory and language. Duff and Brown-Schmidt (2012) review evidence from studies of hippocampal amnesia that that the hippocampus is important in binding information from different sources and supplying a flexibility of operation required for coherent language. Piai et al. (2016) add evidence from recording of hippocampal theta during sentence processing, and suggest that the hippocampus should be considered part of the language network, a conclusion endorsed by Covington and Duff (2016). Individuals such with large-scale destruction of the hippocampus can retain the basic ability to speak, but loss of episodic memory, and of mental time travel more generally, severely restricts communicative content (Wearing, 2005; Corkin, 2013), and word learning becomes sparse and slow (Warren and Duff, 2019). Of course, the language network includes many other functions, such as word knowledge and syntax, and the hippocampus itself has functions independent of language, but normal language does seem to depend on it. Given that declarative memory includes episodic memory, we might conclude that mental time travel more generally can be considered part of the declarative system, accessible in humans through language. The hippocampus thus not only contributes to the generative and integrative aspects of language, but is also the mechanism for displacement, the power of language to refer to, or create, events removed from the present in time and space.

The suggestion here, then, is that the essential properties of I-language lie not in some uniquely human operation called Merge, but rather in the evolutionarily old faculty of imagination. I make no claim that imagination can be reduced to a function like Merge, or that there might be binary distinctions like that between internal and external Merge. This is perhaps something to be explored, but if the generative aspect of internal thought evolved gradually, rather than appearing uniquely in humans, there is no longer a pressure to minimalism. Our ability to conjure imaginary scenes may well-involve more than a single operation like Merge. For example, human imagination probably involves analog processes (Cooper and Shepard, 1984) as well as digital ones, against the spirit of Minimalist theory. Of course our imagination may be well more complex than in other species, such as the rat, because human culture has created a huge number of different objects, largely through manufacture, along with different operations that go with them, and imagination may also have spiraled into more abstract and complex forms.

Mental time travel, or imagination, involves both generative and memorial components, and the historian Fernández-Armesto (2019) makes the interesting suggestion that human evolution traded one for the other. Humans, he suggests, have poorer memories than other primates, but instead have evolved the power to generate novel scenarios and creative ideas, perhaps as adaptations to the shift from a forested environment to the more uncertain world of the Pleistocene. This provides yet another claim for human uniqueness:

> The degree to which humans are, as far as we know, uniquely creative seems vast by comparison with any of the other ways in which we have traditionally been said to excel other animals (p. 3).

A hint as to the early evolutionary origins of that creativity may nevertheless be discerned in the hippocampal trajectories recorded in the rat, and need not disconfirm Darwin's (1871) edict that "[The] difference in mind between man and the higher animals, great as it is, certainly is one of degree and not of kind (p. 126)." Even so, the generative component have well have expanded to the point of allow "discrete infinity," and perhaps helps explain why language itself evolved in the hominin line, and not in our close but largely forest-bound relatives, the apes.

In this account, though, the generativity of language lies not in language itself, but in the imagination that language is designed to express. As Pinker and Jackendoff (2005) remark, "the only reason language needs to be recursive is because its function is to express recursive thoughts (p. 230)." Similarly, Dor (2015) described language as "the instruction of imagination." This raises the question of how our internal thoughts are externalized, so they can be shared with others.

## EXTERNALIZATION

Although minimalist theory puts little emphasis on it, externalization is a necessary aspect of communicative language, and raises further questions about human uniqueness. It is often claimed, for example, that only humans possess the necessary anatomical requirements for speech. In most mammals, the vocal system is relatively fixed, and used for instinctive calls signaling emotion, territory, or danger. Our closest non-human relatives, chimpanzees and bonobos, have some limited degree of intentional control over their vocalizations (e.g., Slocombe and Zuberbühler, 2005), but little evident capacity to produce or learn anything like spoken words, either in number or complexity. According to Petkov and Jarvis (2012), only parrots approach humans as "high vocal learners," with songbirds not far behind, while non-human primates are at best "limited vocal learners."

The production of articulate speech also required alterations to the vocal tract. The optimal configuration is a right-angled vocal tract with equal horizontal and vertical parts (Lieberman et al., 2002), which among primates seems to exist only in humans. In most other mammals the horizontal portion, including most of the tongue, is the longer, constraining the ability to create different sounds. The configuration appears to have been non-optimal even in Neanderthals and Denisovans, who were very nearly identical both genetically and in terms of brain size to *Homo sapiens* (Prüfer et al., 2014), even to the point that was some interbreeding between early humans and these species. Since diverging from these now-extinct species, humans underwent a flattening of the face that optimized the proportions of the vocal tract, and a recent study indicates that this was driven, not by a change in gene sequences, but by a change in gene regulation due to methylation (Gokhman et al., 2019). It is possible that the Neanderthals spoke (Dediu and Levinson, 2013), but probably less distinctly than *Homo sapiens*.

Because voluntary control of vocalization in non-human primates is extremely limited, there must have been changes in neural connections in the course of hominin evolution to enable speech. Simonyan and Horwitz (2011) describe evidence that control of the laryngeal muscles from the premotor cortex is only indirect in non-human primates, but that in humans there are direct connections from the primary motor cortex to brain stem laryngeal muscles. Koda et al. (2018) report that Japanese macaque monkeys do have limited voluntary control over vocalization, but it is slow and evidently effortful. They note too that the emergence of direct connections from motor cortex to laryngeal muscles was still not sufficient for speech, which also required fine motor control of jaws, lips, tongue, and diaphragm—all of which constituted a "unique form of systems integration." These transformative changes presumably occurred late in the course of hominin evolution.

## Language as Gesture

Evidence on the evolution of speech therefore lends some support to the idea that language itself evolved late in hominin evolution and was possibly unique to *Homo sapiens,* although it suggests a more gradual process than the single "great leap forward" endorsed by Chomsky (2007, p. 3). More importantly, it neglects the often-overlooked fact that language cannot be equated to speech. The signed languages invented by deaf communities have all of the essential properties of true language (e.g., Neidle et al., 2000; Emmorey, 2002). It has long been proposed that language evolved, not from vocal calls, but from manual gestures (e.g., de Condillac, 1971; Hewes, 1973; Armstrong, 1999; Corballis, 2002; Arbib, 2012). The gestural theory suggests that precursors to language may extent even further back in evolution, with vocal speech a much more recent development.

One platform for gestural communication may go back as far as our common ancestry with monkeys. So-called "mirror neurons" in the macaque brain respond both when the animal makes a grasping movement with the hand and when it watches another individual making the same movement, mapping input to output. These neurons are located in an area of the frontal lobe homologous with Broca's area in the human brain, leading Rizzolatti and Arbib (1998) to write of "Language within our grasp," suggesting a manual origin. Later research revealed a more extensive mirror system, again largely homologous with cortical language area in the human brain (Rizzolatti and Sinigaglia, 2010). I have speculated elsewhere as to how the mirror system fissioned and lateralized into different circuits, one of the being the language circuit (Corballis, 2017a). The mirror system in macaques is responsive to manual and facial actions, and even to the sound of those actions, but at best only weakly responsive to vocalizations themselves (Coudé et al., 2011), which again suggests the primacy of gesture in language evolution.

Great apes in the wild gesture prolifically to each other intentionally, in ways more language-like than their restricted vocal utterances (Pollick and de Waal, 2007). Byrne et al. (2017) report evidence for repertoires of at least 66 natural gestures in the chimpanzee, 68 in bonobos, 102 in gorillas, and 64 in orangutans, considerably larger than their repertoires of vocal calls. Many of those observed in the wild are common to the different species, suggesting that they are based on phylogeny rather than social learning, but they are also greatly augmented in the case of apes trained to use gestures or on a keyboard containing visual representations (lexigrams). The gorilla Koko, for example, is said to use and understand over 1,000 signs (Patterson and Gordon, 2001). The bonobo Kanzi uses a keyboard with 348 abstract symbols representing objects and actions, and augments his productive vocabulary with signs (Savage-Rumbaugh et al., 2004). Based on studies of gestural communication in apes, Tomasello (2008, p. 55) refers to gestures as "the original font from which the richness and complexities of human communication and language have flowed."

It seems likely that early communication of mental time travels was largely pantomimic, with remembered or planned actions acted out for relatively easy identification. There is some evidence for pantomime in non-human primates. Russon and Andrews (2001) identified 18 different pantomimes produced by orangutans in a forest-living enclave in Indonesia, 14 addressed to humans and four to fellow orangutans. These included mimed offers of fruit, enacting a haircut, and requests to have their stomachs scratched by scratching their own stomachs and then offering a stick to the prospective scratcher. A chimpanzee in the wild watched her daughter trying to use a stone to crack a nut, and then enacted the operation to show her how to do it properly (Boesch, 1993). Tanner and Perlman (2017) note that gorillas combine gestures in sequence creatively and interactively, although this seems to have more to do with play and personal display than with propositional communication, and may be the origin of music and dance rather than of language itself.

Pantomimic communication probably expanded early in the Pleistocene, which dates from about 2.6 million to about 11, 700 years ago, with the emergence of the genus *Homo*, characterized by a threefold increase in brain size, and a shift from facultative to obligate bipedalism, freeing the hands for more effective manual communication. Donald (1991) refers to the "mimetic culture" of the early Pleistocene. These developments in turn were probably driven by a switch from a forested habitat to the more open African savanna, and increasing dependence on communication to maintain social bonds, especially in the face of dangerous predators. As suggested earlier, this change in habitat may have driven the expansion of imagination itself, as it became increasingly important to share information about past and future, and improvise new plans and techniques. The emergent hunter-gatherer pattern resulted in long delays between the acquisition and the use of tools, as well as geographical distance between the sources of raw material for tools and killing or butchering sites (Gärdenfors and Osvath, 2010). The hunter-gatherer lifestyle involved frequent shifts of camp as resources were depleted, forcing the group to move on to another more abundant region—a pattern still evident in present-day hunter-gatherers (Venkataraman et al., 2017).

Pantomime probably did not give way to speech in a single step. Rather, vocalization was probably introduced gradually, and even today manual gestures typically accompany speech (Iverson and Goldin-Meadow, 1998). Caradec's (2005) dictionary of bodily gestures lists over 850 gestures from around the world that either accompany speech or can stand alone (excluding sign languages). Pantomime had the advantage of representing events in iconic fashion, but through conventionalization (Burling, 1999) gestures could be simplified in the interests of communicative efficiency, and could eventually include vocal sounds with little or no iconic reference. I have elaborated this scenario in more detail elsewhere (Corballis, 2017b).

## Theory of Mind

The externalization of thought also depends on theory of mind, the understanding of what is in the recipient's mind. Thus, Chomsky (2007) argues that the elements of language are not what he calls "mind-independent entities" (p. 7 *et seq*), mapping onto aspects of the physical world. Rather, they map more or less directly to the mind, and include emotions and attitudes as much as physical objects and actions. As Chomsky put it, "communication depends on shared cognoscitive powers" (p. 10)—what's in the mind rather than what's in the world.

The understanding of what is in the minds of others has been termed "theory of mind." As the philosopher Grice (1989) pointed out, I cannot have a meaningful conversation with you unless I know what you are thinking, and know that you know that I know this. Recursion, therefore, comes from the mental processes rather than from language itself. The words we actually use are seldom if ever sufficient to convey precise information; we rely extensively and often unconsciously on shared streams of thought. The manner in which use shared knowledge to extract information from linguistic utterance is explored by Sperber and Wilson (2002). Words are effectively used not so much to refer to specific aspects of the world about us as to nudge shared trains of thought. The sharing of thoughts often depends on simple gestures rather than fully fledged language. Scott-Phillips (2015) gives the example of simply catching the eye of the waiter in a café with a nod to indicate that you would like a coffee refill.

Language, then, can be considered a sophisticated way of sharing thoughts, but it remains what Scott-Philips calls *underdetermined*. This is illustrated by the phenomenon of polysemy—many individual words have many different meanings, and need context and parallel trains of thought for the establishment of meaning. An extreme example is the word *set*; according to the Chambers Online Dictionary, it has 105 different meanings. And although expressive language can be complex and convoluted, its contribution to communication pales beside the role played by on-going thoughts that operate below the surface.

Scott-Philips suggests that it is underdeterminacy that makes language unique to humans, but this is questionable. Studies of gestural communication among chimpanzees in the wild are often highly variable, suggesting a lack of determinacy (Hobaiter and Byrne, 2011). De Waal (2019) gives an extraordinary and largely personal account of the subtle and human-like ways in which chimpanzees interact socially, and deplores the sanctions against anthropomorphism—he terms it *anthropodenial*—which may blind us to the ways in which other animals share thoughts and emotions. Monkeys also interact socially. Shepherd and Freiwald (2018) used whole-brain fMRI to examine the responses of face-to-face interaction in macaques, revealing a network that overlapped with the primate mirror system and with homologs of the human speech areas.

The broader question of whether non-human species are capable of theory of mind itself has been much discussed and disputed since Premack and Woodruff (1978) asked the explicit question "Does the chimpanzee have a theory of mind?" Thirty years later, Penn et al. (2008) argued that even chimpanzees, our closest non-human relatives, have no theory of mind, describing such attributions as "Darwin's mistake." In the same year, Call and Tomasello (2008) concluded, more generously, that the 30 years of research showed chimpanzees to have an understanding of the goals, intentions, perceptions, and knowledge of others, but no understanding of others' beliefs or desires. But even that claim may be too limited. A critical criterion for advanced theory of mind is that the individual shows understanding that another individual has a false belief. In a recent study, Krupenye et al. (2016) show that great apes, including chimpanzees, bonobos and orangutans look in anticipation of whether a human agent will falsely believe an object has been hidden. That is, they seem to pass the false-belief test, often regarded as the gold-standard test of theory of mind (Wimmer and Perner, 1983). This study seems to join a chorus of studies gradually showing greater mental continuity between humans and other species than commonly assumed. If de Waal's account is correct, even this may underestimate great ape social intelligence.

## SUMMARY AND CONCLUSIONS

Although this article goes beyond minimalism, it owes much to Chomsky's insights as to the nature of language. It accepts the notion that the basis of language is a mode of thought, which Chomsky calls I-language, and that spoken or signed languages emerge through a process of externalization. It accepts too the idea that the unbounded, generative nature of language is to be found in the underlying thought processes rather than in the externalized products—the 7,000 or so languages of the world. The much-disputed notion of universal grammar (UG), then, is in the structure of thought rather than in communicative languages themselves, with its universality deriving from commonalities of thought rather than in the multiplicity of actual grammars.

Minimalism, though, embeds these ideas in a formal framework, with little reference to biological naturalism. This perhaps reinforced the idea that language, whether as thought or as communication, is uniquely human, and quite different from anything evident in non-human species. In the account given here, I have tried to place Chomsky's insights as formulated in the Minimalist Program in a more naturalistic framework, which allows thought and language to be viewed in a broader perspective, with antecedents in various aspects of non-human behavior and biology. This in turn largely removes the pressure toward minimalism itself, so that thought and language can be understood in the wider context of animal behavior and evolution.

A more expansive view of I-language, then, is that it is largely captured in the internal process of imagination, itself a generative process that is unbounded, at least in humans. The essence of imagination lies in mental time travel, the internal ability to envisage events at other points in time and space, and indeed to create fictitious events. While it has been argued that mental time travel, like language itself, is uniquely human, evidence from animal behavior and neuroscience increasingly suggests evolutionary continuity. Imagination is a conserved and flexible system mapping onto the flux of experience, with its own combinatorial and recursive nature. Even rodents seem capable of generating mental time travels. Whether these mental travels can amount to discrete infinity is no doubt problematic, and the degree to which imagination is bounded may well have decreased over time.

A more naturalistic account of externalization also suggests continuity, and I have focused especially on the proposition that productive language emerged from manual gestures, and on theory of mind. Both have recursive properties that might map onto the recursive nature of imagination, but exactly how this is done might be a project, which I hesitate to call the Maximalist Project. My account is far from a finished product.

There remains the question of why expressive language does seem to be unique to humans, even if generative imagination is not. Evidence increasingly shows varied communication systems in other species—whales, birds, monkeys, bees, even ants—but so far there is little suggestion that any non-human animal can share their internal thoughts, or tell what they did yesterday or might do tomorrow. Perhaps it is for the most part adaptive not to transmit such information—language causes almost as much mischief as benefit, through lying, defamation, and willful misinformation, and in any case even we humans keep most of our internal thoughts to ourselves. Perhaps the balance shifted in favor of sharing when our forebears moved from an enclosed forested habitat to a more open, expansive one leading to hunting, gathering, and migration. Instead of supposing that this happened within the past 100,000 years, we can more realistically consider the past 6 million years since our common ancestry with great apes, with perhaps the major focus on the past two to three million when our forebears became obligate bipeds, brain size underwent a dramatic increase, and the manufacture of tools became more advanced. Unfortunately, this was a period marked by the extinction of all hominin species except ourselves, so that critical biological information is lacking. All we have to go on is fossil evidence and, increasingly, ancient DNA.

Even so, it is surely unlikely that the critical changes that gave us expressive, generative language occurred in a single step within the last 100,000 years—unless there really was a miracle. We need to continue to probe closely into what happened biologically in those dark years between our great-ape ancestry and last extant hominin, our own species.

## AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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frontiers in Psychology

CONCEPTUAL ANALYSIS
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# Systems Underlying Human and Old World Monkey Communication: One, Two, or Infinite

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Using artificially synthesized stimuli, previous research has shown that cotton-top tamarin monkeys easily learn simple AB grammar sequences, but not the more complex $A^nB^n$ sequences that require hierarchical structure. Humans have no trouble learning $A^nB^n$ combinations. A more recent study, using similar artificially created stimuli, showed that there is a neuroanatomical difference in the brain between these two kinds of arrays. While the simpler AB sequences recruit the frontal operculum, the $A^nB^n$ array recruits the phylogenetically newer Broca's area. We propose that on close inspection, reported vocal repertoires of Old World Monkeys show that these nonhuman primates are capable of calls that have two items in them, but never more than two. These are simple AB sequences, as predicted by previous research. In addition, we suggest the two-item call cannot be the result of a combinatorial operation that we see in human language, where the recursive operation of Merge allows for a potentially infinite array of structures. In our view, the two-item calls of nonhuman primates result from a dual-compartment frame into which each of the calls can fit without having to be combined by an operation such as Merge.

**Keywords: language evolution, primate calls, call combinations, merge, Chomsky hierarchy**



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## INTRODUCTION

How did human language arise in evolution? To begin to answer this question, we must first decide what precisely we mean by language. Recently, Chomsky and others (Chomsky, 1995; Hauser et al., 2002) have proposed a characterization of language in which the core of the language faculty is composed of a computational system that contains one operation, Merge, which takes two syntactic objects and puts them together to form a set, {a, b}. For example, if *blue* is *a* and *book* is *b*, the output of Merge that operates on *a* and *b* would be {*blue, book*}. This output could in turn function as the input to another application of Merge, giving rise to the set {*the*, {*blue, book*}}. Much of syntax arises from this operation applying under a general requirement for computational efficiency, such as minimal search domain for Merge to combine *a* and *b*; this view of language is called the Strong Minimalist Thesis (SMT), and more recently, it has been referred to as the "Basic Property" of human language (Chomsky, 2000, 2013, 2016; Berwick et al., 2013; Berwick and Chomsky, 2016). As an example of computational efficiency, if {*blue, book*} serves as an input to Merge, the operation would select the closest object, which is the set itself, instead of prying into the inner structure of the set to pick *blue* or *book*. The recursive application of Merge gives rise to unbounded structured phrases, furnishing human language with the potential to generate an infinite array.

In contrast to the kind of view based on SMT, some scholars suggest that human language is primarily a culturally evolved system or a product of intensive gene-culture coevolution (Tomasello, 1996, 2000; Laland et al., 2000; Enfield and Levinson, 2006; Evans and Levinson, 2009; Chater and Christiansen, 2010; Azumagakito et al., 2018; Laland, 2018). According to this view, human language development relies predominantly on cultural learning skills, rather than on a set of categories predetermined by an innately-specified universal grammar, as Chomsky argues (Chomsky, 1980, 1981, 1988, 2007). We believe that there are aspects of language and evolution that would receive plausible explanation from a view that culture is central to the development and workings of language (e.g., the morphological variation we observe across languages). However, in this article, in which we will compare the basic workings of nonhuman primate and human systems underlying vocal communication, we believe that the SMT is the most appropriate theory of human language to use as a model against which to compare nonhuman primate alarm-calling systems. Other approaches include the theory that deconstructing language involves layers and degrees of complexity and therefore rejects a single structure-building operation such as Merge (Fitch, 2017; Townsend et al., 2018).

Often, scholars who adhere to the Merge + Computational efficiency view of language also suggest that the computational system that underlies language is unique to our species (Chomsky, 1968, 1980, 1981, 1988, 2007; Bolhuis et al., 2014). Note that this view of uniqueness is by no means entailed by the particular design of the computational system for human language; one could imagine other animals having a similar system, which complements recent assumptions (Townsend et al., 2018)[1]. The belief that the human language computational system is unique to humans stems from the observation that we do not find anything comparable to it in nonhuman primates or other animals (Hauser et al., 2002; Fitch and Hauser, 2004; Berwick et al., 2011; Schlenker et al., 2016b). This observation sometimes gives rise to the idea that what we find elsewhere in the animal world, such as the alarm calls of nonhuman primates, is so fundamentally distinct from human language that there are no meaningful commonalities between the systems (Smith and Kirby, 2008; Fischer, 2010). An argument often given in favor of the uniqueness of human language has to do with utility. One aspect of this is the notion that the typical nonhuman primate systems exist for the purpose of communication. For example, an alarm call for a particular predator is viewed as coextensive with the reference to that predator, and functions to communicate a message to or alter the behavior of others in the habitat regarding the predator, and/or to deter the predator itself (Maynard Smith, 1965; Zuberbühler et al., 1999a,b; Seyfarth and Cheney, 2003; Owren et al., 2010). In contrast, Zuberbühler et al. (1997, 1999a,b) provide experimental evidence based on the vocal behavior of Diana monkeys (*Cercopithecus diana diana*) that the calls are suggestively mediated by some form of cognitive semantic representations of the predator.

Human language has two components, the inner system, which is the computational system characterized by SMT, and the interfaces to which the array of structured phrases is sent: the phonological form interface (PF), which interacts with a sensory-motor system, associated with the externalization of the expressions generated; and the logical form interface (LF), which interacts with a conceptual-intentional system, responsible for interpretation. The architecture of the human language faculty, according to this view, roughly follows the representation in **Figure 1**.

The inner nature of the SMT computational system has led scholars to speculate that the utility of this system is not for communication but to represent thought (Chomsky, 2011, 2013; Berwick and Chomsky, 2016; Huybregts, 2017). As for the interfaces, setting aside LF, PF gives output to what we typically think of as language — the externalized form that is characteristically expressed by vocal means, although it could also be signs or written characters (Chomsky, 1995). In this way, sound (PF) and meaning (LF and its cognitive extensions) are only indirectly related, being mediated by the syntactic phrases generated by Merge. This may differ from primate alarm calls, which were originally characterized as having a direct link between the sound and its referent (Seyfarth et al., 1980b). However, further research shows this is by no means clear cut. There is evidence that acoustically distinct calls (a monkey alarm call and the corresponding predator vocalization) may elicit the same mental representation of the predator; thus, uncoupling the direct sound-referent link (Zuberbühler et al., 1999a,b). Similarly, context and other as yet unknown factors, may play a role in the iconic or symbolic nature of primate alarm calls

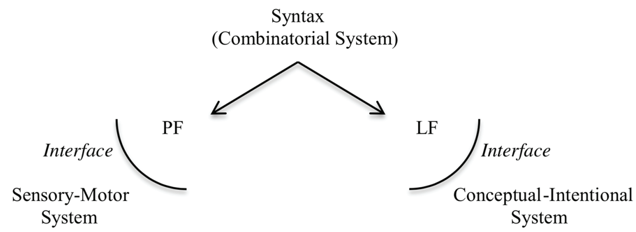


**FIGURE 1** | The architecture of the human Faculty of Language.

[1]In this article, we put forth an incremental approach to the emergence of an infinite, recursive combinatorial system, in line with Townsend et al.'s (2018) observations. Simple cases of compositionality, as seen in primate call combinations, are composed by means of a dual-compartment frame, which may have later served as an input to Merge. However, we do not follow Townsend et al. (2018) in assuming that (frozen) phrasal expressions are structureless (e.g., "duck and cover"), since there is evidence indicating that even simple words comprise a hierarchical structure (see Nobrega and Miyagawa, 2015). Thus, although the dual-compartment frame may have furnished the emergence of Merge, it possibly did not remain active for the formation of linguistic objects, as typically assumed by gradualist approaches (see Progovac, 2015). In our view, Merge —once available— was responsible for the derivation of any linguistic object, from words to sentences.

(Fischer and Hammerschmidt, 2001; Price et al., 2015). For other relevant references, see, for example, Wich and de Vries (2006), Clay et al. (2015), and Scarantino and Clay (2014).

Despite the widespread belief that human language is unique to our species, with properties that are fundamentally different from systems found elsewhere in nature, a significant body of neuroscientific research on language has developed out of comparing human language with that of nonhuman primates. Fitch and Hauser (2004) showed that cotton-top tamarin monkeys are capable of learning the sequence $(AB)^n$, which is based on a simple, regular grammar. But their ability to learn breaks down completely when exposed to the sequence $A^nB^n$, which is based on a formal grammar higher on the Chomsky Hierarchy (Chomsky, 1956) – what Fitch and Hauser term Phrase Structure Grammar, a combinatorial system that requires hierarchical relations that Merge would create in human language. Briefly, the experiment tested two groups of 10 tamarins, one for each grammar, on either a series of nonsense syllables with the simpler, $(AB)^n$ sequence, for example, "no li pa ba" with alternative male and female voices for each syllable, or with the more complex $A^nB^n$ sequence, for example, "yo la pa do," where the first two syllables were in the female voice and the last two in the male voice. A testing phase played back the following day, the same novel eight stimuli to both groups – four of which were consistent with $(AB)^n$ and four of which were consistent with $A^nB^n$. About 72% of monkeys attended to violations of the $(AB)^n$ sequences, but only 29% noticed violations to $A^nB^n$ sequences, suggesting the monkeys could only learn the simpler, finite state grammar sequences. In contrast, humans have no problem learning both types of sequences.

Using experimental stimuli modeled on Fitch and Hauser's experiment, Friederici et al. (2006) showed that the more complex sequence, $A^nB^n$, activates the posterior portion of the Broca's area (*viz*., Brodmann area 44) and also the frontal operculum. In contrast, the simpler sequence of $(AB)^n$ only activates the frontal operculum. The frontal operculum is a phylogenetically older part of the brain compared to the Broca's area (Sanides, 1962), and one of its functions is apparently to create sequences of (AB) combinations (Friederici et al., 2006), which we find both in monkeys (Sanides, 1962) and humans. On the other hand, the Broca's area is a newer part of the brain compared to the frontal operculum. Studies have shown that each region has a unique functional, anatomical, and molecular brain architecture (Sanides, 1962; Amunts et al., 1999, 2010; Zilles and Amunts, 2009). For example, it is Broca's region of the brain that is recruited for the more complex sequence-based Phrase Structure Grammar, which requires a hierarchical structure, and not the flat one we see for AB. Given that Merge[2] is responsible for creating hierarchical structures, it is possible to view the Broca's area as giving human language its distinct uniqueness by furnishing this operation to generate structured hierarchical arrays (Zaccarella and Friederici, 2015). Nevertheless, we acknowledge that other studies implicate the left anterior temporal lobe in human language combinatorial/hierarchical operations without mention of Broca's area and the frontal operculum (Bemis and Pylkkänen, 2011; Brennan and Pylkkänen, 2017). The field of human brain research remains contentious and a discussion of the various viewpoints is beyond the scope of this article. Instead, we focus on the comparative human and nonhuman primate ability to combine call/word units and rely on studies that investigate these phenomena.

We wish to pursue a question parallel to Fitch and Hauser (2004), Friederici et al. (2006), namely, what is the difference between human and nonhuman primate systems that underlie communication? We will closely look at the research on Old World monkeys such as the Diana monkeys, Campbell's monkeys, and De Brazza's monkeys, to see what their vocal behavior can tell us about the actual system that underlies the primate communication system. It is typically believed that alarm calls, which are one stereotypical verbal behavior of monkeys, are composed of acoustically distinct, isolated utterances of alarm, such as those calls given in response to leopard, eagle, and snake predators (Blumstein, 1999). They do not combine, for example, the calls they give to leopards and eagles to create a novel utterance. However, research on the Old World monkeys indicates that some species have what appears to be a combinatorial system in which they can put together two independent items[3]. What we will show, based on the analysis of the reported data, is that these monkeys indeed have a way to create a two-term expression. This is consistent with Fitch and Hauser's finding that tamarins can learn AB sequences (Fitch and Hauser, 2004). Assuming this AB sequence to be associated with the frontal operculum, this is also consistent with the observation that the frontal operculum supports the combining of two elements in sequence, rather than building a hierarchical structure (Zaccarella and Friederici, 2015). In the systems utilized by monkeys, we will see a specific way in which two elements can be put together.

Looking across the systems underlying communication in human and nonhuman primates, we observe that there are essentially three systems: one, two, and infinite. "One" refers to the well-known isolated alarm calls found across the primate world, especially observed in the alarm-calling system of vervet monkeys, while "infinite" refers to the infinite potential of the human language that is made possible by the recursive application of Merge. It is "two" that we will look at carefully; we will see that it is not based on any combinatorial system such as Merge, a point consistent with previous research. The question is, how is "two" made possible? The answer to this may hold a key to how Merge emerged in *Homo sapiens*.

[2]For discussion about Merge, against, and for see, for example, Everett (2005), Kershenbaum et al. (2014), and Nevins et al. (2009).

[3]A reviewer pointed out the work, Kershenbaum et al. (2014), in which a wide range of animal vocal sequences, from birds to whales to primates, is studied, with the intent of testing to see if these calls, some of which are quite complex, can be described as Markovian vocal calls, which would fit well within the Chomsky hierarchy. Their conclusion is that there are calls that may best be described as non-Markovian. It is interesting that primate calls do not fall into the claimed non-Markovian calls; at this point, our understanding is that primate calls, such as the Old World Monkey calls we have studied, fall within the more traditional view of animal communication, which allows for description by a regular grammar.

We begin with a brief discussion of the "one" system.

## SYSTEM OF ONE

Several species of both Old and New World primates have what we call here "isolated" alarm calls, meaning one stereotyped utterance elicited by a specific predator/threat in the environment. Examples include the now famous vervet monkey system, studied first by Struhsaker (1967), and then, in more detail, by Seyfarth et al. (1980b). Vervet monkeys (*Chlorocebus pygerythrus*) give a distinct call when they see a leopard ("bark"), another when they see an eagle ("cough"), and a third when they encounter a snake ("chutter"). All three predators require distinct escape strategies and these calls, when experimentally played back to vervet groups, reliably elicit the appropriate reactions, even in the absence of the predator referent (Seyfarth et al., 1980a). Thus, scholars have concluded that these types of alarm calls should be classified as "functionally referential" (Macedonia and Evans, 1993) functioning as if they carry referential "meaning" to other vervets. Similarly, tamarins (*Saguinus fuscicollis* and *Saguinus mystax*) have an aerial alarm call and a distinct terrestrial alarm call, which both elicit appropriate anti-predatory behaviors (Kirchhof and Hammerschmidt, 2006). In both these cases, the alarm calls to different threat classes (aerial/terrestrial) or predators (eagle/snake/leopard) are acoustically distinct and are not combined to create calls relating to new referents or to carry new "meanings," as far as we are aware. It is of note that the vervet monkey system, which has recently been revisited (Price et al., 2015), shows some intergradation between alarm calls and suggests contextual information, as well as pertinent acoustic cues, is important in determining a monkey's behavioral response to alarm situations. Rather than absolutely discrete calls, these and probably other primates, are able to use similar call types more flexibly.

Functionally referential calls are not restricted to nonhuman primates in the animal kingdom. There are also at least six species of bird that use predator-specific alarm calls: Fowl, White-browned scrub wren, Siberian jay, Great tit, American robin, and Yellow warbler (reviewed in Gill and Bierema, 2013). Additionally, there are other mammals that use functionally referential calls, for example, Gunnison's prairie dogs and domestic dogs (reviewed in Townsend and Manser, 2013). This suggests that the isolated alarm call may be much older than the direct ancestor of modern primates, or it may have evolved more than once in evolutionary history.

Despite an apparent lack of combinatory alarm calls, many nonhuman primates exhibit regular variation *within* isolated call types that may be used to convey different "meanings." For example, red-fronted lemurs (*Eulemur fulvus rufus*) also rely on two alarm calls: a functionally referential call for aerial predators and a more generalized call for terrestrial predators and other ground disturbances. However, they vary the frequency and amplitude of their generalized terrestrial "woof" alarm call. This variation corresponds to threat urgency, with experimentally increased frequency and amplitude eliciting a higher arousal state (Fichtel and Hammerschmidt, 2002). Among the apes, evidence for referential alarm calls is surprisingly sparse. However, chimpanzees (*Pan troglodytes*) produce different *types* or *grades* of "rough grunt" that allow listening conspecifics to determine which type of food has been discovered (Slocombe and Zuberbühler, 2005). In one study, apples (a low value food) elicited a rough grunt with low fundamental frequency, whereas bread (a high value food) elicited a rough grunt with high fundamental frequency (among other varying acoustic parameters). Acoustic differences between the two rough grunts were statistically significant. Gibbons (*Hylobates lar*) also have graded calls, known collectively as "hoos," which subtly vary in context-specific ways (Clarke et al., 2015). In both cases, imposed acoustic variation increases the utility of an isolated call and subsequently the vocal repertoire of the primates. Combining calls to form new meanings would increase the repertoire further, yet in many species evidence of this is lacking [chimpanzee pant-hoots may represent an example of a combined call but there is no evidence, as yet, that the constituent calls have independent "meanings" or that the entire sequence has a compound or new meaning (Zuberbühler, 2018)]. The point is that primate call systems exist that do not combine call elements in order to convey changes in call meaning, thus potentially explaining the dearth of call combinations and subsequent lack of Merge found in many nonhuman primate systems.

## SYSTEM OF TWO

If the system underlying nonhuman primate communication does not contain Merge, as suggested in the work of Fitch and Hauser (2004) and others, a natural conclusion to draw is that the system associated with these primates cannot combine elements but are limited to the System of One with only isolated calls. However, there is a body of research on Old World monkeys, particularly the Guenons (*Cercopithecus*) of Africa, that indicates that these monkeys are capable of vocal behavior in which two elements are combined to form a third call that has "meaning" distinct from its parts. Human language contains at least two combinatorial systems (a duality of patterning) – a simple phonological system and a compositional, semantic system. The crucial difference is that in the compositional system, combined elements have compound meanings, derived from their constituent elements and the way in which they are combined, whereas in the phonological system this is not the case. In language, combined elements can be inserted into other sequences (recursion) and according to Merge theory, only Merge can account for these hierarchical structures. Does the system underlying the communication of these Old World nonhuman primates contain something resembling Merge, contrary to prior research? We do not believe so. The crucial fact, as far as we can determine, is that in every case, the combination is limited to two elements. One never finds a call made up of three or more parts to the call.

What we suggest is that the system used by these monkeys contains a dual-compartment frame that allows them to acquire a two-part call. The two-part call is not the result of some combinatorial operation such as Merge, but rather, the nonhuman primate possesses this dual-compartment frame for creating utterances. Based on prior research, we speculate that this dual-compartment frame is the basis for nonhuman primates being able to learn AB sequences easily (Fitch and Hauser, 2004). Friederici et al. (2006)'s study suggests that the dual-compartment frame exists in the older part of the brain, in the frontal operculum, to allow nonhuman primates to learn AB sequences without the need of Merge, which in humans is in the Broca's area[4].

If the kind of analysis we are proposing for nonhuman primate and human systems underlying communication is correct, it adds to the debate about the origin of human language. In particular, there are scholars who advocate that human language developed through a series of protolanguages, from one-word, to two-words, and so on (e.g., Bickerton, 1990, 1998; Jackendoff, 1999, 2002). In our view, there was a sharp cut-off between the two-word stage and the kind of system we find in modern language that has the potential to generate an infinite array of structured phrases. Our ancestors, prior to developing Merge, simply recruited the same systems of one and two items that had developed in nonhuman primates. In principle, at this point, there was no difference between nonhuman and human vocal behavior. Once Merge developed, an entirely new system emerged that can recursively combine elements into an unbounded array of structured phrases, something we do not see in the nonhuman primate world. The only part of this new system that may have been inherited from the earlier system is binarity. It is well established that the structure of human language is binary (Kayne, 1984; Nowak et al., 2002; Toyota, 2012), and this property naturally arises from Merge that always combines two items. But why does Merge not combine three or more items? In principle, there is no reason why a combinatorial operation that creates a set of three {a, b, c} or more cannot be conceived. But we do not find this in human language, except possibly in highly special constructions such as conjunction. One possibility for the binary nature of human language comes from the dual-compartment frame that first developed in nonhuman primates. In this view, Merge emerged independently, but its input was furnished by the dual-compartment frame of the older system. This may relate to an idea that Friederici proposes (Friederici, 2004, 2009; Friederici et al., 2006) that the Broca's area is involved in the processing of complex (hierarchical) syntax, while local syntactic structure building recruits the deep frontal operculum (see also Zaccarella and Friederici, 2015). In our analysis, the "local syntactic structure building" would be based on the dual-compartment frame, whereas Merge in the Broca's area is responsible for complex syntax building[5].

In an earlier work, Progovac (2015) proposes what she calls a two-slot mold, primarily to account for certain kinds of two-word compounds, two-word sentences, and paratactic attachment of two clauses such as *monkey see, monkey do*, which she considers as reflecting a primitive stage of human language. While we do not consider any combinations in modern human language to be "living fossils" of an older era (Nobrega and Miyagawa, 2015), we acknowledge that Progovac earlier proposed the idea of the two-term frame as a "proto" stage of human language, an idea compatible with our dual-compartment frame for monkeys.

It is worth noting here that nonhuman primate vocal systems may contain more call combinations than currently recognized. For example, some primate examples of the System of One may, on closer inspection, utilize a System of Two. One instance of this comes from the black-fronted titi monkey (*Callicebus nigrifrons*). A study published in 2012 showed that call A is given reliably to threats in the canopy, whereas call B is given to threats on the ground, and these calls are functionally referential (System of One) (Cäsar and Zuberbühler, 2012). A follow up study published in 2013 showed that these monkeys combine A and B calls (in predator-specific ways) to signify, for example, an aerial predator on the ground or a terrestrial predator in the canopy (System of Two) (Casar et al., 2013). An even closer look at the same titi monkeys' combinations of A and B calls by Berthet et al. (2019) reveals more complexity. While the predator type seems more important than its location, both are revealed in the call combinations, particularly by the proportion of "BB-grams" (the proportion of two contiguous B calls). The authors suggest that the information is continuous rather than categorical and has elements of probabilistic meaning. In terms of our theory, the BB-grams would take up one slot ($B^n$) in the dual compartment frame and the other would be taken up by the A calls ($A^n$), still fulfilling the System of Two requirements. However, this example illustrates how the flexibility of monkey call combinations can still be expressed *via* the dual compartment frame theory. Further research is needed to shed light on how other monkeys produce and attend to their call combinations.

[4]Our claim is that the Old World Monkey calls comprise a system that can be described by regular grammar, and one that Friederici et al. (2006) show as using the frontal operculum. This is the same conclusion as Fitch and Hauser (2004), but using the actual vocalization of the animals. This system, and the system in the phylogenetically newer Broca's area that allows hierarchical structure, together comprise human language. It is possible to view both systems as having existed prior to the formation of human language; language simply tapped these pre-existing resources. In this way, language did not arise from primate alarm calls.

[5]A reviewer wonders how our theory based in part on Merge compares to alternative views such as that of Lieberman (2015, 2016). Lieberman argues that hierarchical syntactic structures cannot be considered the product of a genetically determined, species-specific operation. According to his view, hierarchical structures may be acquired by means of associative motor learning, similarly to learning how to walk. If his assumption is on the right track, one should expect that the type of structural embedding observed in natural languages is arbitrarily determined—a point that is not addressed by the author—even though it is patently uniform across the species. Languages do vary in terms of lexical items and superficial distribution, but they do not vary with respect to the nature of sequences it can generate.

## ANALYSES OF OLD WORLD MONKEY CALLS

We begin our analyses with the putty-nosed monkey (*Cercopithecus nictitans*), where we develop the idea of the dual-compartment frame for nonhuman primates. We will then apply this to some other Old World monkeys that also evidence a two-term combination.

### Putty-Nosed Monkey

Putty-nosed monkeys have two main alarm calls, *pyow*s (=P), which are broadly distributed and suggestive of a general alarm call, and *hack*s (=H), which are often used to indicate eagles (Arnold and Zuberbühler, 2012). In addition, the putty-nosed monkeys sometimes produce *pyow-hack* sequences composed of a small number of *pyow*s followed by a small number of *hacks.* Unlike the individual *pyow*s and *hacks*, which are alarm calls made in response to a perceived predator, the *pyow-hack* sequences are apparently predictive of group movement. The length of the sequence is statistically related to the distance traveled. In a series of playback experiments, Arnold and Zuberbühler (2006a,b, 2008, 2012, 2013) showed that it is the length of the overall sequence that is predictive of the distance traveled, and the actual composition of the equal-length sequences did not appear to affect the behavior. Thus, comparative behavioral results were obtained when PPPHHH, PHHHHH, and other P-H combinations of the same length were played back.

What we see here, as Schlenker et al. (2016a) notes, is that the various *pyow-hack* sequences of the same length are phonologically complex, but lexically simple. They are phonologically complex because of the multitude of possibilities for the occurrence of *pyows* and *hacks*. But the sequence is lexically simple because regardless of the actual number of *pyows* and *hacks*, the sequence is apparently associated with comparable behavior — the distance traveled is essentially the same. How can we capture both the phonological complexity and the lexical simplicity of these sequences? When one looks at the various possibilities, there are two compartments, one for *pyows* and the other for *hacks* (**Figure 2**).

Within each compartment, one can have a varying number of *pyows* and a varying number of *hacks*. Crucially, one never finds a sequence that alternates between the two, such as PHPH… (Arnold and Zuberbühler, 2012). We would not expect such an alternation because it would require more than two compartments. So the *pyow-hack* sequence must always fit into a dual-compartment paradigm, with the only variable being the length of the overall sequence as dictated by the number of *pyows* and *hacks*. We suggest that this dual-compartment frame, which Progovac (2015) earlier proposed as "two-slot mold" for an ostensible human protolanguage, is responsible for what roughly appears to be a combinatorial process of word building in these monkeys. Crucially, there is no operator that operates on each term and combines them, as would be the case if Merge were available. This is clearly seen by the varying numbers of *pyows* and *hacks* that, despite the variation, form a unified expression with the same "meaning." If some combinatorial operation were involved, we would need to say that this operation would take each instance of *pyow* and each instance of *hack* and combine them into some expression, but it is not clear what the structure of such an expression would be, nor is it clear how such combinatorial operations could predict that the overall meaning is the same regardless of the number of individual items in the call.

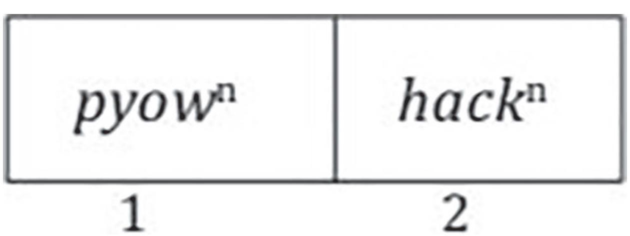


**FIGURE 2 |** Dual-compartment frame proposed for putty-nosed monkey alarm calls.

### Campbell's Monkey

Ouattara et al. (2009b) reports on a study of adult males of six wild groups in the Tai Forest of Cote d'Ivoire. A striking property of the alarm calls of these monkeys is what Ouattara et al. call affixation, where an acoustically invariable "suffix" attaches to acoustically variable "stems." Let us start by looking at the alarm calls of Campbell's monkeys (*Cercopithecus campbelli*) (**Table 1**).

We will focus on four of these calls, *krak*, *hok*, and their "affixed" versions, *krak-oo* and *hok-oo*. Ouattara et al. (2009b), see also (Ouattara et al., 2009a; Schlenker et al., 2016a), note that the "affix" *oo* attaches to a stem to "broaden the call's meaning." In the case of *hok-oo*, the stem *hok* is a specific eagle alarm, while the affixed version is a general arboreal disturbance call. For *krak-oo*, the stem *krak* is a leopard alarm call while the affixed version is a general alert call. By calling *oo* an "affix," Ouattara et al. (2009b) as well as Schlenker et al. (2016a) implicitly assume an operation by which *oo* is attached to a stem with some predictable semantic effect (see Schlenker

**TABLE 1 |** Alarm calls of Campbell's monkeys. Adapted from data in Ouattara et al. (2009b).

| Call | Context |
|---|---|
| *boom* | Given in non-predatory cases, such as a falling branch |
| *hok* | Given when a crowned eagle is detected |
| *krak* | Given when detecting a leopard |
| *hok-oo* | Given to disturbances in the canopy, hence a general aerial call |
| *krak-oo* | Given to almost any disturbance |
| *wak-oo* | Given to the same events as *hok-oo* calls (eagles, etc.) |

et al., 2016a for a detailed semantic/pragmatic analysis, including dialects of Campbell's monkey calls).

However, an equally plausible way to view these alarm calls is that they are learned as independent, whole calls, and the phonological and semantic resemblances we see with *oo* are entirely accidental. This would be consistent with the idea that Merge does not exist in the system underlying monkey communication, and is supported by data showing that the *oo* affix is produced as an independent articulation rather than a co-articulation (Kuhn et al., 2018). So which is it? Does Merge or some such operation exist in Campbell's monkey system to operate on a stem and affix and combine them, or are these alarms simply learned as they are without any composition involved? We will carefully sift through the data (Ouattara et al., 2009b) in order to show that the Campbell's monkey seems to be aware that in the call *krak-oo*, *krak* stands for leopard despite the fact that the overall call, *krak-oo*, is a general alarm call. But this does not entail the existence of a combinatorial operation such as Merge; we will argue when we look at the developmental data of De Brazza's monkeys (*Cercopithecus neglectus*), which has a similar system as Campbell's monkeys, that the calls appear to be learned as whole expressions even when there appears to be an affix, but at the same time, the monkey seems aware that there are parts of calls that carry meaning independent of the entire call. This way of looking at the "affixed" calls parallels what we saw for putty-nosed monkeys. The system that we identified for these monkeys has a dual-compartment frame, with each slot being populated by one or more of the same call, *pyow* or *hack*.

In order to show that Campbell's monkeys are aware that *krak-oo* contains *krak* that signifies a leopard, we need to carefully sift through Ouattara et al.'s data (Ouattara et al., 2009b), and extract from it data that is most widely distributed among the population studied. In one experiment, the researchers presented both visual (model) and acoustic cues of eagle and leopard to the monkeys in their natural habitat. Focusing on the alarms elicited by the visual cue first, we find the following (**Table 2**).

For eagle, the call specific to eagles, *hok*, was most numerous, but there were also *hok-oo*, which is a general arboreal call, and *krak-oo*, which is a general call. For the leopard visual cue, *krak,* which is the leopard call, is the call given. There were four *krak-oo* calls, given by just one of the seven animals, whereas the other calls were distributed across virtually all of the animals under study. We therefore believe that these four *krak-oo* calls are atypical and can be excluded, so that what we have is the following (**Table 3**).

As shown by the rectangle, there is a gap in the paradigm. Why did not all seven animals give out *krak-oo* when presented with a leopard when this call is a general call that would be appropriate for this context? We can see that for eagle, the monkeys gave out this general call in large numbers. A plausible explanation lies in the fact that *krak-oo* contains the form *krak*, which is the leopard alarm call. When faced with a leopard, the monkeys overwhelmingly chose to use *krak* instead of *krak-oo* because *krak-oo*, despite being a general call, nevertheless contains *krak* and apparently a residue of the meaning of leopard associated with it. Faced with a leopard in the vicinity, the Campbell's monkey chose the more direct way to convey the alarm by choosing *krak* instead of *krak-oo*.

According to Schlenker et al. (2016a,b), the Informativity Principle is: "when one call is strictly more informative than another, the most informative one is used whenever possible" (p. 18). We can adapt and apply this to the Campbell's monkey call system to get: "when two alarm calls contain reference to the same predator, the more informative one is used whenever possible." The fact that this principle excludes *krak-oo* when presented with a leopard model suggests that the Campbell's monkeys are aware that this expression is composed of two parts (and was not learned as an unanalyzable unit). This also explains why, when presented with an eagle model, the Campbell's monkeys used both *hok-*, for eagle, and *krak-oo*, the general call; the latter does not contain any reference to the eagle, so it is not excluded by the revised Informativity Principle. There is a question as to why the Campbell's monkeys also produced *hok-oo* when presented with the eagle model. This should be excluded by the Informativity Principle in favor of *hok-*. One possible explanation lies in the observation that *hok-oo* appears to have additional functions beyond *hok-* and is associated with distinctive behavior: "[w]hile producing "hok-oo" calls, males adopted a threat posture, combined with flashing their eyelids, and they sometimes conducted a short dash toward the disturbance" (Ouattara et al., 2009b:3).

The question still remains as to how the Campbell's monkey learns *krak-oo*. Is it by affixation, as previous research suggests, or is it learned as a whole expression, but fitting into the dual-compartment frame as we saw for the system entailed for the putty-nosed monkey? The data available for Campbell's monkeys do not help us to decide, but when we look at De Brazza's monkey system (described later), which has calls similar to that of Campbell's monkeys, we find evidence that there is no combinatorial operation involved during development, but rather, the two items in a call fit into a dual-compartment frame.

If we look now at the Campbell's monkey calls elicited by acoustic cues, we get a very different result (**Table 4**).

**TABLE 2** | Number of call responses to visual predators by Campbell's monkeys. Adapted from data in Ouattara et al. (2009b).

| | krak-oo | krak | hok-oo | hok |
|---|---|---|---|---|
| $Eagle_{visual}$ | 91 | | 37 | 151 |
| $Leopard_{visual}$ | 4 | 273 | | |

**TABLE 3** | Number of call responses to visual predators by Campbell's monkeys, excluding possible outliers.

| | krak-oo | krak | hok-oo | hok |
|---|---|---|---|---|
| $Eagle_{visual}$ | 91 | | 37 | 151 |
| $Leopard_{visual}$ | [ ] | 273 | | |

**TABLE 4 |** Number of call responses to acoustic predator cues by Campbell's monkeys. Adapted from data in Ouattara et al. (2009b).

| | krak-oo | krak | hok-oo | hok |
|---|---|---|---|---|
| Eagle$_{acoustic}$ | 62 | | 7 (3/7) | 9 (2/7) |
| Leopard$_{acoustic}$ | 67 | 42 (4/7) | | |

**TABLE 5 |** Number of call responses to acoustic predator cues by Campbell's monkeys, excluding possible outliers.

| | krak-oo | krak | hok-oo | hok |
|---|---|---|---|---|
| Eagle$_{acoustic}$ | 62 | | | |
| Leopard$_{acoustic}$ | 67 | | | |

Let us exclude the two small instances, seven for *hok-oo*, which were elicited by just three out of the seven animals, and nine for *hok*, elicited from just two of seven animals. In addition, the 42 instances of *krak* were elicited from four out of seven animals, and of these four animals, two of them were responsible for 33 calls, or close to 80% of the total number of *krak* calls. If we temporarily exclude these 42 instances, we get the following (**Table 5**).

What we can see is that contrary to the visual cues, the monkeys reacted to acoustic cues with uncertainty, thus they consistently and overwhelmingly used the most general alarm call regardless of the acoustic cue they heard. One explanation is that acoustic playbacks may be weaker experimental stimuli than visual models due to them being short-lived, and impossible to confirm, especially if a function of alarm calling is to deter the predator (Arnold et al., 2008). Thus acoustic predator cues may make for uncertain/non-uniform responses. Another possibility is that a vocalizing predator is unlikely to be hunting, and therefore does not represent as great a threat as a silent, but visualized predator. For most of the population, then, using the direct call, such as *hok* for eagle and *krak* for leopard, requires visual witnessing of the predator. The exception to this were the two animals that elicited a large number of *krak* calls in response to the acoustic leopard cue, which we excluded in **Table 5**, but will return to now. It is not clear why these animals apparently showed more certainty about the presence of a predator than the others. These individuals were perhaps either more (or less) naïve than their counterparts about leopard hunting strategies.

## Black-and-White Colobus Monkeys

Similar to the above examples, Schel et al. (2009, 2010) report on Black-and-White Colobus monkeys (*Colobus polykomos* and *Colobus guereza*) that have calls which fit the two-compartment frame. These monkeys have three types of calls, *snorts*, *roaring* sequences, made of a series of *roars*, and a *snort-roar* sequence. The single snort is typically used for terrestrial predator contexts (not eagles), repetition of roars for leopard and eagle-related situations (with significant structural differences between the two), and the *snort-roar* sequence appears most often related to leopards. For the two-compartment frame, we propose the first compartment contains *snort*, which is never repeated, and the second compartment contains a *roaring* sequence.

**TABLE 6 |** Distribution of three call types across age and sex in DeBrazza's monkeys. Adapted from data in Bouchet et al. (2012).

| Females | | Males | |
|---|---|---|---|
| **Juveniles** | **Adults** | **Juveniles** | **Adults** |
| *On* | *On* | *On* | *On* |
| *I* | | *I* | |
| *OnI* | *OnI* | *OnI* | |

## De Brazza's Monkeys

Bouchet et al. (2012) studied 23 De Brazza monkeys (*Cercopithecus neglectus*) in captivity that included three juvenile males, three juvenile females, five adult males, and 12 adult females, all captive-born. The inclusion of the juvenile monkeys allowed for developmental study of calls, which becomes important for our study. They report that the monkeys produced 10 distinct call types; we will focus on three of them, *On, I,* and *OnI* since the first two together represent the third. Though the De Brazza study described here does not focus on alarm calls, like our other examples, it highlights the ontogeny of a combined call system in an Old World monkey, which is pertinent to our theory that Merge is not necessary for combining two calls.

*On* calls occurred with gazes directed to the adult male by adult females as well as both sexes of juveniles. The adult male made this call when gazing at zoo-keepers, the research observer, or neighboring groups. *I* calls were uttered by juveniles when approaching the adult male to establish physical contact. *OnI* calls were made by adult females and juveniles of both sexes when approaching a male but with ambivalence about whether to approach or escape. The distribution of these calls among juveniles and adults is given below (**Table 6**).

*On* occurs with both juvenile and adult females and males, while *I* occurs only with juveniles of both sexes. *OnI* occurs with female and male juveniles and with female adults.

Let us turn to the question of whether the two-item *OnI* is a product of a combinatorial operation or is learned whole but fit into a dual-compartment frame. Among juveniles of both sexes we find *On, I,* and *OnI*; *OnI* here could be viewed as resulting from a combinatorial process. However, when we look at the adult female, we see a clear indication that *OnI* cannot be the result of an operation that combined *On* and *I*. This is because among females, *On* occurs but *I* does not, yet *OnI* does occur. It is important to note that as juveniles, the females produced both *On* and *I* as well as *OnI*, hence there is presumably awareness that the *OnI* utterance has parts that fit into the whole. Our suggestion is that this fitting the parts into the whole is made possible by the kind of dual-compartment frame we argued for the putty-nosed monkey system. Although *I* is lost in the adult vocal repertoire, presumably the dual-compartment frame structure holds for the adult *OnI*. Crucially, the two-term call *OnI* is not the product of a combinatorial operation such as Merge.

## CONCLUDING REMARKS

Previous research showed that there is a fundamental difference between AB combinations and more complex $A^nB^n$ combinations that require hierarchy. Cotton-top tamarins and very young human infants can only compute the simple AB combinations, while humans, after a certain age, can learn the more complex array easily (Fitch and Hauser, 2004; Milne et al., 2016). Experiments by Friederici et al. (2006) showed that there is a neuroanatomical distinction between AB sequences and $A^nB^n$. While the former recruits the frontal operculum, the latter recruits, in addition, the phylogenetically newer Broca's area. These experiments on tamarins and on human subjects were conducted with artificially created stimuli. We studied the vocal repertoire of Old World monkeys, and found that their calls were limited at most to a combination of two items. We argue this is equivalent to the AB sequence identified earlier using artificial stimuli. What we can deduct from this is that nonhuman primates likely recruit the frontal operculum to create a dual-compartment frame which allows up to two-term calls, but no more, as predicted by previous research. In contrast, humans tap the combinatorial operation of Merge in the Broca's area to create a potentially infinite array of hierarchical structures. As far as we can tell, there is currently no evidence for Merge in nonhuman primate combined calls.

## ETHICS STATEMENT

This study is exempt from ethical requirements as it utilizes previously reported data only. The studies that were reported in the manuscript were carried out in accordance with the recommendations of their respective Animal Care and Research Protocols.

## AUTHOR CONTRIBUTIONS

SM conceived the paper and performed the analyses. SM and EC researched and interpreted the data and drafted the paper. Both authors contributed to manuscript revision, read, and approved the submitted version.

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# How Grammar Introduces Asymmetry Into Cognitive Structures: Compositional Semantics, Metaphors, and Schematological Hybrids

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This paper presents a preliminary and tentative formulation of a novel empirical generalization governing the relationship between grammar and cognition across a variety of independent domains. Its point of departure is an abstract distinction between two kinds of cognitive structures: symmetric and asymmetric. While in principle any feature whatsoever has the potential for introducing asymmetry, this paper focuses on one specific feature, namely thematic-role assignment. Our main empirical finding concerns the role of language, or, more specifically, grammar, in effecting and maintaining the distinction between symmetric and asymmetric cognitive structures. Specifically, whereas symmetric structures devoid of thematic-role assignment more commonly occur in a non-grammatical and usually also non-verbal medium, asymmetric structures involving thematic-role assignment are more likely to be associated with a grammatical medium. Our work draws together three independent strands of empirical research associated with three diverse phenomenological domains: compositional semantics, metaphors and schematological hybrids. These three domains instantiate conceptual combinations, bringing together two or more subordinate entities into a single superordinate entity. For compositional semantics this consists of a juxtaposition of constituent signs to form a single more complex sign; for metaphors this entails the bringing together of two different concepts in order to produce a comparison; while for schematological hybrids this involves the combination of different entities to form a single new hybrid entity. Our empirical results reveal a remarkable parallelism between the above three domains. Within each domain, symmetric structures tend to be associated with a non-verbal or otherwise non-grammatical medium, while asymmetric structures are more frequently associated with a grammatical medium. Thus, within each domain, grammar introduces asymmetry. More specifically, we find that in all three domains, the asymmetry in question is one that involves the assignment of thematic roles. To capture this effect, we posit two distinct levels, or tiers, of cognition: non-grammatical cognition, more commonly associated with symmetric structures, and grammatical cognition more conducive to asymmetric structures. Within each of the three phenomenological

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domains, we find the distinction between non-grammatical and grammatical cognition to be manifest in three independent realms, phylogeny, ontogeny, and the architecture of human cognition. Thus, grammar constitutes the driving force behind the transition from symmetric to asymmetric cognitive structures.

**Keywords: compositional semantics, metaphor, hybrid, asymmetry, thematic roles, ontogeny, phylogeny, conceptual combination**

## INTRODUCTION

This paper presents a preliminary and tentative formulation of a novel empirical generalization governing the relationship between grammar and cognition across a variety of independent domains.

Its point of departure is an abstract distinction between two kinds of cognitive structures: *symmetric* and *asymmetric*. A cognitive structure of the form XY is symmetric if X is to Y as Y is to X with respect to all relevant features. Conversely, XY is asymmetric if there is one or more relevant features applying differentially to X and Y, thereby effecting an ordering, ranking, or imbalance between X and Y.

While in principle any feature whatsoever has the potential for introducing asymmetry, this paper focuses on one specific feature, namely *thematic-role assignment*. Thematic roles are properties such as agent, patient, location, instrument and theme, that are assigned by one expression to another. For example, in a sentence such as *John ran*, the verb *ran* assigns the thematic role of agent to the noun-phrase *John*. Accordingly, due *inter alia* to thematic-role assignment, the sentence *John ran* is not a symmetric juxtaposition of its two words *John* and *ran*, but rather an asymmetric construction in which *ran* is a thematic-role assigner and *John* its thematic-role assignee.

Our main empirical finding concerns the role of language, or, more specifically, grammar, in effecting and maintaining the distinction between symmetric and asymmetric cognitive structures. Specifically, whereas symmetric structures devoid of thematic-role assignment more commonly occur in a non-grammatical and usually also non-verbal medium, asymmetric structures involving thematic-role assignment are more likely to be associated with a grammatical medium.

Our work draws together three independent strands of empirical research that we have been engaged in, separately and together, over the last several years, associated with three diverse phenomenological domains: *compositional semantics*, *metaphors* and *schematological hybrids*. Although quite different in many respects, these three domains share a common structural property, namely that they involve a bringing together of two or more subordinate entities into a single superordinate entity: X and Y become XY. For compositional semantics this consists of a juxtaposition of constituent signs to form a single more complex sign, e.g., *John* + *ran* > *John ran*; for metaphors this entails the bringing together of two different concepts in order to produce the comparison, e.g., *anger* + *volcano* > *Anger is like a volcano*; while for schematological hybrids this involves the combination of different entities to form a single new hybrid entity, e.g., *man* + *horse* > *centaur*. These three domains may thus be viewed as constituting conceptual combinations, in the sense of Murphy (1988, 1990), Wisniewski and Love (1998), and others.

As such, one may examine the extent to which the composite conceptual structures formed from the subordinate entities are symmetric or asymmetric in nature. For compositional semantics, the question is whether the meaning of, say, *John ran* is just the symmetric sum of the meanings of *John* and *ran*, or whether there are further asymmetries between *John* and *ran*, for example, as suggested above, the assignment by *ran* of the thematic role of agent to *John*. For metaphors, we examine the extent to which comparisons of two terms are symmetric and reversible, as in *Anger and a volcano are alike*, or alternatively asymmetric and irreversible, with a source term lower on a hierarchy of some kind, such as *volcano*, applying to a target term higher on the same hierarchy, such as *anger*. And for schematological hybrids, the issue is whether a centaur is merely a symmetric combination of half-man and half-horse, or whether it inherits more properties from one of its components than from the other, in accordance with various principles such as an Ontological Hierarchy, which might entail that the centaur would be more man than horse.

Our empirical results reveal a remarkable parallelism between the above three phenomenological domains. Within each domain, we find a strong tendency for symmetric structures to be associated with a non-verbal or otherwise non-grammatical medium, and a complementary preference for asymmetric structures to be associated with a grammatical medium. In other words, within each of the three domains, grammar introduces asymmetry. More specifically, we find that in all three domains, the asymmetry in question is one that involves, in some form or another, the assignment of thematic roles.

In order to capture this effect, we posit two distinct levels, or tiers, of cognition: *non-grammatical cognition*, more commonly associated with symmetric structures, and *grammatical cognition* more conducive to asymmetric structures. These two levels of cognition are not on a par; rather, grammatical cognition is derived from non-grammatical cognition by the introduction of thematic-role assignment, which has the effect of transforming symmetric structures into asymmetric ones.

Within each of the three phenomenological domains, we find the distinction between non-grammatical and grammatical cognition to be manifest in three independent realms. First, we show that the non-grammatical/grammatical distinction is a fundamental feature of the *architecture* of human cognition. Secondly, we demonstrate that the transition from non-grammatical to grammatical cognition is characteristic of *ontogeny*, the way cognition develops amongst infants. Thirdly, we offer indirect evidence and argumentation to the effect that a similar transformation from non-grammatical to grammatical cognition was also characteristic of *phylogeny*, the development of contemporary human cognition from that of our pre-human ancestors.

Empirical support for our findings derives from a mix of distinct research methodologies involving experimentation, observation of naturalistic behavior, and deductive argumentation within each of the three domains. Although we have already accumulated a large body of evidence in support of our findings, our presentation here is of a preliminary and programmatic nature, an initial laying out of the terrain to be filled in, hopefully, by future and more detailed studies.

In the next section we provide a brief characterization of the role of thematic-role assignment in effecting a distinction between symmetric and asymmetric structures, following which, in the subsequent three sections we survey the evidence for distinct non-grammatical and grammatical modes of cognition in compositional semantics, metaphors and schematological hybrids respectively. The section on Compositional Semantics represents work in progress by the first author, some preliminary results of which are presented in Gil (2007, 2008, 2015). The section on Metaphors represents work by the second author, some of which is reported on in Porat and Shen (2017) and Shen and Porat (2017). And the section on Schematological Hybrids represents joint collaborative work in progress by both authors, some of which is summarized in Shen and Gil (2017) and references therein.

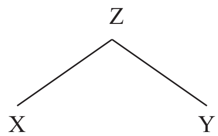
## THEMATIC ROLE ASSIGNMENT

Thematic roles are most familiar to us from linguistic theory. An important part of a word's meaning is its associated thematic roles, also known as semantic frames (Fillmore, 1982, 1985 and others). For example, in order to understand the meaning of the word *hit*, one must know that it assigns its arguments two thematic roles: an agent and a patient.

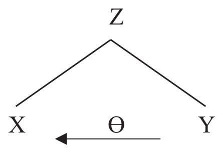
Thematic role assignment is not specific to language; it is a feature of general conceptual structure reflecting our understanding of the world around us (Jackendoff, 1983, 1987, 1990). Thus, when we entertain the concept 'hit,' we know that it involves an agent and a patient, and when we attempt to identify the entities bearing these two roles, we engage in the assignment of thematic-roles at the level of conceptual structure. The independence of thematic-role assignment from language is evident from the behavior of animals, such as for example, great apes. As shown by de Waal (1982) and others, a chimpanzee observing one conspecific hitting another will infer that the one doing the hitting is more dominant on the social hierarchy than the one being hit: such an inference relies crucially on the distinction between thematic roles of agent and patient, and is obviously drawn without recourse to language.

The way in which thematic-role assignment effects asymmetric structures, illustrated with the sentence *John ran*, may be represented schematically as in (1) below:

(1) (a) Symmetric




(b) Asymmetric




In (1a), X and Y combine to form a symmetric structure Z. In (1b), Y assigns a thematic role, denoted Θ, to X, thereby introducing an asymmetry to Z.

Although logically the distinction between symmetric and asymmetric structures is a clear cut binary one, in practice it is quantitative. Purely symmetric structures are hard to come by. Thematic roles aside, an otherwise symmetric structure will often exhibit a degree of asymmetry associated with the medium with which it is associated. For example, even in the otherwise symmetric (1a), X precedes Y in its orthographic representation on the page; in other cases an otherwise symmetric structure may exhibit an asymmetry, such as up vs. down, associated with the spatial medium.

A crucial characteristic of the distinction between symmetric and asymmetric structures is its *privative* nature. Asymmetric structures are derived from symmetric ones by adding features that effect the asymmetry. For example, in (1) above, the asymmetric structure in (b) is derived from its symmetric counterpart in (a) by introducing thematic-role assignment. Thus, symmetric structures are architectonically prior to asymmetric ones; they provide the foundations on which asymmetric structures are constructed.

As we shall demonstrate below, the processes by which asymmetric structures are built on top of symmetric ones are associated with the introduction of language. Although, as noted above, thematic-role assignment is part of general conceptual structure, it is through the medium of grammar that it assumes its role as a central feature underlying asymmetric cognitive structures, thereby providing the basis for the distinction between non-grammatical and grammatical levels of cognition.

## COMPOSITIONAL SEMANTICS

The first of three phenomenological domains to be considered here is that of compositional semantics, which refers to the way in which the meaning of a combination of signs is derived from the meanings of each of its individual constituent signs.

Since language is our primary conveyor of meanings, compositional semantics is most commonly thought of as a specifically linguistic feature; in fact, however, it is a central property of any semiotic system. Pictograms provide a fine illustration of this. Consider the juxtaposition of two meaning-bearing signs in **Figure 1** below.

In **Figure 1**, the meanings of the individual signs can be paraphrased as 'bicycle' and 'thataway' respectively. But what do they mean in combination? In many European cities, similar combinations of signs are commonly used to mark bicycle lanes; however, they can also be used in other contexts, for example to point toward the location of a bicycle sale. Given such variation, one might suggest that juxtapositions such as that in **Figure 1** are multiply ambiguous. Instead, as argued in Gil (2017), the combination of signs in **Figure 1** has a single underspecified meaning which may be represented as follows:

(2) A (BICYCLE, THATAWAY)

In (2) above, the symbol A denotes the *association operator*. In its monadic form, the association operator corresponds in its interpretation to familiar genitive or possessive constructions; for example, A (JOHN) means 'entity associated with John,' or simply *John's*, where the relationship between the associated entity and John is underspecified. For example, *John's picture* could refer, depending on context, to the picture that John owns, the picture that John drew, the picture that portrays John, and so forth. However, in (2), the association operator appears in dyadic guise, where its meaning is 'entity associated with bicycle and thataway.' It thus provides an underspecified meaning encompassing all of the potential interpretations of **Figure 1**, that is to say, anything that has to do in some way with bicycle and thataway. In particular, it says nothing about the thematic role of *bicycle*, and, in particular, whether it is the theme (i.e., the thing that is going) or the goal (i.e., where you get to) of *thataway*.

The meaning represented in (2) is for all intents and purposes symmetric. Obviously, the two constituent meanings had to be written in some order on the page, but the order chosen is immaterial, the formula in (2) could just as easily have been written A (THATAWAY, BICYCLE) without any change in meaning. Thus, the combination of signs in **Figure 1** and their single underspecified interpretation in terms of the formula in (2) provide a straightforward example of the symmetry characteristic of compositional semantics in a non-linguistic medium. Such interpretations, represented in terms of the polyadic association operator alone, may be referred to as *bare-associational* interpretations.

It is not by chance, however, that the formula in (2) has no easy translation into English and many other languages. In order to approach the meaning conveyed in (2) one needs to shed the straitjacket of grammar and construct a grammatically defective utterance with a telegraphic feel such as the following:

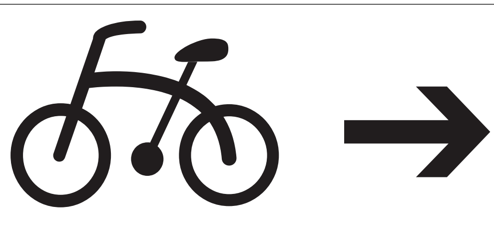


**FIGURE 1 |** Compositional semantics: bicycle and arrow.

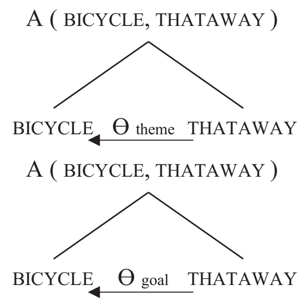
(3) Bicycles thataway

Constructions such as that in (3) are discussed in detail in Progovac (2015). Like (2), the interpretation of (3) is underspecified with regard to thematic roles. However, (3) is stretching English to its limit. A more natural rendition of (2) into grammatical and idiomatic English must necessarily choose between one of a number of more specific interpretations of (2) involving specific assignments of thematic roles to *bicycle*, such as the following:

(4) (a) Bicycles go thataway
(b) Go thataway for bicycles

Building on the representations in (1), the most readily available interpretations of the two sentences in (4) may be represented as follows:

(5) (a) (b)




Whereas in (5a), *thataway* assigns the thematic role of theme to *bicycle*, in (5b) it assigns it the role of goal.

The contrast between (2) and (5) shows how grammar introduces asymmetry into semantic compositionality. Whereas (2), associated with the non-verbal pictogram in **Figure 1**, is symmetric, the two options in (5), corresponding to the English sentences in (4), are asymmetric, by dint of the asymmetric relationship of thematic-role assignment, in which THATAWAY assigns the appropriate thematic role to BICYCLE.

More specifically, the contrast between (2) and (5) shows how asymmetric structures are constructed on the foundations of symmetric ones. Note how the formula in (2), A (BICYCLE, THATAWAY), also forms part of the two representations in (5). This captures the central role that the polyadic association operator plays not just in pictograms but also in ordinary language. Imagine a person who does not know English but who has access to an English dictionary. It suffices for them to look up the meanings of the words *bicycle* and *thataway*, in order to be relatively certain that the meanings of both (4a) and (4b) have something to do with BICYCLE and THATAWAY, as specified by the association operator in the formula A (BICYCLE, THATAWAY). However, without knowledge of English grammar, they will have a harder time figuring out the difference in meaning between the two sentences in (4), and the details of thematic-role assignment distinguishing between them. Thus, the two formulas in (5) capture a fundamental feature of the architecture of compositional semantics, showing how the asymmetric grammatical process of thematic-role assignment, associated with the higher grammatical level of cognition, is built on top of the symmetric pre-linguistic structure effected by the polyadic association operator, associated with the lower non-grammatical level of cognition.

(It should be kept in mind that the asymmetry represented in (5) obtains between the assigner and the assignee of a single thematic role. This asymmetry underlies and sets the stage for another kind of asymmetry that has been the focus of much attention in recent linguistic literature, that which holds between two or more expressions in the same clause bearing different thematic roles; see, for example Kayne (1994) and Moro (2000). The symmetry under consideration here is thus logically prior to, and presupposed by, the latter and more commonly discussed notion of asymmetry.)

The architecture of compositional semantics expressed in the two formulas in (5) is mirrored by the transition from symmetric to asymmetric structures in ontogeny and phylogeny. Consider, first, early child language acquisition, where the child has just begun to produce two word utterances. Bloom (1973) cites the following examples from the spontaneous speech of 20-month-old Allison, who is playing with a pig inside a toy truck. The pig is hurt by a sharp corner of the truck, at which point Allison produces the following utterances:

(6) (a) hurt truck *HURT - cause*
(b) hurt knee *HURT - patient*

Given the context, in (6a) *truck* is understood as the cause of *hurt*, while in (6b), *knee* is understood as its patient — as indicated to the right. Accordingly, Bloom argues that there is no reason to analyze utterances such as these in terms of grammatical structure involving thematic-role assignment. Rather, the juxtaposition of words in early child language may be assigned a bare-associational meaning represented in terms of the polyadic association operator, such as, for (6a), A (HURT, TRUCK), 'entity associated with hurt and with truck' (Gil, 2017, p. 484). Thus, early child-language compositional semantics resembles that of pictograms, as illustrated in **Figure 1** above. It is the symmetric foundation that forms the basis for the subsequent development of asymmetric thematic-role assignment in the adult language.

In this respect, ontogeny recapitulates phylogeny. Rudimentary symmetric compositional semantics would appear to be present in the natural communicative systems of primates in their natural habitat (Arnold and Zuberbühler, 2006, 2012; Schlenker et al., 2014 and others). A somewhat more productive compositional semantics would seem to be accessible to apes in captivity. Two well-known cases are those of the Kanzi, a bonobo using lexigrams (Greenfield and Savage-Rumbaugh, 1990), and Chantek, an orangutan using American Sign Language (Miles, 1990). Some examples of Kanzi's spontaneous sign-language production are presented below:

(7) (a) LIZ HIDE *agent - HIDE*
(b) WATER HIDE *patient - HIDE*
(c) HIDE AUSTIN *HIDE - agent*
(d) HIDE PEANUT *HIDE - patient*

Example (7) above forms a mini-paradigm, represented schematically at right, in which HIDE is either preceded or followed by a participant, which, in accordance with the utterance's context as provided by the authors, may, in either position, be understood as either the agent or the patient of HIDE. There is thus no evidence for any grammatical assignment of thematic roles in Kanzi's use of lexigrams; rather, the relationship between the two signs is semantically underspecified. As in the pictograms in **Figure 1**, and also early child language in (6), the juxtaposition of lexigrams has a single bare-associational meaning, represented in terms of the polyadic association operator as, for (7a), A (LIZ, HIDE), 'entity associated with Liz and with hiding' (Gil, 2017, p. 482). Thus, the bonobo Kanzi's use of lexigrams exhibits purely symmetric compositional semantics. Similar observations hold also for the orangutan Chantek's usage of American Sign Language. Given that the common evolutionary ancestor of great apes such as bonobos and orangutans is shared also by humans, it may be concluded that this common ancestor also had symmetric compositional semantics in the form of the polyadic association operator, which then formed the basis for the subsequent development of asymmetric thematic-role assignment in human language. Thus, as shown above, the development from symmetric to asymmetric compositional semantics in both ontogeny and phylogeny underlies the architecture of compositional semantics, with the asymmetric polyadic association operator providing the foundation on which asymmetric thematic-role assignment then takes place.

The distinction between symmetry and asymmetry in the domain of compositional semantics is not categorical but rather gradated. Thematic-role assignment is not something that is either present or absent; instead, it can be present to various degrees, depending on a wide variety of factors, both grammatical and extra-linguistic. An extensive empirical exploration of some of these factors is conducted in an ongoing study, the *Association Experiment*. While some preliminary results of the Association Experiment are presented in Gil (2007, 2008, 2015, pp. 308, 321–322), most of its results have not yet been published.

In the experiment, speakers of different languages are asked to judge the truth conditions of sentences in their languages. Stimuli consist of written sentences, each accompanied by two pictures; speakers are asked which picture is correctly described by the sentence (they also have the options of choosing both pictures or neither). The experiment contains 32 stimuli measuring the relevance of thematic-role assignment to compositional semantics. The stimuli are controlled for a variety of factors, such as the nature of the activity (e.g., reversible vs. non-reversible), the type of the participants (e.g., animate vs. inanimate), and the participants' spatial orientation in the pictures. For each language, at least 30 subjects are examined, all of lower socio-economic status, in order to control, as much as is practically possible, for effects due to lifestyle and education. The experiment has been conducted on 69 languages.

In (8) and (9) below, two examples of stimuli are shown for four selected languages: English, Japanese, Yali (a Trans-New-Guinea language of Papua, Indonesia) and Tikuna (a language isolate of the Amazon region of Colombia). In (8) and (9), speakers of the respective languages are asked to judge whether the given sentence is true in the situation depicted, and in an alternative picture not shown here. The percentages indicate the proportion of speakers who accepted each sentence as a true description of the picture, for the stimuli presented here together with other structurally similar picture-sentence pairs.

(8) Stimulus 1

(a) *English* 7%

The clown is drinking the book

(b) *Japanese* 16%

| | | | | | |
|---|---|---|---|---|---|
| Piero | wa | hon | o | nonde | iru |
| clown | TOP | book | ACC | drink:PTCP | be |

(c) *Yali* 84%

| | | |
|---|---|---|
| Puahun | buku | naruk |
| clown | book | consume:REAL:PRS.PROG |

(d) *Tikuna* 84%

| | | | |
|---|---|---|---|
| Dauraũ̃kü | popera | ni | àű̃ |
| clown | book | 3 | drink |

(9) Stimulus 2

(a) *English* 4%

The car is pushing the woman

(b) *Japanese* 3%

| | | | | | |
|---|---|---|---|---|---|
| Kuruma | wa | zyosei | o | osite | iru |
| car | TOP | woman | ACC | push:PTCP | be |

(c) *Yali* 79%

| | | | |
|---|---|---|---|
| Mobil | heap | mealtil | laruk |
| car | woman | push | go:REAL:PRS.PROG |

(d) *Tikuna* 67%

| | | | |
|---|---|---|---|
| Karu | ngeẽ | na | kunetà |
| car | woman | 3 | push |

For each of the languages examined, the sentence in (8) is derived from a sentence such as 'The clown is drinking the water' by replacing the word for 'water' with the word for 'book,' while the sentence in (9) is derived from a sentence corresponding to 'The woman is pushing the car' by interchanging the words for 'woman' and 'car.'

The Association Experiment measures the degree to which subjects distinguish between thematic roles by recourse to construction-specific rules of grammar involving morphosyntactic features such as word order and flagging (a cover term that includes case marking and adpositions). Consider, for example, English sentence (8a) *The clown is drinking the book*. In accordance with the polyadic association operator, the meaning of the sentence must have something to do with a clown, a drinking, and a book. And indeed, the test picture does involve a clown, a drinking, and a book. However, adult speakers of English overwhelmingly rejected sentence (8a) as a true description of the picture. This is because the compositional semantics of English contains much more than just the polyadic association operator: bare association is supplemented by thematic-role assignment. In particular, the structure of (8a) is such that *drink* assigns the thematic role of patient to *book*, which results in a semantically anomalous interpretation, while ruling out the test picture, in which *drink* and *book* are only loosely connected via bare association. Similarly, for English sentence (9a), *The car is pushing the woman*, the test picture does have a car, a pushing and a woman; however, adult speakers of English overwhelmingly rejected (9a) as a true description of the picture, because "it's round the wrong way," and the grammar is telling us, again anomalously, that the car is the agent of the pushing and the woman its patient.

The results of the Association Experiment provide further support for the two-tiered architecture of compositional semantics as represented in (5) and the way in which it plays out in ontogeny and phylogeny. Support for the two-tiered architecture in (5) is provided by a *wait-a-moment effect* produced by many subjects when responding to the experimental stimuli. For example, in (8), subjects would notice a clown drinking and a book and point to the picture, but then right after, realize that the grammar was wrong, say "wait a moment," and retract their response and offer a negative one in its place. This effect points toward a two-stage process in which subjects first applied the symmetric polyadic association operator, as per (2), and only then, shortly after, added asymmetric thematic-role assignment, in accordance with (5). This two-stage process echoes Friederici's (2002) neural model of sentence processing, and, in particular the "ELAN phase" occurring at 150–200 ms followed by the "LAN/N400 phase" at 300–500 ms.

Support for the ontogenetic trajectory from symmetry to asymmetry is provided by a study of children speaking the Riau dialect of Indonesian. While by age 10, subjects' responses were at adult levels, 8 and 9 year old subjects were significantly more likely to ignore the adult-language preferences for particular thematic-role assignments and respond instead on the basis of bare association; for example, for (8) and (9), they would be more likely to point to the picture as being an acceptable interpretation of the corresponding sentence in Riau Indonesian.

Finally, support for the phylogenetic trajectory from symmetry to asymmetry is provided by inferences drawn from patterns of cross-linguistic variation in subjects' responses to the experimental stimuli. Not all languages work the same way as English: as suggested by the percentages in (8) and (9), languages vary significantly in the degree to which bare association is narrowed down by additional grammatical rules governing the assignment of thematic roles. Whereas in languages such as English and Japanese, thematic-role assignment is largely specified by the grammar, and speakers usually reject bare-associational interpretations, in languages such as Yali and Tikuna, bare associational interpretations are obtainable in a majority of cases.

The degree to which thematic-role assignment is specified by the grammars of different languages is the product of several diverse factors, of which the most important one, which we focus on here, is the complexity of the polity with which the language is associated. It is no accident that many readers may not have heard of the two languages, Yali and Tikuna, chosen in (8) and (9) to exemplify greater tolerance of bare associational interpretations. The 69 languages of the Association Experiment sample may be ranked in accordance with a scale of polity complexity, as shown in (10) below:

(10) *Polity Complexity*

| | | | |
|---|---|---|---|
| high | 1 | National Language: World | English |
| | 2 | National Language: Primary | Japanese |
| | 3 | National Language: Secondary | Malagasy |
| | 4 | National Language: Colloquial Variety | Riau Indonesian |
| | 5 | Regional Language: 4 Tiers (Large States) | Javanese |
| | 6 | Regional Language: 3 Tiers (States) | Fongbe |
| | 7 | Regional Language: 2 Tiers (Larger Chiefdoms) | Tobelo |
| | 8 | Regional Language: 1 Tier (Petty Chiefdoms) | Yali |
| low | 9 | Regional Language: 0 Tiers (Autonomous Bands) | Tikuna |

The scale in (10) combines several measures of polity complexity. First is a basic dichotomy between national and regional languages. National languages are further distinguished with respect to more specific characteristics pertaining to the language's functions and status. And regional languages are classified in terms of the complexity of their associated societies as reflected in the number of levels of "jurisdictional hierarchy beyond local community," as defined in the D-Place database (Kirby et al., 2016). In (10), each of the 9 levels of complexity is exemplified by one of the languages in the sample.

The 9-valued scale of polity complexity shown in (10) correlates positively with the degree of complexity of the compositional semantics of the associated languages, as evident in the results of the Association Experiment. In general, languages whose polities are of high complexity, such as English and Japanese, exhibit high grammaticalization of thematic roles and concomitant low tolerance of bare-associational interpretations, whereas languages of low polity complexity, such as Yali and Tikuna, exhibit low grammaticalization of thematic roles and high tolerance of bare-associational interpretations. Taking the 69 languages of the sample to be independent variables, the correlation turns out to be of high statistical significance. In the real world, though, the 69 languages are not all independent of each other; however, examining sets of closely related language varieties differing with respect to polity complexity provides even more convincing support for the correlation. For example, Standard Indonesian, with polity complexity 2, has higher grammaticalization of thematic-role assignment than Riau Indonesian, with polity complexity 4, which in turn has higher grammaticalization of thematic-role assignment than Minangkabau, with polity complexity 7 — even though all three language varieties are closely related exhibiting a certain degree of mutual intelligibility.

The correlation between polity complexity and grammaticalization of thematic-role assignment provides a direct window into the evolution of compositional semantics. Although we have no direct evidence with regard to the linguistic abilities of pre-modern humans or their hominin ancestors, we do know one obvious fact about their socio-political organization, namely that it was near the bottom of the scale of polity complexity in (10) above. Regardless of the nature and directionality of the causation underlying the correlation between polity complexity and grammaticalization of thematic-role assignment, the presence of the correlation suggests that the languages of today's low-complexity polities may provide a model for the languages of our ancient ancestors: whatever today's low-polity-complexity languages are like, that is how all languages used to be. The results of the Association Experiment thus provide further support for the conclusion that, in the course of the evolution of human language, compositional semantics began from bare association and the polyadic association operator, and gradually, over the course of time, evolved the grammatical structures that give rise to thematic-role assignment.

In summary, then, the Association Experiment provides additional evidence, architectural, ontogenetic and phylogenetic, for a two-tiered compositional semantics in which a symmetric polyadic association operator constitutes the foundation on which the asymmetric rules of thematic-role assignment may apply. In conjunction with the other sources of evidence discussed earlier, it thus shows how the asymmetry of thematic-role assignment is introduced by grammatical structure, both in the evolution of human language and in its acquisition by children — as is reflected in the two-tier architecture of compositional semantics represented in (5) above.

The results of this section thus run counter to many or most current approaches to compositional semantics in linguistic theory, in which asymmetric structures are posited directly, without recourse to a prior symmetric foundation. However, the two-tiered architecture argued for here would appear to be akin in spirit to Progovac's (2015) approach, in which functional categories are built up on top of lexical ones, to form structures that also provide a reflection of an evolutionary past.

Compositional semantics represents one of the simplest and most ubiquitous domains in which two terms are brought together to form a third, and in which a pre-linguistic symmetric structure is rendered asymmetric by the introduction of grammar. We now go on to consider two additional phenomenological domains which also involve the bringing together of two terms, but which differ from compositional semantics in one important respect, namely that they involve some kind of conceptual anomaly.

## METAPHORS

Consider **Figure 2** below, a popular internet meme, occurring under headings such as "funny lookalikes".

In **Figure 2**, the baby and the dog assume near identical postures, resulting in two very similar spatial contours. The relation between the baby and the dog can be represented as in (11) below, where the symbol "∼" represents the relationship of similarity:

(11) BABY ∼ DOG

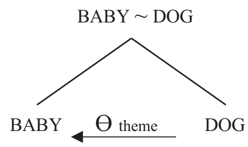
As represented in (11), the relationship of similarity between BABY and DOG is symmetric. From a purely logical point of view, if X is similar to Y then Y is similar to X. And indeed, in terms of processing, a search for similarities can just as readily start out by taking the baby as a reference point and seeking similar properties of the dog, or the other way around.

However, when people are asked to judge whether they prefer verbal comparisons in which the baby is said to resemble the dog, or alternatively ones in which the dog is said to resemble the baby, they exhibit a preference for the former. This preference is independent of the order in which the two entities are shown. (Indeed, the fact that the internet meme usually shows the baby to the left and the dog to the right, as in **Figure 2**, is probably a consequence of this preference, in conjunction with the predominance of left-to-right writing systems on the internet.) Experimental evidence for preferences such as these is provided in Connor and Kogan (1980) and Kogan et al. (1989).

**FIGURE 2 |** Metaphor: baby and dog.

Such preferences thus reveal an asymmetry, which may be represented as in (12) below, in terms of thematic-role assignment:

(12)




In (12), DOG assigns the thematic role of theme to BABY. (More specifically, as argued in Gil (2013), it assigns the thematic role of essant —a subrole of theme whose prototypical usage is in predicate nominal constructions such as *John is a teacher*.) What this says is that 'baby is (like) a dog,' where, of course, 'is (like) a dog' is understood as something along the lines of 'resembles a dog with respect to a particular set of properties.' Conventional terminology captures this asymmetry by characterizing the dog as the *source* of the metaphor and the baby as its *target* (Lakoff and Johnson, 1980).

The contrast between the structures in (11) and (12) closely mirrors that between the structures in (2) and (5) in the preceding section. In both cases, thematic-role assignment imposes an asymmetry on an architecturally prior symmetric structure — the symmetry in question being that of bare association in the first case, similarity in the second. And as we shall see below, here too it is grammar that introduces the asymmetry in question.

Empirical evidence of various kinds has been offered in support of both bidirectional symmetric and unidirectional asymmetric approaches to metaphors. *Prima facie*, these different kinds of evidence appear to be contradictory. In reality, however, they reflect what Wolff and Gentner (2011) insightfully refer to as the "double life" of metaphors. And in fact, as shown in Porat and Shen (2017) and Shen and Porat (2017), the divergent conclusions are due to the variable mediums associated with the different sources of evidence. Specifically, while non-grammatical evidence lends support to bidirectional approaches, evidence based on grammatical phenomena tends to support unidirectional approaches.

Evidence for the bidirectional symmetric approach derives from various psychophysical experiments in which the manipulation of one domain affects the perception of another domain in ways that often correspond to hypothesized conceptual metaphors. For example, participants who held a warm (rather than cold) beverage in their hands tended to judge target individuals as having a warmer personality (Williams and Bargh, 2008), in accordance with the conceptual metaphor AFFECTION IS WARMTH; in another study, participants were likely to judge currency to be more valuable when they were holding a heavy (rather than a light) clipboard (Jostmann et al., 2009), in accordance with the conceptual metaphor IMPORTANT IS HEAVY. However, other experiments found effects applying in the direction opposite to that of the corresponding conceptual metaphor. For example, it was also found that manipulating participants' feelings of social acceptance (by excluding or including them in a social game) can change their evaluation of room temperature — a mapping that defies the regular concrete-to-abstract pattern and has no verbal equivalent in ordinary language (Zhong and Leonardelli, 2008). Similarly, manuscripts that were evaluated as more important were experienced as heavier, in a reversal of the IMPORTANT IS HEAVY conceptual metaphor (Schneider et al., 2011). More generally, analysis of the various psychophysical experimental findings reveals a clear bidirectional pattern for many hypothesized conceptual mappings (see IJzerman and Koole, 2011 for an overview). Experiments such as these show that in the absence of an overt grammatical expression of the metaphor, the relationship between the two terms is bidirectional. Although such birectionality results from a combination of two opposing unidirectional processes, the cooccurrence of both processes means that, at a more abstract level, they "cancel each other out," resulting in a pattern that may accordingly be characterized as symmetric (see Porat and Shen, 2017 and other articles in the same volume for further discussion).

The most common medium for the expression of comparisons is, however, verbal; and the linguistic nature of most experimental tasks is the reason why the bulk of the existing empirical evidence has always pointed toward a unidirectional, or asymmetric process. Thus, when the above-mentioned bidirectional experiential correlations are expressed in a verbal medium, the resulting metaphors are fundamentally unidirectional (Porat and Shen, 2017; Shen and Porat, 2017). For example, it is widely held (Lakoff and Johnson, 1980; Gibbs et al., 1994) that conventionalized metaphorical expressions such as *warm person* or *cold-hearted*, reflecting an underlying conceptual metaphor AFFECTION IS WARMTH, are cross-culturally unidirectional, in that they tend to map concrete domains, such as TEMPERATURE, on to abstract ones, such as INTERPERSONAL RELATIONS, rather than the other way around. Similarly, as noted previously, when confronted with stimuli such as those in **Figure 2**, speakers would rather say that the baby looks like the dog than the dog looks like the baby. Similar findings are reported in many other experimental and corpus studies (Connor and Kogan, 1980; Connor and Martin, 1982; Kogan et al., 1989).

It is sometimes suggested that the unidirectionality of metaphors reflects a conceptual asymmetry inherent to conceptual metaphors (Lakoff and Johnson, 1980). However, while this may be true in part, it cannot be the whole story; language, or more specifically grammar, plays a crucial role in introducing and amplifying the unidirectionality of metaphoricity. One obvious piece of evidence is provided by conceptually symmetric metaphors, in which the two terms are ontologically on a par, such as the following, adapted from Glucksberg and Keysar (1990):

(13) Surgeons and butchers are alike

(14) (a) This surgeon is a butcher
(b) This butcher is a surgeon

In (13), the two nouns occur in a symmetric coordination, whose most readily available interpretation is non-metaphorical (they both cut flesh). However, in (14), the two nouns occur in subject and predicate positions in a syntactically asymmetric predicate-nominal construction, with two significant consequences. To begin with, the asymmetric grammatical structure is itself conducive to metaphorical interpretations (Fishman, (n. d.)). Moreover, the metaphors expressed by the two sentences in (14) are in effect opposites: while in (14a) the surgeon is rough and careless, in (14b) the butcher is delicate and careful. Crucially, there is nothing in conceptual structure that can account for the different meanings of (14a) and (14b) and the opposite assignments of source and target in these two sentences. Rather, the different meanings that we associate with the two metaphors can only be attributed to the mirror-image syntactic structures in which they are expressed. In particular, it is the grammatical asymmetry of the predicate-nominal constructions in (14) that introduces the asymmetry of thematic-role assignment.

Thus, although forming the basis for competing theoretical approaches, bidirectionality and unidirectionality actually represent two distinct stages in the construction of metaphors, with symmetric comparisons such as those in (11) constituting the foundation for asymmetric metaphors such as those in (12), involving thematic-role assignment introduced by the grammatical medium.

Empirical support for a two-stage model for the comprehension of metaphorical comparisons is provided by Wolff and Gentner (2011). Subjects were asked to judge the comprehensibility of metaphors in either canonical order, e.g., *Some arguments are wars*, or reversed order, e.g., *Some wars are arguments*. When the metaphors were presented for a short duration of 500 ms, the sentences in the two orders did not differ in comprehensibility (although the metaphorical statements were still judged as being more comprehensible than nonsensical comparisons). In contrast, when the metaphors were presented for longer periods of time, the metaphors in canonical order were judged to be more comprehensible than their reversed counterparts. Their experiment thus provides direct evidence for a two-stage process in metaphor comprehension, with an earlier symmetric bidirectional stage followed by a subsequent later asymmetric unidirectional stage, again consistent with Friederici's (2002) model mentioned earlier — though it says nothing about the role of grammar in this process.

Evidence for the role of grammar in the transition from bidirectionality to unidirectionality is provided by two further experiments conducted by Porat and Shen (2017) and Porat (in preparation). The first experiment made use of novel abstract-concrete concept pairs, such as childhood memories and migrating birds, while the second experiment made use of conventionalized concept pairs, such as fear and cold. Each experiment consisted of two phases.

In the first phase of each experiment, subjects were asked to arrange the pairs within the grammatically asymmetrical simile construction __ *is like* __. Subjects exhibited a strong preference for the concrete-to-abstract arrangement for both novel and conventional pairs, preferring sentences such as *Childhood memories are like migrating birds* and *Fear is like cold* over their reversed counterparts, *Migrating birds are like childhood memories* and *Cold is like fear*. This finding suggests that the conceptual asymmetry between the members of each pair was strong enough to dictate a preferred direction of mapping, regardless of the novelty/conventionality of the comparison.

In the second phase of each experiment, subjects were presented with the above pairs expressed either in a grammatically symmetric construction, e.g., *Childhood memories and migrating birds are alike*, or in a grammatically asymmetric construction e.g., *Childhood memories are like migrating birds.* For each item, subjects had to decide in which of two given contexts the sentence was more likely to be uttered: while one of the contexts was about the abstract concept, e.g., a nostalgic writer speaking about his youth, the other was about the concrete concept, e.g., an enthusiastic ornithologist describing the flight of birds. In this case, subjects preferred the context consistent with the concrete-to-abstract mapping, e.g., the nostalgic writer, not the enthusiastic ornithologist, significantly more often when presented with the grammatically asymmetrical construction than when presented with the grammatically symmetrical one, for both novel and conventional concept pairs. What this shows, then, is that despite the clear conceptual asymmetry between the two parts of the comparison, the abstract noun phrase, e.g., *childhood memories,* was not automatically assigned the role of metaphorical target; instead, this assignment occurred only after the two concepts were encountered in a grammatically asymmetrical structure.

The picture emerging from the above experiments is thus one of a two-tiered cognitive architecture, with a lower, non-grammatical level of cognition associated with symmetric bidirectional comparisons forming the basis for a higher level of cognition, in which asymmetric unidirectional metaphors are introduced and supported by the medium of grammar. Moreover, as was the case in the preceding section for compositional semantics, the two-tiered cognitive architecture of metaphorical comparisons can be shown to constitute a dual mirror of both ontogenetic and phylogenetic processes.

Several studies have shown that the unidirectionality of metaphors is a product of developmental maturation, and that for younger children bidirectionality is the rule. Connor and Martin (1982) applied the original task by Connor and Kogan (1980) to younger subjects and found that whereas the judgments of high-school students were similar to those of adult subjects, fifth- and seventh-graders exhibited no preference for a particular ordering of the test items. To see whether these findings were restricted to metaphors or reflect a general insensitivity to asymmetric comparisons, Connor (1983) investigated the judgments of third-, fifth- and seventh-graders, as well as college students, in a similar task involving asymmetrical literal comparisons. Again, while college students demonstrated significant inter-subjective agreement regarding the preferred order of each pair, this agreement decreased with age until it almost completely disappeared in the judgments of third-graders, for both metaphorical and literal comparisons. In a further study, Cerbin (1985) found that 4-years-olds are more likely to detect the metaphorical ground of grammatically asymmetrical comparisons, such as *A boat is like a leaf*, than grammatically symmetrical ones, such as *A boat and a leaf are alike*. In this respect, even pre-schoolers show some sensitivity to the difference between the two grammatical structures. However, the ordering of terms in the target and source roles did not affect the children's performance: as in Conner's study, a conventionally ordered sentence such as *A boat is like a leaf* was as easy to understand as its reversed version, *A leaf is like a boat*. Thus, as shown by these studies, metaphorical comparisons start out symmetric and bidirectional, and only later develop into their asymmetric unidirectional form.

A similar journey from bidirectionality to unidirectionality would appear also to be observable phylogenetically. In a cross-linguistic study, Gil et al. (in preparation) modify the Porat and Shen (2017) experiment above, presenting subjects with novel metaphorical constructions such as *A mackerel is like forgetfulness*, and asking them which of two potential speakers is more likely to utter the sentence — in the case at hand, a very old man or a fisherman. The experiment pits the directionality of conceptual hierarchies against the asymmetries of grammar, posing subjects with a dilemma. In accordance with the tendency to explicate abstract entities in terms of concrete ones, the comparison should be about forgetfulness, and hence the speaker is more likely to be the very old man. However, the grammatical structure of the sentence is such that the mackerel is the subject, and hence the speaker is more likely to be a fisherman. Who wins? Our findings, so far, suggest that the results depend on the language, and, in particular, on its associated polity complexity in accordance with the scale presented in the previous section in (10). Specifically, whereas in high-polity-complexity languages such as English, grammar wins out, with subjects exhibiting a strong preference to choose the fisherman as the speaker, in low-polity-complexity languages such as Abui (a language of the Timor-Alor-Pantar family of eastern Indonesia), grammatical and conceptual hierarchies are more equally balanced, with similar numbers of subjects choosing each of the two possible speakers. As was argued for compositional semantics in the preceding section, polity complexity may be used as a window into phylogeny, the assumption being that properties associated with languages of lower polity complexity are characteristic of a prior stage in the evolution of language and cognition. Specifically, we may conclude that at an earlier evolutionary stage, a somewhat weaker grammar played a relatively smaller role in the support of metaphor directionality.

Thus, the empirical evidence surveyed in this section shows that grammar plays a crucial role in the introduction of the asymmetry of thematic-role assignment into metaphorical structures — phylogenetically, ontogenetically, and in the cognitive architecture that mirrors these two developmental realms. Moreover, it does so in a way that presents a remarkable parallel to the way in which grammar was shown, in the preceding section, to introduce a similar asymmetry in a logically independent domain, that of compositional semantics. As we shall now see, a similar asymmetry-inducing role is played by grammar in yet a third, unrelated phenomenological domain, that of schematological hybrids.

## SCHEMATOLOGICAL HYBRIDS

A *hybrid* is an entity conceptualized as an inseparable combination, or fusion, of components associated with two or more distinct entities, which may be referred to as the hybrid's *parents*. The notion of hybrid is very broad; Wikipedia (accessed on 18 May 2016) offers links to 55 different entries with titles containing the term hybrid, concerned with a variety of items from domains such as biology (e.g., hybrid grape), technology (e.g., hybrid vehicle), art (e.g., hybrid genre), and many others (Shen and Gil, 2017, Gil and Shen, unpublished).

An important subclass of hybrids is that of *schematological hybrids.* A schematological hybrid is one representable in a two- or three-dimensional image such as a statue or drawing. Some familiar examples of schematological hybrids include *centaurs*, part-human part-horse, and *mermaids*, combining the top half of a woman with the bottom half of a fish. Schematological hybrids are widespread in art, religion, folklore and popular culture, and have been around since time immemorial (see Wengrow, 2014, Gil and Shen, unpublished). The common occurrence of such hybrids in time and space suggests that they may reflect universal properties of human cognition. A novel example of a schematological hybrid is presented in **Figure 3** to the right.

**FIGURE 3 |** Schematological hybrid: man and bird.

An important property of schematological hybrids is that while its parents are often familiar entities belonging to well-known categories, the hybrid itself is, or at least starts out as, a novel and unfamiliar entity whose categorial membership is not immediately obvious. For example, the hybrid in **Figure 3** above clearly contains the top half of a bird and the bottom half of a man, but the entity as a whole does not instantiate any familiar concept, and there is no common conventional word for it: it's just a "man-bird," or something similar to that (Shen and Gil, 2017, p. 1179).

Schematological hybrids thus pose questions such as the following: What is it? What category does it belong to? For example, does the man-bird belong to the category of humans, or of animals? What properties does it have? For example, can the man-bird speak, or can it fly? More generally, one may ask whether one of the hybrid's parents is more central to its conceptualization, and if so, which one? For example, is the hybrid in **Figure 3** more man or more bird? In other words: is the construction of the hybrid conceptualized as symmetric or asymmetric?

In our work, we examone the ways in which the conceptualization of hybrids is governed by the *Ontological Hierarchy* (Keil, 1979; Connor and Kogan, 1980; Deane, 1992 and others), a basic knowledge structure that imposes a hierarchical order on different kinds of entities:

(15) The Ontological Hierarchy
*humans > animals > plants > inanimates.*

Our focus is on the following question: What is the effect of the Ontological Hierarchy on the conceptualization of hybrids? Specifically, to what extent is there a tendency for hybrids to be categorized in accordance with the parent that is higher on the Ontological Hierarchy; for example, a man-bird as a kind of man, not as a kind of bird (Shen and Gil, 2017)?

Our main finding is that the Ontological Hierarchy is in fact relevant to the conceptualization of hybrids. However, the Ontological-Hierarchy effect depends crucially on the medium in which the categorization takes place; specifically, it is dependent on the presence of grammar. In the absence of grammar, subjects tend to conceptualize hybrids symmetrically; for example, a man-bird is not more manlike than birdlike, and when forced to choose, similar numbers of subjects will choose either option. However, in grammatical contexts they are more likely to verbalize the same hybrids asymmetrically, in accordance with the Ontological Hierarchy; for example. A man-bird might be described as a man with bird's wings rather than a bird with man's legs.

The effect of grammar on the categorization of hybrids may be observed in the following three ways (Shen and Gil, 2017, p. 1181):

(16) (a) The Ontological-Hierarchy effect is greater for tasks that involve grammatical structure than for non-verbal tasks or tasks that involve just the lexicon.
(b) The Ontological-Hierarchy effect is greater for non-verbal tasks when they are primed by verbal ones.
(c) The Ontological-Hierarchy effect is greater for verbal tasks when there is "more grammar"; specifically, asymmetric vs. symmetric grammatical structures.

Our experimental studies make use of a set of 24 custom-designed visual stimuli representing schematological hybrids, such as that shown in **Figure 3** above. The 24 hybrids instantiate all 6 possible binary combinations of the 4 categories of the Ontological Hierarchy: human–animal, human–plant, human–inanimate, animal–plant, animal–inanimate, and plant–inanimate. Each of these 6 combinations is represented by 4 stimuli, 2 in which the parent higher on the Ontological Hierarchy is located above the parent lower on the hierarchy, and 2 in which the parent higher on the Ontological Hierarchy is positioned beneath the other parent — as happens to be the case in **Figure 3**. This was in order to neutralize potential effects of spatial orientation on the hybrids' categorization (Shen and Gil, 2017, p. 1183).

The first series of tasks examined the conceptualization of the hybrid stimuli in non-verbal and other contexts devoid of grammar. In the first *non-verbal categorization task* (Shen and Gil, 2013; reported on in Shen and Gil, 2017, p. 1185), Hebrew-speaking subjects were presented with the 24 hybrids; under each hybrid were two sets of visual images representing members of the two categories associated with each of the hybrid's two parents. For example, for the man-bird hybrid in **Figure 3**, subjects were shown a set of images of humans and a set of images of birds. Subjects were asked to decide which of the two sets the hybrid belonged to. The results were around 50%, that is to say, at chance level.

In a similar *lexical label categorization task* (Shen and Gil, 2013; reported on in Shen and Gil, 2017, p. 1187), Hebrew-speaking subjects were presented with the same 24 visual hybrids; however, instead of being asked to assign the hybrid to a set of visual images, they were asked to match it with a descriptive word label. For example, for the hybrid in **Figure 3**, subjects were shown the word *iš* 'man' and the word *cipor* 'bird.' Although this task was verbal, it did not involve any recourse to grammar. And just like the previous task, the results were around 50% — at chance level.

In a somewhat different *color inference task* (Mansour, 2008; Shen and Gil, 2013; reported on in Shen and Gil, 2017, p. 1187), speakers of Arabic were shown visual images of the hybrid's parents, each in a different color. Beneath the two parent images they were given a colorless silhouette of the appropriate hybrid. Subjects were then requested to infer the color of the hybrid based on the colors of its two parents. For example, for the hybrid in **Figure 3**, they might have been given a green man and a red bird: would the hybrid silhouette then be green or red? Again, subjects' choices were at chance, as in the two preceding tasks.

Thus, the above series of tasks all show that in the absence of grammar, conceptualization of hybrids is symmetric: subjects are no more likely to categorize a visual stimulus of a hybrid in accordance with one of its parents than in accordance with the other. However, when grammar is introduced, an entirely different picture emerges, as is shown in the second series of tasks.

In the first *description task*, speakers of Hebrew were asked to produce a short verbal description of each of the 24 hybrids (Shen et al., 2006; Shen and Gil, 2013; reported on in Shen and Gil, 2017, p. 1183–1184). Their responses were then coded according to whether the description represented a conceptualization of the hybrid as (i) belonging to the category of the parent higher on the Ontological Hierarchy, (ii) belonging to the category of the parent lower on the Ontological Hierarchy, or (iii) neutral, not belonging to either category to the exclusion of the other. Examples of subjects' responses to the stimulus in **Figure 3** illustrating these three possibilities are provided in (17) – (19) below:

(17) *Consistent with Hierarchy*

| adam | šepeleg | gufo | haʕelyon - | nešer |
|---|---|---|---|---|
| person | REL:part | body:3SG.POSS | DEF:upper | eagle |

'a person whose upper body is an eagle'

(18) *Inconsistent with Hierarchy*

| nec/nešer | ʕim | ragley | adam |
|---|---|---|---|
| hawk/eagle | with | leg.CONSTR.PLM | person |

'hawk/eagle with person's legs'

(19) *Neutral*

adam-kondor
person-condor
'person-condor'

A large majority of the descriptions offered were asymmetric, as in (17) and (18); amongst these, roughly two-thirds of the descriptions were consistent with the Ontological Hierarchy, as in (17). (The remaining neutral descriptions, as in (19), were too few for any tendencies to be observed.)

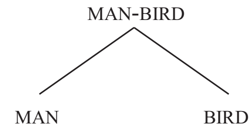
In a second *choice of description task* (reported on in Shen and Gil, 2017, pp. 1186–1187), Hebrew-speaking subjects were shown hybrids from the basic set of 24 stimuli, where alongside each hybrid two descriptions were presented, one consistent with the Ontological Hierarchy, e.g., 'man with bird's wings,' the other inconsistent with the hierarchy, e.g., 'bird with man's legs'. The results of this perception task mirrored those of the preceding task: subjects displayed a significant preference for descriptions in accordance with the Ontological Hierarchy.

In a third *choice of metaphor task* (also reported on in Shen and Gil, 2017, pp. 1186–1187), speakers of Arabic were shown the same hybrids, except that this time, each hybrid was accompanied by two metaphors based on the hybrid's parents, one consistent with the hierarchy, e.g., 'the man is like a bird,' the other inconsistent with it, e.g., 'the bird is like a man.' Once again, subjects displayed a significant preference for metaphors that were constructed in accordance with the Ontological Hierarchy.

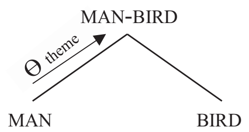
The contrast between the two sets of tasks is thus striking. While the first, non-grammatical set of tasks reveals a symmetric state of affairs in which neither of the hybrid's parents is preferred over the other, in the second, grammatical set of tasks, grammar brings about a preference for hybrids to be categorized in accordance with the parent that is higher on the Ontological Hierarchy. In other words, grammar introduces asymmetric cognitive structures.

The effect of grammar on the conceptualization of hybrids is represented schematically in (20) and (21) below:

(20)



(21)




Whereas the structure in (20), representing the non-grammatical tasks, is symmetric, that in (21), representing the grammatical tasks, is asymmetric. As is the case for compositional semantics and metaphors previously, the asymmetry introduced by grammar involves thematic-role assignment — but in a rather different way. Whereas in (5) and (12) one of the two constituent terms assigns a thematic role to the other one, for hybrids, as represented in (21) above, the constituent term assigns a thematic role to the superordinate constituent. Specifically, the hybrid MAN-BIRD, as a whole, is assigned the role of theme by its parent MAN: the man/bird hybrid *is* a man. This specific configuration of thematic-role assignment may be viewed as a particular case of headedness, in which a property of the head constituent MAN percolates upwards to the superordinate constituent (Gil, 1985).

To this point, all of the tasks described involved speakers of Hebrew or closely related Arabic. However, given that what is at issue is an effect of grammar on cognition, it is reasonable to ask whether all languages work the same way as Hebrew and Arabic; after all, as is well known, although the Animacy Hierarchy itself is universal, its manifestations vary greatly from one language to another. To examine the cross-linguistic applicability of the animacy effect on the categorization of hybrids, we replicated two of the preceding tasks, the non-verbal categorization task and the verbal description task, in three additional languages: Bulgarian (Admon, 2008), Indonesian, and Minangkabau (Shen and Gil, 2013). In all three languages, the same pattern as in Hebrew was obtained: whereas in the non-verbal categorization task, categorization was roughly at chance, in the verbal description task, a significant Ontological-Hierarchy effect was in evidence.

So far, all of the tasks described here were off-line, dealing with the products of hybrid conceptualization. One may ask whether a greater Ontological-Hierarchy effect for tasks involving grammar is present also in the on-line processes of hybrid comprehension. To address this question we developed two *reaction-time tasks* (Mashal et al., 2014), summarized in Shen and Gil (2017). Both tasks showed that for the categorization of hybrids, the greater Ontological-Hierarchy effect associated with grammatical tasks in the off-line products of conceptualization is matched by a similar linguistic effect also in the on-line processes of hybrid comprehension.

A further *grammatical priming task* provides evidence for a rather more striking version of the effect of grammar, namely that, as formulated in (16b), the Ontological-Hierarchy effect is greater for non-verbal tasks if they are primed by verbal ones (Shen and Gil, 2013; reported on in Shen and Gil, 2017, 1194–1195). The verbal priming task sequence was performed in two stages 1 week apart. In the first stage, speakers of Hebrew performed the non-verbal categorization task. In the second stage, the same subjects were requested to perform the non-verbal categorization task again; however, before categorizing each hybrid, they were asked to produce a verbal description. The results showed that hybrids would be more likely to be non-verbally categorized in accordance with the Ontological Hierarchy if such categorization took place right after the grammatical description task.

To this point, we presented a variety of experimental studies showing that, in accordance with (16a) and (16b), the Ontological-Hierarchy effect is greater for tasks that involve, or are primed by, grammatical structure, than it is for non-verbal tasks or tasks that involve only the lexicon. One may now ask whether it is the mere presence of grammar that is responsible for the observed hierarchy effects, or conversely whether some specific feature of grammatical structure might underlie the role of the Animacy Hierarchy in the categorization of hybrids. Two further studies point toward the latter alternative. Specifically, they suggest that the crucial property of grammar responsible for the hierarchy effects is the pervasive asymmetry that is characteristic of most grammatical constructions: as specified in (16c), more grammatical asymmetry leads to more of an Ontological-Hierarchy effect (reported on in Shen and Gil, 2017, pp. 1191–1194).

Consider, for example, a garden-variety verbal description of the hybrid in **Figure 3**: *man with bird's head*. The two nouns denoting the hybrid's two parents, *man* and *bird*, are not of equal status; rather, they embody an array of grammatical asymmetries, pertaining to features such as linear order, c-command, agreement, and semantic referentiality. Grammatical asymmetries such as these present a natural target for the Ontological Hierarchy to map on to, in the variegated ways that linguists generally subsume under the workings of the Animacy Hierarchy.

Consider, now, an alternative description of the hybrid in **Figure 3**, involving a coordination: *man and bird*. In contrast to the previous example, *man and bird* displays just one asymmetry, that of linear order: *man* occurs before *bird*. We shall thus refer, somewhat loosely, to coordinative constructions as symmetric, in contrast to other constructions which exhibit a larger variety of grammatical asymmetries. Alternatively, one might say that asymmetric constructions exhibit "more" grammar than their (almost) symmetric coordinating counterparts.

As specified in (16c), the Ontological-Hierarchy effect on the conceptualization of hybrids is more pronounced for verbal tasks when there is "more grammar," involving asymmetric structures, than it is when there is "less grammar," as is the case for symmetric structures. Evidence comes from the measurement of reaction times, as in the tasks discussed above (Mashal et al., 2014). Speakers of Hebrew were shown schematological hybrids and potential verbal descriptions, and asked to judge whether each description was appropriate for the corresponding hybrid. The verbal descriptions were of the following kinds: (a) asymmetric descriptions, either in accordance with the Animacy Hierarchy, as in (17), or in opposition to it, as in (18), or (b) symmetric descriptions, as in (19), in which the order of the two items was consistent or inconsistent with the hierarchy.

If the hierarchy effect shown previously is due solely to the verbal medium and the presence of grammatical structure, then we might expect to observe differences in reaction time between the two cases: (a) for asymmetric descriptions, shorter reaction times for descriptions in accordance with the Animacy Hierarchy than for descriptions in opposition to it, and (b) for symmetric descriptions, shorter reaction times for descriptions in which the order of the two items was consistent with the hierarchy than for descriptions in which the order of the two items was inconsistent with it. On the other hand, if the hierarchy effect is dependent specifically on the presence of grammatical asymmetries, then one would expect to observe reaction-time differences only in the former (a) case, with the asymmetric descriptions, but not in the latter (b) case, with the symmetric descriptions. And in fact, this is what the results of the experiment showed: reaction-time differences were observed for the asymmetric descriptions but not the symmetric ones (reported on inShen and Gil, 2017, p. 1193).

Thus, the online judgment task reveals that it is not the grammatical medium itself but rather the presence of asymmetric grammatical structures that introduces the Animacy-Hierarchy effect. In accordance with (16c), then, more grammar means more of an Animacy-Hierarchy effect in the categorization of hybrids.

We have thus provided empirical evidence for three distinct but related ways in which grammar introduces asymmetries in the conceptualization of hybrids, as spelled out in (16a–c). As was the case in the preceding sections, for compositional semantics and metaphors, the two-tiered cognitive architecture of hybrid conceptualization can now be shown to constitute a reflection of both ontogenetic and phylogenetic trajectories.

While 10 and 6 years old speakers of Hebrew were found to perform at adult level with respect to the non-verbal categorization task and description task (Aleluf, 2005), some significant differences emerged when the same two tasks were performed by 3 years olds (Sanhedrai, 2017). As pointed out earlier, in the case of the description task, most of the descriptions offered by adults were asymmetric — either in accordance with the Ontological Hierarchy, as in (17), or, in smaller numbers, in violation of it, as in (18). However, for the 3 years old, a significantly larger number of descriptions offered were symmetric, as in (19). Thus, children follow an ontogenetic trajectory mirroring the two-tiered architecture of hybrid conceptualization observed amongst adults. Specifically, just as the asymmetric non-grammatical mode of hybrid categorization forms the foundation upon which the symmetric grammatical mode is constructed, so younger infants start out with more symmetric descriptions of hybrids, before moving on to more asymmetric descriptions as they mature.

An additional manifestation of the same ontogenetic path from symmetric to asymmetric categorization of hybrids becomes evident in a more fine-grained analysis of the performance of the 3-year-old children. Like with the older groups, the hierarchy effect was significantly higher for the description task than for the non-verbal categorization task. However, for both tasks, the hierarchy effect was weaker overall than it was for the older groups; see Shen and Gil (2017) for additional details. These facts thus provide further support for the presence of an ontogenetic trajectory from symmetric to asymmetric conceptualization of hybrids, one that mirrors the two-tiered architecture of hybrid conceptualization amongst adults.

One may now ask whether here, too, in the domain of hybrid conceptualization, ontogeny also recapitulates phylogeny. Given the lack of archeological attestations of schematological hybrids amongst hominins, and the obvious challenges posed by conducting experiments involving hybrids on primates, direct evidence is hardly forthcoming. Still, we do know that higher animals are clearly capable of non-verbal categorization (Zentall et al., 2008); and we know that they don't have grammar. On this basis, it would seem plausible to assume, as a default hypothesis, that their categorization of hybrids would resemble that of humans in a non-grammatical mode, that is to say, it would be symmetric.

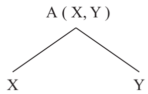
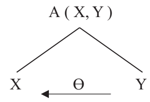
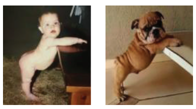
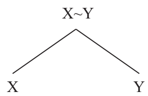
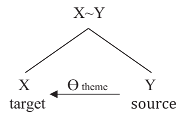
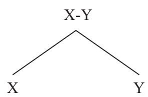
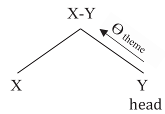
Some preliminary indirect support for this assumption is provided by a hybrid description task performed by native speakers of Arabic, in two different registers, standard and colloquial (Kadan, 2019). The task was designed to test for possible effects of the medium in which the description is couched. Whereas in the previous description tasks the descriptions were written, in the present study written descriptions were compared with oral ones. For both standard and colloquial registers, the written descriptions were in accordance with the Ontological Hierarchy, replicating their counterparts in Hebrew and other languages. However, the oral descriptions did not exhibit an Ontological-Hierarchy effect. Since writing is a relatively recent innovation in human history, one may tentatively conclude that differential cognitive behavioral patterns associated with oral and written language may reflect earlier and later points on an evolutionary trajectory. In the case at hand, then, the symmetric descriptions of the oral task would represent an earlier evolutionary stage than the asymmetric descriptions of the written task, thereby suggesting that for schematological hybrids as well, phylogeny also embraces a journey from symmetry to asymmetry.

## CONCLUSION

The empirical findings presented in this paper demonstrate a striking and hitherto unobserved parallel between three quite different phenomenological domains of human cognition, pointing toward a central role played by grammar in the architecture, ontogeny and phylogeny of cognition. These findings are summarized in **Table 1**.

In **Table 1**, the three rows represent the three phenomenological domains discussed in the preceding three sections illustrated, in the first column, with their respective leading examples reproduced from **Figures 1–3** respectively. The remaining two columns, recapitulating the structures posited in (1) and (5), (11) and (12), and (20) and (21), show the symmetric structures associated with the absence of grammar,

**TABLE 1 |** Symmetry and asymmetry in compositional semantics, metaphors and schematological hybrids.

<table>
<tr><th></th><th>Symmetry</th><th>Asymmetry</th></tr>
<tr><th></th><th>No grammar</th><th>Grammar</th></tr>
<tr><td>Compositional semantics<br></td><td>Bare association<br></td><td>Thematic-role assignment<br></td></tr>
<tr><td>Metaphors<br></td><td>Bidirectionality<br></td><td>Unidirectionality<br></td></tr>
<tr><td>Schematological hybrids<br></td><td>No resolution<br></td><td>Resolution<br></td></tr>
</table>

contrasted with the asymmetric structures resulting from the introduction of grammar.

In all three domains, the asymmetry introduced by grammar involves thematic-role assignment, albeit in rather different configurations. Whereas for compositional semantics and metaphors, one of the two terms assigns a thematic role to the other, for schematological hybrids, the term in question assigns a thematic role to the superordinate term, pointing toward its characterization as the head of the construction. Moreover, whereas for compositional semantics, it is thematic-role assignment *per se* that is introduced by grammar, in the two remaining domains, thematic-role assignment is put to service to effect a further asymmetry: for metaphors, their unidirectionality and the distinction between source and target terms, and for schematological hybrids, their resolution and identification with one of their parents to the exclusion of the other. Finally, whereas for compositional semantics, any thematic role may be involved, in the case of metaphors and schematological hybrids, the thematic role involved is that of theme.

The role of theme made reference to in this paper is somewhat broader than that which is commonly assumed within many grammatical theories, which tend to focus on more semantically specific roles such as agent, patient, source, locative and so forth. To say that B assigns the role of theme to A is to assert that B *applies to* A, or in other words that B describes, characterizes or says something about A. Within some variants of formal semantic theory (Keenan, 1979; Barwise and Cooper, 1981; Keenan and Faltz, 1985), the theme A is an *argument*, while the thematic-role-assigner B is its *function*. Alternatively, within the more psycholinguistically oriented theory of conceptual combination (Rumelhardt, 1980; Cohen and Murphy, 1984; Murphy, 1988, 1990), the theme A is associated with a *schema*, while the thematic-role-assigner B *fills a particular slot* within that schema. It should be kept in mind that the relationship between A and B is not one of predication in the usual sense of the word; while in some cases B may indeed be predicated of A, in other cases B may stand in an attributive relationship to A. Similarly, the relationship between A and B is not a pragmatically based relationship such as topic-comment; whereas in many contexts A may be the topic and B its comment, in other contexts a variety of other discourse configurations may obtain. Instead, we view thematic roles, including *inter alia* the generalized role of theme, as constituting particular manifestations of a deeper and more fundamental asymmetric semantic relationship integrating properties of the argument/function relation of formal semantics and the schema/slot-filler relation of conceptual combination theory.

Why should grammar introduce asymmetric thematic-role assignment into otherwise symmetric cognitive structures? Given that thematic roles are part and parcel of our general conceptual structures, it is not obvious why their occurrence, in domains as diverse as compositional semantics, metaphors and schematological hybrids, should require, or at least be strongly supported by, the presence of grammar. We speculate that the answer to this question may lie in the central role played by the twin relations of predication and attribution in grammatical organization. In Gil (2012) it is argued that predication and attribution are composite emergent structures resulting from the conventionalized convergence of thematic-role assignment and headedness. Specifically, a predicate is defined as a thematic-role-assigner head while its arguments are its thematic-role-bearing modifiers; conversely, an attribute is defined as a thematic-role-assigner modifier while its head is its thematic role-bearing head. Like thematic-role assignment, as pointed out earlier, headedness is also an element of general conceptual structure, manifest in diverse domains ranging from our conceptualization of every-day objects through tonal music to language, and, within language, from phonology through syntax to discourse structure — see Gil (1985) and references therein. However, unlike thematic-role assignment, we are, at present, unaware of any evidence to the effect that headedness is present in the cognitive structures of non-human animals. Whereas thematic-role assignment and headedness are part of general conceptual structure, their convergence in the form of predication and attribution is thus specific to grammar. We conjecture that it is the pervasive nature of predication and attribution in grammar that is responsible for the introduction, through grammar, of thematic-role assignment into cognitive structures such as those associated with compositional semantics, metaphors and schematological hybrids.

To summarize, this paper has provided novel empirical evidence, from compositional semantics, metaphors and schematological hybrids, for the existence of two distinct levels, or tiers of cognition, non-grammatical and grammatical, the latter derived from the former by the introduction of thematic-role assignment and its associated asymmetries. This two-tiered architecture, with grammatical cognition placed on top of non-grammatical cognition, is argued to reflect the phylogeny and ontogeny of cognition, proceeding hand in hand with the evolution and development of language and grammar.

The results of this paper may perhaps be construed as supporting a variant of the so-called Whorf Hypothesis, one in which it is not the distinctive properties of particular languages, in contrast to other ones, that differentially shape our thought processes, but rather the universal properties shared by all languages that affect our common processes of conceptualization. This would also be in line with Slobin's (1996) notion of "speaking for thinking," where the act of representing the conceptualization of non-verbal stimuli in language leads to the rendering of such conceptualizations into the grammatical structures made available by the language, resulting in the subsequent adaption and modification of the conceptualizations in accordance with these grammatical structures.

As important as we consider them to be, the findings of this paper remain tentative and preliminary. We expect that future investigations into other phenomenological domains will reveal further instances of grammar introducing asymmetries into cognitive structures, thereby providing further support for the distinction between non-grammatical and grammatical cognition, and, *ipso facto*, for the central role that grammar plays in human cognition.

## DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

## ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

## AUTHOR CONTRIBUTIONS

DG and YS contributed equally to all aspects of this manuscript. The order in which the authors are listed is merely alphabetical.

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# Constructing a Consensus on Language Evolution? Convergences and Differences Between Biolinguistic and Usage-Based Approaches

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Two of the main theoretical approaches to the evolution of language are biolinguistics and usage-based approaches. Both are often conceptualized as belonging to seemingly irreconcilable "camps." Biolinguistic approaches assume that the ability to acquire language is based on a language-specific genetic foundation. Usage-based approaches, on the other hand, stress the importance of domain-general cognitive capacities, social cognition, and interaction. However, there have been a number of recent developments in both paradigms which suggest that biolinguistic and usage-based approaches are actually moving closer together. For example, theoretical advancements such as evo-devo and complex adaptive system theory have gained traction in the language sciences, leading to changed conceptions of issues like the relative influence of "nature" and "nurture." In this paper, we outline points of convergence between current minimalist biolinguistic and usage-based approaches regarding four contentious issues: (1) modularity and domain specificity; (2) innateness and development; (3) cultural and biological evolution; and (4) knowledge of language and its description. We show that across both paradigms, researchers have come to increasingly embrace more complex views of these issues. They also have come to appreciate the view that biological and cultural evolution are closely intertwined, which lead to an increased amount of common ground between minimalist biolinguistics and usage-based approaches.

**Keywords: usage-based linguistics, construction grammar, biolinguistics, cognitive linguistics, evolutionary linguistics**

## INTRODUCTION

As Jackendoff (2010) famously stated, "[y]our theory of language evolution depends on your theory of language." However, the converse is also true: Looking at language "in the light of evolution" (Dobzhansky, 1973; Hurford, 2007, 2012) can inform theories of language. For instance, Johnson (2017, p. 171) points out that "Chomsky's Minimalist Program is largely motivated by the challenge of explaining the evolution of language." For usage-based and emergentist approaches, the evolutionary dimension is also central to their view of language. In these approaches, language is seen as a complex adaptive system emerging out of the multifactorial and non-linear interactions of factors on ontogenetic, cultural, and evolutionary timescales (e.g., Beckner et al., 2009; Steels, 2011; Kirby, 2017).

However, minimalist biolinguistics and usage-based approaches have traditionally adopted quite opposing views on central issues such as modularity, domain specificity vs. domain generality, as well as innateness and development. As is well-known, these different views have been part of a long-standing controversy in linguistics (see e.g., Harris, 1993) that has recently been fueled by a number of publications (e.g., Evans, 2014; Dąbrowska, 2015; Adger, 2015a,b, among many others). Naturally, this divide also has repercussions for the field of language evolution research: For example, Johansson (2014) deplores a deep divide "between Chomskyan biolinguistics and everybody else" and speaks of a "Kuhnian incommensurability problem," alluding to the mutually incompatible ways of viewing the world that different schools of thought in science tend to develop, which Kuhn (1970) sees as characteristic of scientific revolutions.

However, the views on these complex issues have not remained static within these approaches but have evolved considerably, especially in recent years. They also continue to play an important role in research on the evolution of language, as indicated, for example, in the recent collections of articles by Fitch (2017), Ferretti et al. (2018), and Petkov and Marslen-Wilson (2018). Intriguingly, in many ways both minimalist biolinguistics, on the one hand, and usage-based and emergentist approaches, on the other, have moved closer together in their conceptualizations of these long-standing issues. It can be argued that the convergent conceptual evolution seen in both approaches is in large part influenced by the fact that both biolinguistics and usage-based approaches have become increasingly interdisciplinary and empirically minded in their outlook. As we argue in this paper, by integrating perspectives and results from the cognitive and biological sciences such as evolutionary-developmental biology (evo-devo) and complex adaptive systems, both fields are in fact moving toward convergent conceptualizations on a number of key issues.

In this paper, we discuss these potential points of convergence, but we also show where there is still considerable dissent between the different paradigms. We would like to stress at the outset that the notions of "biolinguistics" and "usage-based approaches" that we are going to use in this paper are of course gross idealizations. Needless to say, the theoretical approaches subsumed under these umbrellas are wildly different. Nevertheless, traditionally these two approaches have been characterized by their divergences on issues of modularity, domain specificity, innateness, and development that we would like to highlight in this paper. While biolinguistic and usage-based approaches obviously provide very different answers to these questions, the potential convergence that we would like to highlight in this article crucially relies on empirical findings that have recently become available.

In many respects, biolinguistics and usage-based approaches have very different goals and different perspectives on what "knowledge" of language entails, how it is represented, how it is acquired, and how it emerged both culturally/historically and evolutionarily. We believe that many of these differences are not going to be resolved anywhere in the near future – and in terms of different goals and interests, resolution might not even be necessary. However, one of the main points of our paper is that regardless of seemingly "irreconcilable" differences, it is worth pointing out what biolinguistics and usage-based approaches have in common and where we see potential and opportunity for even further convergences and overlap in the future.

We will start by characterizing in broad strokes the two frameworks, *Usage-Based Approaches,* on the one hand, and *Biolinguistics,* on the other, to give a general conceptual map for comparison. Then, we will turn toward *Convergence and Divergence* between these approaches. First, we will focus on *Modularity and Domain Specificity*. Following this, we will discuss emerging trends in the way *Innateness and Development* are conceptualized in biolinguistics and usage-based approaches. We will then consider how these developments influence the way these approaches investigate the *Biological and Cultural Evolution* of language as well as their interrelation. Finally, we will deal with a number of theoretical and methodological differences between usage-based approaches and biolinguistics regarding *Knowledge of Language and Its Description*, which still set the two approaches apart quite clearly. We will end with a concluding summary of the potential for convergence and remaining divergences and with a call for further cross-fertilization and dialogue.

## THE FRAMEWORKS

### Usage-Based Approaches

Under the heading "usage-based approaches," we subsume a variety of frameworks that share a number of important assumptions. These approaches include but are not limited to Cognitive Linguistics (e.g., Geeraerts and Cuyckens, 2007; Dąbrowska and Divjak, 2015; Dancygier, 2017), Construction Grammar (e.g., Goldberg, 1995, 2003; Hoffmann and Trousdale, 2013; Diessel, 2015), and Functional-Cognitive Approaches (Butler and Gonzálvez-García, 2014). Usage-based approaches can be counted as belonging to the general approach of emergentism (e.g., MacWhinney and O'Grady, 2015), and we will often use the terms "usage-based" and "emergentist approaches" interchangeably.

First of all, usage-based approaches assign a key role to language usage. As Tomasello (2009, p. 69) puts it, "meaning is use – structure emerges from use." This means that in these approaches, linguistic knowledge, and knowledge of constructions, proceeds *via* the abstraction and schematization of actual language use in context, yielding fixed chunks as well as more abstract linguistic patterns that become cognitively entrenched. This also means that, secondly, they tend to reject the notion of an innate Universal Grammar. Third, and also related to this, the rejection of a specific "language organ" of any kind usually goes in tandem with the assumption that cognition in general is "continuous" and distributed rather than modular (see Spivey, 2007). That is, language is thought to be based on general cognitive mechanisms (domain-general mechanisms, see sections "Modularity and Domain Specificity" and "Innateness and Development"). A fourth assumption shared by most usage-based approaches is that language can be described as a complex adaptive system, i.e., a system whose global properties emerge from multiple independent interactions of agents at a more local level (see e.g., Beckner et al., 2009).

Usage-based approaches usually focus on the cognitive organization of language in present-day speakers or on developments in the traceable history of human languages. However, it has been argued that the view of language as a complex adaptive system and the processes of cultural evolution that can be observed in language history allow for drawing conclusions about the emergence of language. For instance, Heine and Kuteva (2002, 2007, 2012) and Bybee (2010) argue that grammaticalization processes can account for the development from early (proto-)language to modern languages (see also Arbib, 2012, 2015). It has also been noted that the complex adaptive system view of language is highly compatible with those strands of language evolution research that focus on the (cumulative) cultural evolution of language (see e.g., Pleyer and Winters, 2014; Pleyer, 2017), such as the Iterated Learning paradigm that has become one of the most influential approaches in language evolution research (Kirby and Hurford, 2002; Kirby et al., 2008; Kirby, 2017).

Some usage-based linguists have put forward fairly strong hypotheses regarding the origins of language. Perhaps most prominently, Michael Tomasello, coming from a background of usage-based Construction Grammar, has proposed an elaborate theory of the evolution of language – as well as cultural cognition and species-specific symbolic behavior more generally – in the context of his shared intentionality framework (see e.g., Tomasello et al., 2005; Tomasello, 2008, 2019). Another usage-based linguist who has put forward a less broadly received (and far more sketchy) theory of language evolution is Talmy (2007), who sees the mechanism of "recombinance" as crucial for the evolution of language. By recombinance, he means "the assembly of discrete units into a new higher-level unit with its own identity" (Talmy, 2007, p. 26). As a final example, consider Keller's (1995) monograph on historical language change, which contains a chapter proposing a Gricean theory of the evolution of the predispositions for language (but see Moore, 2017 for an updated view on the evolutionary foundations of the Gricean communicative infrastructure). These examples show that linguists coming from a usage-based framework have made fairly explicit proposals regarding the question of language origins. Researchers adopting the framework of construction grammar in particular have argued for the fruitfulness of a constructionist approach to the evolution of language (Steels, 2004; Arbib, 2012, 2015; Hurford, 2012; Johansson, 2016; Pleyer, 2017). Also, construction grammarians have adopted the generalized theory of evolution (e.g., Hull, 1988) to account for the cultural evolution of language over historical time, a particularly well-known example being Croft (2000).

## Biolinguistics

In this section, we briefly outline what we mean by biolinguistics when comparing usage-based approaches with biolinguistics. Some conceptual clarification is necessary, as the degree of consensus and dissensus of course differs depending on which sets of theories and approaches within this broad paradigm are being compared. Biolinguistics can be described as the investigation of knowledge of language within the tradition of the generative enterprise with a commitment to take into account the biological foundations of language and view it from an interdisciplinary perspective. Boeckx and Grohmann (2007) distinguish between a strong sense and a weak sense of biolinguistics. The weak sense captures the type of work that generativists have engaged in following the tradition that started with Chomsky (1957, 1965). In its strong sense, biolinguistics refers to work that explicitly integrates insights from evolutionary biology, psychology, and related disciplines. This approach can be seen as following in the tradition of Lenneberg (1967). As Boeckx and Martins (2016) point out, much of biolinguistics "has in practice been seen as a sub-field or rebranding of generative linguistics, and as such most of the work said to be biolinguistic came from there." As such, the biolinguistic enterprise is closely related to the Minimalist Program (Chomsky, 1995) and its core tenets.

However, there is also a broader definition of biolinguistics, which Boeckx and Benítez-Burraco (2014a) have termed "biolinguistics 2.0." Biolinguistics 2.0 can be seen as a research program whose aim is to uncover the biological foundations of language. On this view, the biolinguistics research program is not tied to a minimalist and generative view of language but characterizes a methodological approach of productively and explicitly combining research from different fields. As Di Sciullo and Boeckx (2011) state, from this perspective researchers with very different theoretical persuasions, such as Tomasello (e.g., Tomasello et al., 2005; Tomasello, 2008), can be described as doing biolinguistics (cf. Ferretti et al., 2018). This means that usage-based and emergentist researchers investigating factors such as the biological properties of the language-ready brain (e.g., Arbib, 2012, 2015), the neurological foundations of entrenchment (Schmid, 2015; Blumenthal-Dramé, 2016), the neurological foundations of semantic simulation (Bergen, 2012), or the neurological foundations of constructions (Pulvermüller et al., 2013; Goldberg, 2019), are doing biolinguistics as well. In this paper, however, our interest in convergences and divergences is somewhat more specific. Here, we want to outline similarities and differences between usage-based approaches and work that explicitly labels itself as biolinguistic, with much of it adopting a minimalist framework. In other words, we are interested in the relationship between usage-based linguistics and what Boeckx (2015, p. 436) has called the "generative/biolinguistic enterprise."

They key commitment of the minimalist framework is the reduction of the computations and theoretical operations needed to explain language. As already mentioned in the introduction, this theoretical reduction is very much motivated by evolutionary concerns (Johnson, 2017). That is, minimizing what needed to evolve in order to make language possible can be seen as a direct reaction to the challenge of explaining the evolution of language (Johnson, 2017). In minimalism, this has been done by identifying a key conceptual component, Merge, as being central to language and its evolution (e.g., Radford, 2004; Berwick and Chomsky, 2016; Fitch, 2017). This solitary focus on Merge as the key explanandum of the complexity of the language faculty has also been criticized (Progovac, 2019). Indeed, as we are going to outline in the following sections, there have been developments in biolinguistics toward an agenda that takes other factors and domains equally seriously (e.g., Benítez-Burraco and Boeckx, 2014).

## CONVERGENCE AND DIVERGENCE

In the following, we will outline some of the key areas where usage-based and biolinguistic approaches have traditionally diverged and which have been and continue to be discussed quite controversially. We will outline where we see potential convergences and where we still judge that there are (probably) irreconcilable differences between the two frameworks.

### Modularity and Domain Specificity

As Balari and Lorenzo (2016, p. 4) point out, "[t]he task of disentangling the evolutionary origins of language suffers from the lack of a consensual view about what the evolved linguistic phenotype is supposed to be." They argue that the theoretical positions differ along two coordinates: on the one hand, language is seen as "an external, socially shared code" – on the other hand, it is viewed as "a self-contained component of the human brain." Thus, the issues of modularity and domain specificity are partly connected with the question of "what evolved," as, e.g., Christiansen and Kirby (2003, p. 4) and Hurford (2012, p. 173) have framed one of the most crucial questions of language evolution research. However, the key disagreements are not necessarily about what belongs to the linguistic phenotype *per se* but rather about what components of language, if any, are specific to this particular cognitive "module." Fitch (2017) summarizes the broadly shared view that language builds upon a broad array of mechanisms shared with other species, such as concepts and categories – which underlie semantics –, voluntary control over vocalization – which underlies phonology – or sequencing and working memory, which can be seen as underlying syntax. In addition to that, he characterizes complex Theory of Mind, supra-regular grammar (i.e., a grammatical capacity that goes beyond that of so-called finite state automata, which cannot deal with more than one level of nesting; see Fitch, 2018), and complex vocal learning as "unusual human capacities." However, there is disagreement about the extent to which such foundations of language belong to the linguistic phenotype in the strictest sense: As will become clear below, some biolinguistic approaches reduce the phenotype to the "Faculty of Language in the Narrow Sense" (FLN) as proposed by Hauser et al. (2002), while usage-based approaches tend to take a much broader view.

Bates (1994, p. 136) stresses that the logically separable issues of modularity, brain localization, and innateness are often conflated, and traditionally most approaches that see language as a module of the mind have also tended to assume an innate Universal Grammar (see section "Innateness and Development"). Still, it is important to tease these different aspects apart.

Modularity refers to the idea that the mind (partly) divides into highly specialized modules (Prinz, 2006, p. 22). Sperber (1994, p. 40) defines a cognitive module as "a genetically specified computational device in the mind/brain [...] that works pretty much on its own on inputs pertaining to some specific cognitive domain and provided by other parts of the nervous systems." Anderson and Lightfoot (2002), who take Chomsky's (1988, p. 133) view of language as an "organ of the mind/brain," quite literally argue that language can indeed be seen as "a biological entity, a finite mental organ" (Anderson and Lightfoot, 1999, p. 703) and hold that UG, which they call the "linguistic phenotype," is modular. The modules they propose include the mental lexicon and a module containing abstract compositional structures. They argue that many of the modules relevant for language are specific to language but concede that they "may or may not be separately represented in neural tissue" (Anderson and Lightfoot, 2002, p. 23).

Thus, we can distinguish two different aspects of modularity that play a role in biolinguistics: on the one hand, the idea that language is a distinct module of the mind; on the other hand, the idea that this module is characterized by modular structure in itself. Hornstein (2009, p. 5f.), for instance, accepts the former hypothesis but eschews the idea of internal modularity, arguing that a highly modular faculty of language could only have evolved *via* natural selection, which would take much longer than the 50,000–100,000 years since language first emerged according to the estimates he cites (but see Tallerman and Gibson, 2012; Dediu and Levinson, 2013, for different estimates from 150,000 to 500,000 years). Hornstein (2009, p. 8) argues that the short timespan only allows for a very small number of operations to be adapted, while the basic operations and principles of the language faculty are recruited from those that were available before the emergence of language.

This leads us to the notion of domain specificity. According to Robbins (2017), "[a] system is domain specific to the extent that it has a restricted subject matter, that is, the class of objects and properties that it processes information about is circumscribed in a relatively narrow way." Despite the fact that modularity and domain specificity are, as per Bates' statement cited above, logically separable entities (and as the Anderson and Lightfoot quote above shows, they are actually teased apart at times), the notion of domain specificity is often taken to refer to whether or not there is a neuronal network in the brain specialized for language (cf. Prinz, 2006, p. 24). It has to be acknowledged, though, that the concepts of module and modularity mean very different things in different contexts and disciplines (see Bates, 1994, p. 137).

This shows that the notions of modularity and domain specificity can be understood in quite different ways, which pertain to different aspects of the language-cognition interface: On the one hand, they can be considered hypotheses about the organization of language in the *brain*, in which case they are statements about the neuronal underpinnings of language. On the other hand, they can be understood as more heuristic terms describing specific functions that pertain to a specific domain (such as language) but that may still be distributed across various cortical regions.

Bates (1994, p. 139f.) even distinguishes five levels at which claims of domain specificity may apply (the task or problem to be solved; the behaviors or skills that develop to solve the problem; the representations or knowledge that must be present to solve the problem; the neural processing mechanisms required to sustain those representations; and the genetic substance that makes the aforementioned aspects possible). She argues that language can be considered domain specific at the first three levels, as it represents "a special response to a special problem" that "must be supported by a detailed and unique set of mental/neural representations." The controversial questions, according to Bates, pertain to the question of whether we have evolved a "special form of computation that deals with language, and language alone" and if that new mechanism is biologically encoded.

This is also where opinions tend to differ between biolinguistic and usage-based approaches. The radically usage-based complex adaptive system view of language holds that language is not shaped by any domain-specific factors but rather by "[p] rocesses of human interaction along with domain-general cognitive processes" (see section "Cultural and Biological Evolution"). However, Christiansen and Chater (2008, p. 508) take a more nuanced perspective by conceding that language-specific cognitive adaptations may have occurred *via* so-called Baldwin effects, i.e., the internalization of within-generation developmental accommodation leading to evolutionary change (Badyaev, 2009, p. 1126). According to de Ruiter and Levinson (2008), it seems plausible to assume cognitive adaptations not for language but for *communication* more generally, which also raises the question of whether domain specificity may be a matter of degree both regarding the breadth of the domain to which it applies and regarding the extent of specificity. Ambridge and Lieven (2011, p. 361, 368), reviewing a wealth of studies on language development in ontogeny (including atypical development) and on the genetic basis of language, take such a gradual approach when they conclude that language can neither be completely domain general nor an entirely modular system. On the biolinguistic side, Boeckx (2012, p. 30) argues that linguistic minimalism helps overcome previous tendencies toward over-modularization, and he compares this development to a similar shift in emphasis in comparative psychology, where earlier work tended to focus on the seemingly unbridgeable gap between human language and other communication systems, whereas more recent work tends to take a bottom-up perspective that "focuses on the constituent capacities underlying larger cognitive phenomena" (de Waal and Ferrari, 2010, p. 201). In fact, Benítez-Burraco and Boeckx (2014) criticize strictly modular approaches such as that of Anderson and Lightfoot (2002) as "simplistic." Modular approaches in general have also become more complex, so that there is more overlap with non-modular views of cognition (Barrett and Kurzban, 2006).

Overall, this more recent biolinguistic view on modularity is therefore much more in line with usage-based approaches. It is also consistent with, and informed by, neuroscientific evidence that linguistic processing might recruit other neural circuits for sequence processing, forming associations, working memory, and others (e.g., Prat, 2013; Christiansen and Chater, 2016; Gong et al., 2018; Hernandez et al., 2019).

What many biolinguists take away from such neuroscientific evidence is that language should not be seen in modular isolation but "as part and parcel of a broader cognitive basis" (Boeckx, 2017). Of course, the question to what degree language represents a neurologically domain-specific system is still intensely debated in the neuroscientific literature (e.g., Fedorenko et al., 2011; Fedorenko and Thompson-Schill, 2014; Vogel et al., 2014; Friederici and Singer, 2015; Campbell and Tyler, 2018; Dick and Krishnan, 2019). Although this debate is far from settled, the above discussion shows that different approaches are potentially converging on a more complex view of the issue of modularity. Generally, we share the view held by Boeckx and Martins (2016) that, ultimately, "modular conceptions of cognitive domains like language are likely to dissolve as we learn more about the (generic) mechanisms implementing cognition at the molecular and cellular levels."

An important argument in favor of domain specificity in generative linguistics have been structural dissimilarities between the operations assumed to be at work in UG and what has been described for other cognitive domains (see e.g., Bates et al., 1991, p. 30). But as will become clear in the subsequent sections, the number of operations that are assumed to be part of the language faculty has been reduced substantially in current biolinguistic approaches compared to the early days of generative grammar. Hauser et al. (2002) famously distinguished a "Faculty of Language in the Broad Sense" (FLB) from the "Faculty of Language in the Narrow Sense" (FLN), the latter containing the core grammatical computations underlying language. They argued that FLN is limited to recursion, which they hypothesized to be a uniquely human and domain-specific adaptation. A complex debate (see e.g., Fitch et al., 2005; Jackendoff and Pinker, 2005; Pinker and Jackendoff, 2005; Boeckx, 2009; Watumull et al., 2014; Behme and Evans, 2015; Adger, 2015a,b, among many others) revolves around the questions of what exactly the concepts of FLN and recursion encompass and how they relate to Merge, "a process that takes any two syntactic objects (words, phrases, clauses, etc.) and joins them to form a new syntactic object" (Bickerton, 2013, p. 29). According to Berwick and Chomsky (2011, p. 30), "[o]ptimally, recursion can be reduced to Merge." The nature of Merge is also subject to debate within biolinguistic approaches: While, e.g., Watumull et al. (2014) see it as irreducibly elementary, Boeckx (2009, p. 47) argues that it can be decomposed into more basic operations. Also, Hornstein (2009, p. 109) sees Merge as a combination of (pre-linguistic) concatenation with labeling, "an operation whereby one of the two inputs to concatenation 'names' the resulting concatenate" (Hornstein, 2009, p. 58). In particular, he argues that endocentric labeling, which marks one of the constituents as head, can be considered the key evolutionary innovation giving rise to unbounded recursive hierarchy.

Usage-based approaches also acknowledge the key role of recursion in human language. However, in contrast to the view of recursion as domain specific for language, emergentist approaches have suggested that recursion arises from combined activities of memory, lexicon, discourse, and role activation (MacWhinney, 2009). Christiansen and Chater (2015) propose a usage-based account of recursion, according to which the ability to process recursive structure emerges on top of domain-general learning abilities. On this view, FLN is in fact "empty," which also calls into question the usefulness of the distinction in the first place. In fact, the FLN/FLB distinction has also been criticized within biolinguistics for directing attention away from a mosaic or composite view of language as a whole (Boeckx, 2013).

We can thus conclude that biolinguistic and usage-based approaches agree that there is a "species-specific linguistic capacity" (Benítez-Burraco and Boeckx, 2014, p. 122) and that this capacity has biological foundations.[1] The point of contention is what exactly these biological foundations entail and to what degree they are specific to language. This can be illustrated with one of the core concepts in biolinguistics and the Minimalist Program, namely Merge. Regardless of its formal description, it is clear that some kind of process in this direction is important for language and human cognition more generally. This is also recognized in usage-based approaches: For instance, MacWhinney (2015), writing about the mechanisms of language emergence, stresses the importance of a cognitive mechanism of "composition" and explicitly remarks that "the emphasis in UG Minimalism on the Merge process (Chomsky, 2007) is compatible with emergentist accounts." However, MacWhinney (2015) also stresses that compositionality is not a feature specific to language but is also required for non-linguistic tasks such as "basic action processing" (see also Steedman, 2004; MacWhinney, 2009; Arbib, 2015). This, then, points toward a possible divergence between usage-based approaches and biolinguistics. However, as Merge is often seen as a mechanism for combining *concepts* as well, we do see broad compatibility between usage-based approaches and biolinguistics if biolinguists acknowledge a Merge-like mechanism to operate in non-linguistic tasks such as action processing or concept formation and human hierarchical processing as well. In fact, Chomsky actually acknowledges this possibility: "Merge is one such operation that can be seen as a UG principle but also as one possibly 'appropriated from other systems' (Chomsky, 2007, p. 7) and relevant to other systems" (van Gelderen, 2009, p. 227).

In addition, the foundations of language are not only biological. Specifying the aspects that make the human brain "language-ready" (Arbib, 2012) is one important aspect not only of biolinguistics but also of evolutionary approaches to language more generally. Other important questions regard the evolution of the "language-ready social settings" (Pleyer and Lindner, 2014), that is, questions regarding the interactional, ontogenetic, and cultural processes that give rise to language and linguistic structure. As Balari and Lorenzo (2016) outline, much earlier work on language in the generative tradition conceived of language as a "self-contained component of the human brain" (4) that is modular and domain specific. However, they stress that there is currently a shift toward "a composite or mosaic conception of language" (see also Boeckx, 2017). Strong domain specificity is therefore demoted in recent biolinguistic theorizing. This means that in this domain, biolinguistics has moved closer to the position held in usage-based approaches.[2] In fact, the metaphor of a "mosaic" (Wang, 1982) view of the language-ready brain can be found in both biolinguistics (Benítez-Burraco and Boeckx, 2014; Boeckx, 2017) and usage-based and emergentist, domain-general approaches (Gong et al., 2018) to language and its evolution.

## Innateness and Development

In this section, we want to focus on two key areas where we see a potential for convergence between biolinguistics and usage-based approaches. The first concerns changing conceptions of UG and the role of innate, domain-specific biological foundations of language within biolinguistics. The second concerns the growing importance in both biolinguistics and usage-based theories of more refined and complex views of the dynamic, interactive relationship of biology, development, environment, and evolution (e.g., Benítez-Burraco and Longa, 2010; Benítez-Burraco and Boeckx, 2014; MacWhinney, 2015). We will discuss each of these issues in turn.

In the traditional generative view, notions of innateness, Universal Grammar, and the poverty of stimulus argument are of central importance. According to the traditional view, following Chomsky (e.g., Chomsky, 1988), external language data are not sufficient for children to constrain the hypothesis space of how language works. The proposed solution for this problem was linguistic nativism: the child has to come equipped with prior innate knowledge of certain features of language in order to be able to learn language. These language-specific biological foundations of the language faculty have become known under the term Universal Grammar, or simply UG. Much of the work in generative grammar was done with the aim of specifying what is part of UG. We support Boeckx and Benítez-Burraco's (2014b) use of "language-ready brain" as an alternative to UG and "language organ," as we agree that these terms "have come to be seen as too ideologically loaded." However, we are not sure if UG as such an entrenched

[1]As one reviewer pointed out, it has to be noted that "species-specific" can actually mean different things in biolinguistics and usage-based approaches. For biolinguistics, this often means *Homo sapiens sensu stricto* (e.g., Berwick and Chomsky, 2016), which, for example, would exclude Neanderthals. Usage-based researchers, on the other hand, often see "species-specific" as referring to the human lineage while remaining open to the possibility that pre-hominins possessed a language-ready brain (cf., e.g., Dediu and Levinson, 2013, 2018; Johansson, 2015).

[2]For this as well as for the other points of convergence we attest in this paper it can of course be questioned whether they represent a positive development in the language sciences. Balari and Lorenzo (2018), for example, also see recent developments as paving the way to convergences between biolinguistics and "cognitive, externalist-inclined approaches" as represented, for example, by usage-based and Cognitive Linguistics (e.g., Croft and Cruse, 2004). However, they are much more skeptical whether this represents a positive development, as the convergences they observe "lead together (programmatically or not) to the dissolution of a well-delimited concept of language."

concept – albeit one that is in constant change and in permanent definitional turmoil – will vanish from the biolinguistic literature anytime soon. For this reason, we think that it is worthwhile to explicate how the perspective of UG minimalism, or a biolinguistic UG, differs from usage-based approaches in regard to some core issues.

The assumption of a domain-specific innate Universal Grammar, "language organ," or "language acquisition device" has traditionally been the single most important difference between the approaches outlined above. Discussions have long revolved around the question of "what is innate and why" (Putnam, 1980). What these approaches have in common is that they agree that language acquisition builds on biological foundations. The question, however, is to what extent these capabilities are language-specific. As shown in section "Modularity and Domain Specificity," these terms are construed in different ways not only across different theoretical frameworks but also within minimalist/biolinguistic accounts. Meanwhile, the concept of UG continues to be hotly contested.

Proponents of usage-based approaches tend to evoke Occam's razor (e.g., Everett, 2016): If there is no need to assume an innate UG, we should drop the assumption in order to arrive at a leaner theory. As Tomasello (2003, p. 304) puts it, "[w]hy do we need the phlogiston/ether of universal grammar (...) at all? What is it doing anyway? Why not just chuck it?" From a usage-based perspective, domain-general mechanisms can fully account for virtually all aspects of language emergence, acquisition, and use, which is why UG is seen as theoretical ballast that should be shed, unless there are compelling arguments in its favor. Bickerton (2013, p. 110), by contrast, argues that a dedicated adaptation for language "should be the null hypothesis, and the burden of proof should lie on those who challenge it" (see also Wunderlich, 2004).

Much of the work taking a UG perspective on language was done in the Principles and Parameters framework (e.g., Lohndal and Uriagereka, 2014). In this framework, UG was taken to consist of principles covering structural features shared by all languages, as well as parameters, whose settings were fixed by external data from individual languages, akin to a switch being flipped into one position or another. However, with the advent of the minimalist program (Chomsky, 1995), the P&P framework has become less and less popular as the new goal of generative research, as outlined above, was reducing UG to its minimum requirements. This has led many biolinguists to reject the P&P framework (Boeckx, 2015, p. 435; see also Dąbrowska, 2015).

The minimalist conception of language acquisition has led to a number of tensions within generative approaches to language acquisition as well as to a number of problems, as discussed in detail by Longa and Lorenzo (2008). For one, it is unclear what the status of the poverty of stimulus argument is in biolinguistics and minimalism (Longa and Lorenzo, 2008). In usage-based approaches, as well as in others, the poverty of stimulus argument has come under quite intense criticism (see e.g., Pullum and Scholz, 2002; Tomasello, 2004; Clark and Lappin, 2011; Dąbrowska, 2015). Usage-based and emergentist approaches have instead concentrated on the question of how language arises from usage through processes of generalization and self-organization (e.g., O'Grady, 2008; MacWhinney et al., 2014). These approaches emphasize that the input learners receive is actually quite rich and that distributional and item-based learning strategies are highly effective ways of learning complex linguistic structures (cf. Tomasello, 2003; Clark, 2015; MacWhinney, 2015). This remains a hotly debated topic. For example, Perfors et al. (2006) proposed a Bayesian model of grammar induction able to learn syntactic structures without the need for language-specific biases. This and other models, in turn, were criticized by Berwick et al. (2011), who reiterated the need for innate, domain-specific factors in accounting for language acquisition. However, in line with our reasoning in this paper, Berwick et al. (2011) state that in principle they share similar goals with usage-based, emergentist, and general cognitive approaches: "we share the desire to reduce any language-specific innate endowment, ideally to a logical minimum" (Berwick et al., 2011, p. 1210).

Overall, conceptualizations of UG continue to evolve, and more recent formulations of what UG is can be argued to be more consistent with usage-based and emergentist theorizing (cf. Mendívil-Giró, 2018). Many researchers in biolinguistics acknowledge that UG could in fact not contain domain-specific and language-specific properties. For example, Roberts and Holmberg (2011) acknowledge that "UG does not have to be seen as either language-specific or human-specific" (quoted in Dąbrowska, 2015). This possibility is also explicitly acknowledged by Fitch et al. (2005) when talking about the distinction between FLB and FLN: "The contents of FLN are to be empirically determined, and could possibly be empty, if empirical findings showed that none of the mechanisms involved are uniquely human or unique to language, and that only the way they are integrated is specific to human language." This is consistent with the desire shared by minimalists, biolinguists, as well as usage-based and emergentist approaches to reduce what is specific to language as much as possible. In fact, the "minimalist" desire to try to attribute as little as possible to language-specific biological prerequisites is shared by many other approaches as well (Haspelmath, 2017).

One other key point of potential convergence between usage-based approaches and biolinguistics is the increasing acknowledgment that ontogenetic development should be seen in terms of a complex adaptive system in which multiple factors interact. This has direct consequences for conceptions of innateness, nativism, and the nature-nurture debate that have plagued the field for such a long time.

If complex traits like language emerge from the dynamic interactions of different factors at different timescales, this also means that "[a]sking whether a particular principle is "innate" or due to "external stimuli" is meaningless – it is both" (Dąbrowska, 2015, see also Mendívil-Giró, 2018). This is also echoed in recent biolinguistic publications. For example, Bowling (2017) stresses that separating cultural and biological contributions perpetuates a false dichotomy between nature and nurture. In biolinguistics, this focus on the developmental dynamics of language is often seen in the context of evo-devo, with the proposal that concepts from (ecological) evolutionary developmental biology such as developmental plasticity, robustness, and canalization (e.g., Gilbert and Epel, 2009; Pigliucci and Müller, 2010; Laland et al., 2015) might play an important role in explaining language emergence as well as its variation and variable acquisition (e.g., Benítez-Burraco and Boeckx, 2014, p. 126). From an evo-devo perspective, it

> is not possible to distinguish relevantly between the influence of the genes and the influence of the environment in development, since the end product is the result of the interaction of the information from both levels. In light of Evo-Devo, few dichotomies (e.g. I-Language/E-Language, Nature/Nurture, FLN/FLB, gradualism/saltationism and even adaptation/exaptation) make perfect sense (Martins et al., 2016, p. 161).

Evo-devo also goes along with a reconceptualization of the concept of gene. In an interactive perspective, it has become clear that "[g]enes are not blueprints" (Benítez-Burraco and Boeckx, 2014, p. 125). They "do not encode specific behaviors, cognitive processes, or even neural circuits, they make proteins that interact in complex, environmentally modulated networks, to build and maintain brains" (Bowling, 2017; cf. Fisher, 2006, 2017). Thus, biolinguistics is moving past simple genetic determinism, leading to common ground with usage-based approaches. However, as biolinguistics is not a unified field but more of a program or enterprise, as outlined in section "Biolinguistics," this view seems not to be the consensus in biolinguistics yet. In fact, much of the literature is still dominated "by naive depictions of the biology of language" (Benítez-Burraco and Boeckx, 2014). For example, Benítez-Burraco and Longa (2010) take Chomsky (2010) to task for advocating a simplistic and deterministic genetic view of evo-devo that does not do justice to the complexity of more dynamic evo-devo approaches (Benítez-Burraco and Boeckx, 2014, p. 124). In the context of language evolution, Bowling (2017) also criticizes the view according to which language emergence must be explained with reference to specific genetic modifications – a view espoused, for example, by Bolhuis et al. (2014). It has to be noted, though, that Bowling (2017) also criticizes, e.g., Kirby's (2017) and colleagues' work on iterated learning (see section "Cultural and Biological Evolution" below) for not taking developmental processes and gene-culture interactions seriously enough. Thus, it is fair to say that at least some of the work in usage-based and emergentist approaches still needs to properly integrate research from evo-devo and developmental systems theory. Overall though, as Dąbrowska (2015) points out, "it is encouraging to see the two traditions in cognitive science are converging, to some extent at least."

However, this is not to say that questions of innateness are not still prevalent in debates between generativists and usage-based theorists. For example, Adger (2013, 2018) claims that usage-based approaches are, in the words of Quine (1969), "knowingly and cheerfully up to [their] neck[s] in innate mechanisms of learning readiness." He claims that usage-based and cognitive-linguistic theories of language use such as Talmy (1975, 2000), Langacker (1987), and Goldberg (2006) presuppose innate mechanisms and therefore simply reject one form of innateness, namely language-specific innateness, for another one, domain-general innateness. Such criticisms do not take into account the need for a more complex and dynamic perspective on ontogenetic processes. This point is also made by Goldberg (2013) in her response to Adger's (2013) criticism: "Constructionists generally do not make any claims about whether these other biases are 'innate' since the term woefully underestimates the typically complex interactions between genes and the environment before and after birth."

Indeed, if an evo-devo and complex adaptive systems approach to development is taken seriously, it might be time to discard the concepts of innateness and maturation altogether, a position taken, for example, by Overton (2015). As he writes, "any characteristic is the outcome of a long and continuous epigenesis entailing embodied activities and actions (experiences), beginning at conception and continuing through prenatal and postnatal phases of development, as well as across the life span" (see also Bateson, 2015; Lickliter and Honeycutt, 2015). This renders concepts such as innateness meaningless and possibly even counterproductive as they do not take into account the importance of experience and environmental factors. To move past the concept of innateness, both biolinguistics and usage-based approaches need to properly acknowledge that development is always scaffolded in myriad ways (Caporael et al., 2014; see also Balari and Lorenzo, 2016) and that there are complex interactions within developmental systems. Development takes place in a particular evolutionary niche shaped and geared toward scaffolding learning processes. This ranges from the structure of interactions available to learners to symbolic artifacts that scaffold learning. These environments in turn are also shaped by learners themselves. Moreover, the emergence of particular learning factors in turn scaffold subsequent development in cascading, dynamic feedback loops within a multidimensional developmental web (e.g., Karmiloff-Smith, 2009; Caporael et al., 2014; Mascolo and Fischer, 2015; Overton, 2015; Carpendale et al., 2018).

Two domains where the growing importance of evo-devo and complex system considerations have direct impact on linguistic theorizing are the issue of modularity, discussed in section "Modularity and Domain Specificity" above, and the question of a critical period of language learning.

In traditional generativist accounts, a critical period was directly linked to concepts of an innate language faculty and its genetically determined maturation. On this view, which is still held by many researchers in a generative framework (see e.g., Lust, 2006, p. 93), there is a "time-window," a critical period, in which experience can trigger the development of the language faculty. Outside of this critical period, language acquisition might be severely impaired or hindered. Many usage-based and emergentist language acquisition researchers have long preferred to talk about sensitive instead of critical periods for language learning (e.g., Rowland, 2014). A decline in language learning abilities is framed in terms of an interplay of social factors – such as different types of and less rich interactions –, cognitive factors – such as entrenchment and competition with first language structures –, as well as biological factors such as reduced neuroplasticity (e.g., MacWhinney, 2012).

However, recent theorizing in biolinguistics has significantly reformulated the critical period concept in a way that makes it much more compatible with usage-based and emergentist approaches (Balari and Lorenzo, 2015). Balari and Lorenzo (2015), for example, argue that the way that critical periods are being talked about in generative approaches often does not take into account that language is a complex developmental phenomenon. They argue for a conception of language not as a faculty but as a "gradient," i.e., an aggregate of cognitive abilities, the weight of which is variable from one to another developmental stage, and which exercise crucial scaffolding effects on each other (Balari and Lorenzo, 2015). Of course, both approaches agree that there are age effects in language acquisition (see e.g., Werker and Hensch, 2015; Blom and Paradis, 2016). However, in contrast to the traditional maturation-trigger model, more recent approaches have taken a much more dynamic, interactive, complex systems view of this complex relationship, which can be seen as offering potential for finding common ground between the approaches. Of course, many researchers continue to talk of critical periods, critical period effects, and maturation (e.g., Werker and Hensch, 2015). However, these approaches still share a dynamic conception of age of acquisition effects with usage-based and emergentist approaches. Werker and Hensch (2015), stress that conceptions of critical periods are in a constant process of being modified to take into account the dynamic interplay of experiential and maturational influences that lead toward a trend for system stability and the fact that critical period effects themselves exhibit features of plasticity. That is, work on age of acquisition effects from different traditions can help specify the processes that mediate, narrow, and reopen learning processes (cf. Bavelier et al., 2010).

The evo-devo and complex systems perspective also has implications for conceptualizations of modularity, which were discussed in detail in section "Modularity and Domain Specificity." From this perspective, possible domain-specific effects can be captured by the concept of developmental modularity (Karmiloff-Smith, 1992). This view is encapsulated in Bates et al.'s (1988, p. 284) dictum that "[m]odules are not born, they are made." For example, Hernandez et al. (2019) propose a neuroemergentist framework in which complex functions such as language arise out of the interactional dynamics of pre-existing neural mechanisms which have evolved for different functions. These then become recycled and restructured and self-organize into new networks, yielding apparent functional specialization. This view is also consistent with research showing that weak, domain-general biases can have domain-specific effects (Culbertson and Kirby, 2016).

In evolutionary terms, these considerations are in line with the position that evolution is a "tinkerer" combining existing systems to yield new functions (Jacob, 1977; Gong et al., 2018). They are also consistent with the view that, as Bates et al. (1991, p. 34) put it, "[l]anguage is a new machine built out of old parts," with the old parts, however, keeping "their day jobs" (Bates, 1999, p. 237). This perspective also takes seriously the fact that many different developmental trajectories can lead to the emergence of language and that language can be quite variable developmentally, cognitively, as well as neurobiologically (see also Benítez-Burraco and Boeckx, 2014, p. 124). Developmental modularity therefore sees modularity as being an emergent, permeable, and interactive process leading to robust and reliable development *via* variable pathways and through variable system implementations (McClelland et al., 2006; MacWhinney, 2015). In fact, if developmental modularity is framed in this way, the discussion can move away from all-or-nothing choices regarding modularity and toward the factors that influence the emergence of relatively stable and specialized functional neurobiological systems (cf. Barrett and Kurzban, 2006).

One interesting question is to what extent the emergence of co-opted, recycled functional systems had co-evolutionary, emergent effects. This is also explicitly acknowledged by usage-based linguists such as Dąbrowska (2015), who states that the "old parts" such as attention, motor planning, and memory consolidation evoked by Bates (e.g., Bates, 1999) might have "undergone further selection as a result of the role they play in language, so that language is now their 'day job,' although they continue to 'moonlight' doing other jobs." This is also echoed in the biolinguistic literature. Boeckx (2017, p. 327), for example, states that

> [o]f course, once collected under a single roof ("language-ready brain"), these traits may give rise to nonlinear, "emergent" effects. Likewise, as Fujita (2016) has stressed, when placed in the context of the human brain, "old" pieces may acquire new roles that transform their nature (the sort of feedback loop familiar in biology).

Their linguistic recruitment might therefore in turn influence the biological evolution of domain-general constraints such as brain size, memory load, storage capacity, and patterns of neural development, perspective-taking, and sociocognitive skills, among others. This co-evolutionary relationship between language and the biological foundations adapted by language is explicitly acknowledged in both usage-based approaches and biolinguistics (Gong, 2011; Hurford, 2012; Steels, 2012).

These considerations move away from the ontogenetic process and more toward an integrated evolutionary account of ontogeny, culture, and biology, which is the topic we are going to turn toward next.

Overall though, although we see a potential for increasing dialogue and convergences between usage-based approaches and biolinguistics, we agree that the question of how the language system "specializes and the extent to which it interfaces with evolutionarily conserved processes needs to be much better understood mechanistically and across neural scales" (Petkov and Marslen-Wilson, 2018). In addition, as Fitch (2017) points out, many of the issues discussed in this section are "not likely to be resolved until we know more about how genes, brains, and language are interrelated."

## Cultural and Biological Evolution

The complex adaptive system view on ontogenetic development described in the previous section can be related to a broader complex adaptive system view of the relationship between ontogeny, cultural, and biological evolution (e.g., Beckner et al., 2009; Steels, 2011; Pleyer and Winters, 2014; MacWhinney, 2015; Kirby, 2017). After focusing on ontogeny in the previous section, in this section, we will spell out possible convergences and differences between biolinguistics and usage-based approaches in the domains of biological and cultural evolution. Here the complex adaptive systems view as a framework opens up new possibilities of dialogue about the factors that influence the emergence of language across multiple timescales. As Bentz (2018) points out, the complex adaptive system approach functions as an overarching framework and can accommodate both strong minimalism and usage-based theories of language.

However, apart from the adoption of an overarching framework that enables more fruitful dialogue, there are also other developments that bring biolinguistics and usage-based theory closer together. As outlined in the previous section, biolinguists and minimalists have realized that they made too heavy demands on the genetic endowment required for language (Boeckx, 2017; see also O'Grady, 2012). We have already seen in the previous sections that much of the developmental "burden" of UG has been shifted to other factors. This holds not only for the ontogenetic level but also for the development of language across multiple timescales, as well. Chomsky (2005), for example, has proposed that next to genetic endowment as a first factor, and experience as a second factor, there is a third factor contributing to language design, namely "principles not specific to the faculty of language." Some authors, such as O'Grady (2012), cautiously treat this concept as offering the potential for convergence with usage-based approaches, while others remain extremely skeptical (e.g., Johansson, 2013). Usage-based and emergentist approaches have concentrated on the question of how language arises from multiple competing constraints, such as usage and processes of generalization and self-organization (e.g., MacWhinney et al., 2014; MacWhinney and O'Grady, 2015). As O'Grady (2012) puts it, "[b]roadly speaking, the rest of the field has been committed to the primacy of third-factor explanations for decades." As he points out, the fact that minimalism and biolinguistics show an increasing interest in "third factor principles" offers the "opportunity – the first in half a century – for the discipline to focus on a common research question: What are the nongrammatical mechanisms and forces that shape language and contribute to its effortless acquisition?"

Even though we can observe convergences between biolinguistics and approaches that stress the cultural component of the emergence of language (cf. Boeckx, 2017), the central question remains how much of language can be explained in terms of cultural evolution.[3] Regarding the importance of the cultural dimension of language emergence, there is a wealth of research in grammaticalization research which shows that structure and complexity emerge historically through processes of language change (e.g., Heine and Kuteva, 2007). Some approaches therefore assume that the evolution of language can be explained exclusively by recourse to cultural evolution. For instance, in Steels' recruitment theory, "genetic evolution by natural selection is not seen as the causal force that explains the origins of language" (Steels, 2007, p. 131). Instead, other, domain-general cognitive and neural resources are "recruited" for communication (Steels, 2007, p. 130). Other approaches do not rule out the existence of innate, language-specific mechanisms entirely but still emphasize the key role of cultural evolution (see Hurford, 2012). For instance, Kirby (2017), in line with the complex adaptive systems approach, posits that "[w]ith a trait like language, biological evolution takes place alongside individual learning and cultural transmission." The iterated learning paradigm adopted by Kirby and colleagues (e.g., Kirby and Hurford, 2002; Kirby et al., 2008; Kirby, 2017) is one particular approach to the cultural emergence of structure that is highly relevant to evolutionary linguistics. In a number of computational modeling studies as well as in experimental studies, iterated learning research has shown that structured communication systems as well as linguistic structure can emerge through iterated learning. The learning biases of learners exposed to unstructured input over time lead to the emergence of structure if the second generation of learners is exposed to the output of the first generation, and the third generation is exposed to the output of the second generation of learners, and so forth. Linguistic structure can therefore be said to emerge from repeated and iterated cycles of usage and learning. Adger (2017) sees these results as consistent with generative grammar. As he states, such results are in line with Chomsky's (2005) view of third factor effects. Adger (2017) interprets the emergence of structure through Bayesian Iterated Learning as resulting from "general laws of computational economy," which interact with social and cultural pressures. In his view, it is still important to note that such changes still take "place within the constraints imposed by the nature of the human language capacity itself." This is echoed by O'Grady (2012), who states that both usage-based and emergentist approaches on the one hand as well as minimalist and biolinguistic approaches on the other must look toward "yet-to-be-discovered constraints on processing, perception, cognition, and interaction" that shape human language.

Bentz (2018, p. 25) makes a similar point by stating that results from iterated learning might indeed be consistent with minimalism, as iterated learning explains the origin of structure in language, whereas minimalism is interested in the core computational features which make the computation of such structure possible in the first place. Usage-based

[3]As one reviewer points out, research on the cultural evolution of the linguistic categorization of color serves as a paradigmatic example of fruitful attempts to explicate the biological foundations and socio-cultural factors influencing a given phenomenon (see e.g., Loreto et al., 2012; Gong et al., 2019).

and biolinguistic approaches seem to differ regarding the aspects of the emergence of language they focus on. The emergence of structure is of course constrained and based on the properties of the "language-ready brain," but many usage-based theorists also emphasize the fact that the structures of languages adapt to and are shaped by the brain (e.g., Christiansen and Chater, 2008, 2016) as well as by social, communicative, and processing factors. With increasing biolinguistic forays into "third factor principles," however, there is more potential for both approaches to enter into a dialogue with regard to the factors that shape language. From this perspective, both approaches can deal with the question of "which aspects of language in a usage-based sense are potentially to be explained by factors external to FLN, and maybe even external to FLB?" (Bentz, 2018, p. 26).

Recent variants of the iterated learning paradigm have taken the connection between culture and biology into account more thoroughly, partly in response to the frequent criticism that the individuals involved in the lab experiments are fully modern humans. Thompson et al. (2016) propose a series of Bayesian computational models of gene-culture coevolution and arrive at the conclusion that "[c]ulture facilitates rapid biological adaptation yet rules out nativism: Behavioral universals arise that are underpinned by weak biases rather than strong innate constraints."

In general, then, the importance of cultural evolution and non-biological factors in the emergence of language is acknowledged in biolinguistics, and both approaches might find common ground in investigating these factors. In fact, Gong (2011) argues that biolinguistics can help in identifying biological constraints on language structure and in evaluating their role in language evolution. He explicitly argues that biolinguistics and evolutionary linguistics can meet in tackling the question of how biological constraints are differentially recruited in language evolution and learning.

One caveat that has to be noted here, though, is that the emphasis of much of minimalist biolinguistics lies less on general cognitive and social factors in explaining the emergence of language. Instead, minimalist biolinguistics tend to stress the importance of more abstract, computational principles. Chomsky (2005), for example, divides third factors into the following subtypes:

> (a) principles of data analysis that might be used in language acquisition and other domains; (b) principles of structural architecture and developmental constraints that enter into canalization, organic form, and action over a wide range, including principles of efficient computation, which would be expected to be of particular significance for computational systems such as language.

Whereas much of usage-based theory, as seen above, has focused on the effect of specific cognitive mechanisms as well as interactional, communicative, and social factors, Chomsky (2005) stresses that it is the second subcategory that is expected to be much more significant in explaining language emergence. This raises problems for finding common ground with usage-based approaches on two levels.

First, as noted by O'Grady (2012), computational efficiency is very much a theory-internal concept. A minimalist analysis of a given linguistic phenomenon looks very different from the analysis of the same phenomenon from a construction grammar perspective or from analyses in other linguistic frameworks (see Müller, 2018 for an extended discussion). This is especially so as computational efficiency in a minimalist framework is not the same as processing cost, as minimalism still upholds the competence/performance distinction, a position that is rejected in usage-based approaches. We will outline this fact in section "Knowledge of Language and Its Description" below. Therefore, if one adopts a minimalist framework that does not enter into contact with biological and psycholinguistic considerations, it is not possible to independently and interdisciplinarily test assumptions about the influence of third factor principles without also taking on board the assumptions of minimalism (O'Grady, 2012). Of course, to a degree this presents a general challenge for all theoretical linguistic approaches that appeal to computational efficiency. This point is also made by Fitch (2017), who notes that computational simplicity "does not necessarily translate into implementational simplicity at the neural level (or vice versa)" (see also Poeppel and Embick, 2005).

Second, the minimalist focus on "more general principles that may well fall within extra-biological natural law" (Chomsky, 2011, p. 263) has been criticized for being too vague and ultimately unhelpful in capturing the factors involved in language emergence (Johansson, 2013). Johansson (2013), in his critique of the third factor concept, argues that there is no clear consensus in biolinguistics on how to approach the question of what might count as a third factor principle, making appeals to third factors a "vague and disparate collection of unrelated components." Moreover, he criticizes the often sweeping references to physics without principled explanations. Speaking of generalized third factor principles might therefore be much less productive than proposals of specific factors of a non-linguistic nature that influence the emergence of language. It is this potential for debating specific factors influencing language design where we see the greatest potential for cross-fertilization between the approaches.

One prominent usage-based approach relevant to this discussion is that of Christiansen and Chater (2008, 2016), who argue that "language is shaped by the brain." That is, they argue that language emergence was driven by linguistic structure adapting to the non-linguistic mechanisms and constraints that operate when generations of language users learn and process language in real time. Specifically, they point to the pressure deriving from multiple interacting constraints that shape language. These constraints belong to a number of different domains, namely

1. the nature of the cognitive activities and thoughts language is used to express,
2. constraints from the perceptual and motor machinery underlying language,

3. cognitive constraints on learning and processing such as memory constraints and constraints from processing sequential and hierarchical structures, and
4. pragmatic constraints.

Deacon (1997, 2012) takes a similar approach to constraints on language structure. He breaks down such constraints into four main categories, which partly overlap with those proposed by Christiansen and Chater (2008), but in part extend them as well: (1) semiotic constraints on the structure inherent in a referential symbolic system, (2) processing constraints that enable language processing to be automatized, (3) phylogenetic sensorimotor biases relating to the embodied nature of language and conceptualization (see also Lakoff, 1987; Langacker, 1987; Hurford, 2007; Johnson, 2018), and (4) communicative constraints relating to the way and types of information shared in human societies. Although much of minimalist biolinguistics has been more interested in what the core features of language are, it can be argued that it is crucial to focus on the question of what kinds of constraints shape the emergence of language to get a clear picture of what the core features of language are. In fact, many biolinguists agree that the deep systematic constraints on language are a central factor in accounting for the emergence of language in all its variation that is not only consistent but also very much in line with an evo-devo approach to language (e.g., Benítez-Burraco and Boeckx, 2014).

Of course, the key questions for the future will be to what degree such factors can explain the emergence of language and what picture of the structure of "the language-ready brain" emerges from these investigations. Fitch (2017), for example, agrees "with Keller (1995), Deacon (1997), Heine and Kuteva (2002), Steels (2017), Kirby (2017), and many others that much of the complexity evident in the syntax of modern languages has arisen repeatedly by grammaticalization processes of cultural evolution and required no further neural changes beyond those needed for dendrophilia," a domain-general ability to process and perceive hierarchical structure, which evolutionarily came to be applied to language and other hierarchical behaviors such as music and art.

However, the debate about the role of grammaticalization and cultural evolution is still ongoing. This is also related to the notion of protolanguage. Whereas the notion is rejected outright by minimalist approaches that take a saltationist view, as the emergence of unlimited Merge is seen as the *sine qua non* of any form of "language" (e.g., Berwick and Chomsky, 2016), others have proposed quite detailed models of protolanguage stages, which are also rooted in evolutionary changes (e.g., Jackendoff, 2002; Progovac, 2015). Usage-based and emergentist approaches, such as that of Arbib (2012, 2015) and Heine and Kuteva (2002, 2007, 2012), on the other hand, differ from these approaches in that they assume that processes of cultural evolution and grammaticalization can lead from a protolanguage stage to language without any further biological changes. This perspective in turn is criticized by researchers in biolinguistics, many of whom accept a protolanguage stage, but, in contrast to Arbib (2012, 2015), "while recognizing the importance of cultural learning and transmission, still allow for significant changes at the level of the brain between a protolanguage user and a full-fledged, modern-language user" (Boeckx, 2017). This view, it is argued, is consistent with recent research indicating that there have been changes to the human brain even after the emergence of modern humans, which might have influenced the cognitive mechanisms involved in the process of grammaticalization (Benítez-Burraco, 2017).

So while there clearly are convergences regarding the recognition of the importance of cultural evolution between usage-based approaches and biolinguistics, the relation between cultural and biological evolution in the emergence of language is in need of further exploration.

## Knowledge of Language and Its Description

Another contested topic that is closely related to – and immediately follows from – the issues discussed above is the relative importance of competence and performance, or "I-language" and "E-language." It has often been noted that the various terms that have been suggested for these different facets of language are not fully congruent: For instance, Jackendoff (2002, p. 29) points out that while I(nternalized)-language "coincides more or less with competence," E(xternalized)-language does not refer to "the mechanisms that speakers use to exhibit linguistic behavior (i.e., performance), but either (a) external linguistic behavior of individuals or (b) language regarded as an object external to human minds." He also notes that Saussure's *langue* and *parole* both correspond to aspects of E-language.

From a minimalist perspective, the study of language amounts to the study of I-language. The term "I-language," introduced by Chomsky (1986), in essence refers to "the linguistic knowledge in the head of a native speaker, that is, the grammar" (Culicover, 2013, p. 194). Interestingly, this definition could also be applied to what construction grammarians have termed the "construct-i-con." According to Hilpert (2013, p. 1), summarizing Goldberg (2003), the main objective of Construction Grammar is "to find out what speakers know when they know a language and to describe this knowledge as accurately as possible." However, the answer to this question trivially depends on whether one assumes an I-language in the first place.

Usage-based approaches do not usually distinguish between I-language and E-language. This is not to say, of course, that they do not make a distinction between language as an externalized, "materialized" phenomenon, and its cognitive underpinnings. But while generative approaches hold that the properties of I-language cannot be derived from the observable facts of E-language (see e.g., Anderson and Lightfoot, 2002, p. 9), usage-based approaches put the study of E-language center stage, arguing that linguistic usage patterns allow for important conclusions regarding the cognitive organization of language (see e.g., Bybee, 2010; Taylor, 2012).

The question of whether we have to distinguish between I-language and E-language (or make related distinctions) also entails important epistemological and methodological consequences. Adli et al. (2015, p. 10), discussing points of convergence and difference between generative syntax and variationist sociolinguistics (which tends to be conducted in a usage-based framework), phrase the main issue quite succinctly: "In essence, the question is whether grammar contains numbers or not?" In other words, the question is what, if anything, we can learn from usage data about language as a (cognitive) system. According to Taylor's (2012) "mental corpus" hypothesis, which is heavily influenced by other usage-based approaches (especially the works of Bybee and Langacker, e.g., Langacker, 1987; Bybee, 2010), language users keep track of the utterances they encounter, which leads to the (ontogenetic) emergence and lifelong reconfiguration of a network of linguistic constructions. From this perspective, the cognitive organization of language can be fully understood by describing E-language. This is why usage-based constructionist approaches posit that language can be exhaustively described in terms of constructions, that is, form-meaning pairs at various levels of abstraction (Croft, 2001; Goldberg, 2006) or, in Goldberg's (2019, p. 7) most recent definition, "emergent clusters of lossy memory traces that are aligned within our high- (hyper!) dimensional conceptual space on the basis of shared form, function, and contextual dimensions." However, it has increasingly become clear to proponents of usage-based approaches that a direct mapping from usage to cognition is not possible. For example, Dąbrowska (2016, pp. 486–488) sees the corpus-to-cognition fallacy, i.e., the assumption "that we can deduce mental representations from patterns of use," as one of the "seven deadly sins of Cognitive Linguistics." This may be seen as an indication that usage-based approaches have become less radically usage-based in the sense that they have become more cautious regarding an apodictic identification of "grammar" (or, perhaps more generally: linguistic knowledge) with "usage."

Still, the conceptualization of grammar (and its relation to usage) differs considerably between the two approaches. The difference between the holistic stance taken by usage-based approaches and the modularistic stance taken by minimalist ones is reflected in different scientific metaphors used to describe how language makes use of finite means to create a potentially infinite array of different utterances. Abrahamsen and Bechtel (2012, p. 14) describe the Chomskyan "rules-and-representations" approach to language that has proven influential not only in generative linguistics but also in cognitive science more generally as an instance of the so-called computer metaphor (see e.g., Boyd, 1993; Johnson and Rohrer, 2007; Hartmann, 2015). In line with the idea that cognition consists of representations and rules that combine them, generative approaches typically assume a strict distinction between the lexicon as an inventory of elements that cannot be derived on the basis of rules, on the one hand, and the grammar as a set of rules for combining these elements, on the other. Taylor (2012) calls this the "dictionary-and-grammar-book" approach.

Usage-based approaches, by contrast, have proposed a dynamical systems view of the mind (Spivey, 2007, p. 305). On this view, as outlined in section "Modularity and Domain Specificity," we cannot strictly distinguish between different cognitive "modules," let alone between different subsystems of language. Instead, "[e]verything is connected" (Beckner et al., 2009, p. 18). While the distinction between grammar and lexicon remains an important heuristic device in usage-based linguistics – especially in approaches to grammaticalization, many usage-based theorists assume a continuum between lexicon and grammar (termed "lexicon-syntax continuum" in constructionist approaches; see e.g., Broccias, 2012; Hoffmann and Trousdale, 2013; but see Pulvermüller et al., 2013 for some caveats from a neurolinguistic perspective). This entails a unified approach to the description of linguistic units – lexical as well as grammatical – on various levels of abstraction. As Hilpert (2013, p. 2) puts it, "[a]ll that speakers need to have, according to the constructional view, is knowledge of constructions." In a similar vein, Langacker's (e.g., Langacker, 2008) Cognitive Grammar limits the descriptive apparatus to semantic, phonological, and symbolic structures.

Given the holistic outlook of usage-based approaches, their conceptualization of how complex units are formed differs from the one in minimalist approaches: Usage-based and emergentist approaches often prefer the concept of "schemas" over that of rules. Interestingly, Booij (2010, p. 5), who combines Goldbergian Construction Grammar with a Jackendoffian Parallel Architecture approach in his Construction Morphology, sees the difference as merely terminological:

> Jackendoff uses the term "rules" for regularities on a particular level of linguistic description, such as phonology or syntax. However, nothing hinges on this term, and one could use the term "schema" here as well.

However, one could also argue that the use of "rules" vs. "schemas" entails a fundamental difference in conceptualization. According to Michaelis (2012), "[a] leading insight of CxG from its inception is that grammar rules are not procedures but category descriptions, and as such, subject to taxonomic organization. Such taxonomies, which have come to be known in the CxG literature as inheritance networks, provide for cross-cutting generalizations about constructions." Therefore, inheritance networks and different levels of abstraction and multicomponential type instantiations are the theoretical terminology used in CxG instead of "rules." Similarly, Langacker (1987) analyzes grammatical "rules" as symbolic units that are both complex and schematic. So in terms of how the language system works, there is a deep divide between usage-based and emergentist and biolinguistic approaches. This also relates to computational approaches and the computational theory of mind, which is rejected in usage-based and emergentist approaches. However, ultimately, biolinguistic approaches are interested in conceptualizing language in terms of neural oscillation patterns and spiking activation in brain circuitry. In usage-based and emergentist approaches, this is also what schematizations eventually boil down to, meaning that even though there is a terminological difference between "rules" on the one hand and "networks" and "schemas" on the other, this terminological difference might actually be less important once we get to the granularity of neuronal activation patterns and neural implementation generally. Note also the so-called granularity problem, which refers to the fact that theoretical concepts in linguistics and neuroscience do not match, which at the moment might still present a challenge for both approaches (Poeppel and Embick, 2005; Shay et al., 2017).

In sum, then, the theoretical conceptions of linguistic knowledge still differ quite considerably between both approaches, which entail methodological differences in the sense that (externalized) language data are interpreted in different ways. Thus, the biology of language looks quite different if seen through a minimalist-biolinguistic lens, compared to the conceptualization of language from a usage-based perspective. In particular, it is an open question to what degree actual usage data can give clues to the underlying biology of language. Also, there are many open questions regarding the neuronal basis of language and the degree to which it is compatible with theoretical assumptions and concepts in linguistics. These questions can only be answered by amassing further empirical evidence from various disciplines, especially from psycho- and neurolinguistics.

## CONCLUSION

Despite all controversies that still persist between minimalist and usage-based frameworks, there seems to be a broad agreement that there are "many mechanisms and pressures that shape the emergence of language" (MacWhinney, 2015, p. 12). There are many interesting parallels, especially between the complex adaptive system framework adopted in much research within usage-based and emergentist frameworks, on the one hand, and the evo-devo approach that has become influential in biolinguistics, especially in "biolinguistics 2.0", on the other. What has become clear is that neither of the extreme positions sometimes found in the literature are wholly correct (Hurford, 2018) and that instead of making a distinct either/or decision, there is potential for the different approaches to find common ground on issues such as modularity, domain specificity vs. domain generality, innateness and development, and cultural and biological evolution.

Our view is that "progressive biolinguistics" (as represented in publications such as Di Sciullo and Boeckx, 2011; Boeckx and Benítez-Burraco, 2014a,b; Balari and Lorenzo, 2016, 2018; Boeckx and Martins, 2016; Boeckx, 2017) is partly converging with usage-based approaches. Traditional, or "orthodox" (Kirby, 2017; Balari and Lorenzo, 2018) biolinguistics, however, is not. This is evident, for example, in a recent paper by Crain et al. (2017), which compares the "biolinguistic approach" with the "usage-based approach" in child language acquisition. Crain et al. (2017) come to the conclusion that biolinguistic approaches are superior to usage-based approaches in terms of descriptive and explanatory adequacy. Yang et al. (2017) and Bolhuis (2019) represent further examples of the views held by "traditional" biolinguistics. Usage-based linguists, however, disagree with this assessment (see e.g., Ambridge and Lieven, 2011; Rowland, 2014; Ambridge, 2019). Here, we do in fact not see many points of convergence. This paper has therefore focused on the potential of convergence between certain strand of usage-based approaches and "progressive" biolinguistics.

Of course, the converse is also true. Not all versions of usage-based approaches are compatible or convergent with progressive biolinguistics. For example, Ambridge (2019) recently proposed a radical exemplar model of language acquisition that does not posit stored abstractions. Instead, novel forms are comprehended and produced *via* on-the-fly analogy across multiple stored exemplars. Clearly, again, there seems to be relatively little potential for points of convergence between these models and progressive biolinguistics. Overall, there are still many biolinguists who hold a more traditional view that is not compatible with the possible emerging consensus we have outlined here. Conversely, it is also true that not all proponents of usage-based approaches have fully integrated the perspectives from evo-devo, complex adaptive systems and dynamic system theory into their work. For example, Carpendale and Lewis (2015) criticize Tomasello (2014) for not adequately integrating the dynamic relationship of evolution and development as well as the interactive dimension of ontogeny into his model of the emergence of uniquely human cognition (see also Carpendale et al., 2018).[4] Our comparison has therefore only scratched the surface of the conceptual convergences and divergences between the approaches. In particular, as illustrated in the discussion above, we have partly neglected the differences within the field of biolinguistics and usage-based approaches, respectively. As Balari and Lorenzo (2018) point out in their discussion of different ontological commitments regarding the status of language and the issue of modularity, "many middle ground positions exist that complicate the picture." In addition, we have not discussed challenges that face both approaches equally, for example the question of how to integrate multimodality (Pleyer et al., 2017; Wacewicz and Zywiczynski, 2017) and embodiment (Ferretti et al., 2018; see also Gomez-Marin and Ghazanfar, 2019) into accounts of language evolution. The same holds for the challenges of integrating language evolution research with evo-devo research, a project that is still very much in its infancy (e.g., Benítez-Burraco and Boeckx, 2014). Overall,

[4]Overall, it has to be stated that at the moment, biolinguistics exhibits a much stronger commitment to integrating current trends and developments in biology than do most usage-based approaches. This then clearly presents a desideratum for usage-based approaches, which also stand to profit greatly from integrating biology more fully into their models of language.

taking into account recent and future developments in (evolutionary) biology likely represents the most important step toward an integrative and biologically sound theory of language evolution. We also have not addressed the differences in the ontological conceptualization of language as an internal vs. external object, a topic that Balari and Lorenzo (2018) see as a fundamental axis of disagreement in the study of language.

Overall, though, it is an interesting perspective to see biolinguistics and usage-based and emergentist approaches being broadly compatible, which enables fruitful and structured debates about the mechanisms and pressures that exist on language emergence and their respective roles and interactions. Thus, we hope to have shown that the deep divide mentioned by Johansson (2014) is not as unbridgeable as it may seem and "there is actually much more complementarity than incompatibility between the findings and results of the two major research frameworks" (Mendívil-Giró, 2018).

## AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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# Merge-Generability as the Key Concept of Human Language: Evidence From Neuroscience

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Ever since the inception of generative linguistics, various dependency patterns have been widely discussed in the literature, particularly as they pertain to the hierarchy based on "weak generation" – the so-called Chomsky Hierarchy. However, humans can make any possible dependency patterns by using artificial means on a sequence of symbols (e.g., computer programing). The differences between sentences in human language and general symbol sequences have been routinely observed, but the question as to *why* such differences exist has barely been raised. Here, we address this problem and propose a theoretical explanation in terms of a new concept of "Merge-generability," that is, whether the structural basis for a given dependency is provided by the fundamental operation Merge. In our functional magnetic resonance imaging (fMRI) study, we tested the judgments of noun phrase (NP)-predicate (Pred) pairings in sentences of Japanese, an SOV language that allows *natural*, unbounded nesting configurations. We further introduced two pseudo-adverbs, which *artificially* force dependencies that do *not* conform to structures generated by Merge, i.e., non-Merge-generable; these adverbs enable us to manipulate Merge-generability (*Natural* or *Artificial*). By employing this novel paradigm, we obtained the following results. Firstly, the behavioral data clearly showed that an NP-Pred matching task became more demanding under the Artificial conditions than under the Natural conditions, reflecting cognitive loads that could be covaried with the increased number of words. Secondly, localized activation in the left frontal cortex, as well as in the left middle temporal gyrus and angular gyrus, was observed for the [Natural – Artificial] contrast, indicating specialization of these left regions in syntactic processing. Any activation due to task difficulty was completely excluded from activations in these regions, because the Natural conditions were always easier than the Artificial ones. And finally, the [Artificial – Natural] contrast resulted in the dorsal portion of the left frontal cortex, together with wide-spread regions required for general cognitive demands. These results indicate that Merge-generable sentences are processed in these specific regions in contrast to non-Merge-generable sentences, demonstrating that Merge is indeed a fundamental operation, which comes into play especially under the Natural conditions.

**Keywords: syntax, Chomsky Hierarchy, Merge, Merge-generability, inferior frontal gyrus, lateral premotor cortex, fMRI**

## INTRODUCTION

The present study aims to support the concept of human language, by putting forth a new theoretical hypothesis and by providing novel experimental evidence drawn from neuroscience. Our newly designed functional magnetic resonance imaging (fMRI) experiment focused on the fundamental operation of human language – *Merge*, with its ramified functions in characterizing various formal dependencies and their computation in the brain. Merge is a simple and primitive combinatory operation that takes *n* objects (usually two, in the case of human language), say *X* and *Y*, and forms an unordered set of the objects (Chomsky, 1995, 2000). The literature of theoretical linguistics has converged on the hypothesis that human language at its core is a uniquely human system of unbounded Merge, and this simple operation is the single generative engine underlying the infinity of linguistic expressions.

If this hypothesis is correct, then it follows that natural linguistic dependencies (such as those defined over embedding and coordination) are possible only when phrase structures that lie behind the relevant dependencies are generable by unbounded Merge (Fukui, 2015). Capitalizing on the proposal put forth in Fukui (2015), we make the distinction between "Merge-generable" dependencies and "non-Merge-generable" dependencies. A dependency is Merge-generable if it is based on a structure generated by Merge; otherwise, the dependency is non-Merge-generable. The central role of Merge in characterizing linguistic dependencies, as explicitly depicted by the notion of Merge-generability just defined, leads to the following hypothesis:

(1) **Hypothesis:** Only Merge-generable dependencies are naturally computable as linguistic dependencies by the human language faculty.

This hypothesis makes sense under the "Merge-only" hypothesis above, because if there is no structure generated by Merge for a given dependency, there will be no strictly linguistic way to characterize such a dependency. Thus, Merge-generability sets a necessary condition for "linguistically possible" dependencies. Non-Merge-generable dependencies are, then, strictly speaking, "linguistically impossible." This is a big – and crucial – line that we would like to draw between various types of dependencies defined over linguistic expressions.

Merge-generable dependencies (i.e., "linguistically possible" dependencies) are further divided into two subtypes. One subtype is a dependency that is based on a structure *totally* determined by Merge. This type of *totally* Merge-generable dependencies includes, among many other "core" dependencies, subject-predicate linking – typically instantiated by noun phrase (NP)-predicate (Pred) pairing – as observed in Japanese sentence-embedding (carried out by the so-called "External Merge;" see below), as well as filler-gap dependency and operator-variable relations in movement (created by the so-called "Internal Merge"). Note that the latter type of dependency is the one holding between more than one *copy* (occurrence) of the same, single syntactic object (Chomsky et al., 2019) (see also the "Discussion" section), and is thus different in nature from the former type of dependency that holds between distinct syntactic objects, NP and Pred for example. While much "processing/parsing" literature in psycholinguistics has been focused on filler-gap dependencies, we do not directly deal with this type of dependency between copies of the same syntactic object in this study, simply pointing out that filler-gap dependencies are totally Merge-generable.

The other subtype of Merge-generable dependency is the one such that although based on a structure generated by Merge (i.e., Merge-generable), the conditions for the relevant dependency are *not* totally determined by Merge alone; rather, it requires some other factors such as left-to-right precedence, isomorphy, and pragmatic factors. This subtype of dependencies is called *partially* Merge-generable, and it typically includes group reading and cross-serial interpretation in coordinate structures. Totally and partially Merge-generable dependencies are naturally expected to be treated differently in the brain, but the thorough and detailed experimental study of the different functioning of these dependencies falls outside of the scope of this article, and we leave the investigation of this important topic for future research, focusing on, in the present study, the crucial and fundamental distinction between Merge-generable and non-Merge generable dependencies.

Regarding the neural basis of Merge, in our previous fMRI study we demonstrated that Degree of Merger (DoM) accounted for syntax-selective activations in the pars opercularis and pars triangularis (L. F3op/F3t) of the left inferior frontal gyrus (L. IFG) (Ohta et al., 2013b). The DoM is the *maximum depth* of merged subtrees usually within an entire sentence, and it properly measures the complexity of tree structures. In contrast, the number of applications of (External) Merge in a sentence always becomes one less than the number of terminal nodes, *irrespective of sentence structures* (see Appendix S2 of Ohta et al., 2013b). The DoM domain, i.e., the subtrees where the DoM is calculated, is an entire sentence when there is no constraint, but this changes dynamically in accord with syntactic operations and/or task requirements (Ohta et al., 2013a). By comparing short postpositional phrases/sentences with word lists, another fMRI study also showed that Merge operations activated the L.

F3op/F3t, as well as a smaller region in the posterior superior temporal sulcus (Zaccarella and Friederici, 2015). These fMRI studies strongly suggest that the fundamental structure-building operation, i.e., Merge, activates the L. F3op/F3t and the left lateral premotor cortex (L. LPMC), which have been proposed as grammar centers (Sakai, 2005). We are of course aware that there is a general methodological challenge, not disproportionately serious for the present study alone, but troublesome for any attempt to connect linguistic computation and neural activation: the problem as to how to substantively link cognition and neurobiology, as has been discussed in the literature (Chomsky, 2002; Embick and Poeppel, 2015). Our approach in this paper can be taken as an "integrated" approach in the sense of Embick and Poeppel (2015), with the goal of constructing an "explanatory" study in future work. We thus focus here on the above-mentioned main Hypothesis (1), and we report the findings revealed by our fMRI experiment that conforms to this overarching hypothesis.

We designed and conducted an fMRI experiment, the results of which provided a novel set of evidence supporting Hypothesis (1). As the target language, we chose Japanese because it exhibits unbounded nesting at the core of its syntax – sentence embedding. This is not the case in, say, English due to its SVO order. Japanese, by contrast, straightforwardly provides natural, unbounded nesting configurations, thanks to its SOV order. Natural sentences with various Merge-generable structures (**Figure 1A**) were first tested with native speakers of Japanese [the *Natural conditions*, using four-word (4W) and six-word (6W) sentences (excluding an adverb in the middle), i.e., Natural (4W) and Natural (6W), respectively]. On a separate day, we tested other conditions using two pseudo-adverbs (which do not exist in the actual Japanese), in which these dependencies switched with each other [the *Artificial conditions*, using 4W and 6W sentences, i.e., Artificial (4W) and Artificial (6W), respectively]. More specifically, these pseudowords were designed to require the participants to assign certain dependencies that do *not* conform to structures generated by Merge, i.e., non-Merge-generable. We predicted that Merge-generable dependencies would induce more specific activations in the grammar center and other syntax-related regions than non-Merge-generable dependencies would. By our testing of Merge-generability, we speculated that the fundamental status of Merge would be clearly elucidated, further highlighting the nature of the human language faculty.

## Theoretical Background

In this section, we explain the theoretical background of our study that is minimally necessary for understanding the significance of the experimental results reported in this paper.

One of the remarkable – and fundamental – discoveries of modern theoretical linguistics is the recognition that human language involves abstract "structures," and that its mechanisms generate an infinite set of such structures. Linguistic expressions are not merely sequences of sounds or words; rather, they are associated with their "structural descriptions" – an array of abstract hierarchical structures – that determine their interpretations, both in terms of sound (pronunciation) and meaning (semantic interpretation). A speaker of a particular language has acquired and internalized a language in this sense – in current terminology, an "I-language" (Chomsky, 1986). The theory of an I-language is its generative grammar, a grammar of a particular language (henceforth in this text, "language" means "I-language"). A grammar is said to achieve *descriptive adequacy* (Chomsky, 1965), when it correctly describes the properties of the target language, i.e., how it generates a digitally infinite array of hierarchically organized abstract structural descriptions for linguistic expressions with the systematic interpretations at the two "interfaces" (sound and meaning) at which the language interacts with other internal systems. The general theory of languages is called Universal Grammar (UG), which is the theory of the genetic component of the language faculty that makes it possible for humans to acquire a language under limited conditions (Crain and Pietroski, 2001). UG determines the class of generative grammars that provide a set of correct structural descriptions for each language, thereby providing an explanation for the well-known facts about language acquisition (Berwick et al., 2011), in which case UG is said to achieve *explanatory adequacy*. It is important to note that in this conception of human language, there is virtually no room for the concept of "left-to-right" precedence or linear order, like how sounds or words are arranged left-to-right, without referring to hierarchical structures. Rather, it is always an array of abstract structures assigned to linguistic expressions – their structural descriptions – that plays a crucial role in the study of human language.

The relevant notion of *weak* and *strong* generation was introduced by Chomsky (1963, p. 325, 1965, p. 60), and the standard definition, adapted here from Chomsky (1965, p. 60), is as follows: "Let us say that a grammar *weakly generates* a set of sentences and that it *strongly generates* a set of structural descriptions. . ." Examples of weak generation are {aa, bb, aabb, . . .}, {John likes music, John ate an apple, . . .}, etc., depending on the Vocabulary of a grammar; those of strong generation are {[aa], [bb], [[aa] [bb]], . . .}, {[$_S$ [$_{NP}$ John][$_{VP}$ [$_V$ likes] [$_{NP}$ music]]], [$_S$ [$_{NP}$ John] [$_{VP}$ [$_V$ ate] [$_{NP}$[$_{Det}$ an][$_N$ apple]]]], . . .}, etc. Structural descriptions assigned by a grammar are complex objects and may be more than a single bracketing (or "tree") structure (or a "layered" set structure, in the case of Merge systems), but rather, they can be a sequence of such abstract hierarchical structures (Chomsky, 1957, 1965). It should be clear, though, from the definition (and the examples provided) above that weak generation is just an enumeration of sentences (strings of elements), whereas strong generation has to do with more abstract hierarchical structures (or sequences of hierarchical structures) assigned to sentences by a grammar. On strong generation, an illuminating discussion is found in Kuroda (1976).

Theories of Merge aim to provide a minimal characterization of *strong generation*, namely the generation of structural descriptions of linguistic expressions (Chomsky, 1965). While theoretical linguistics has been developing increasingly better and refined accounts of strong generation, attention has been largely restricted in cognitive neuroscience to the study of *weak generation*, i.e., the formation of terminal, left-to-right strings of words (or word-like elements). There is a practical reason for the status of cognitive neuroscience in which a consistent focus has been placed on weak generation,

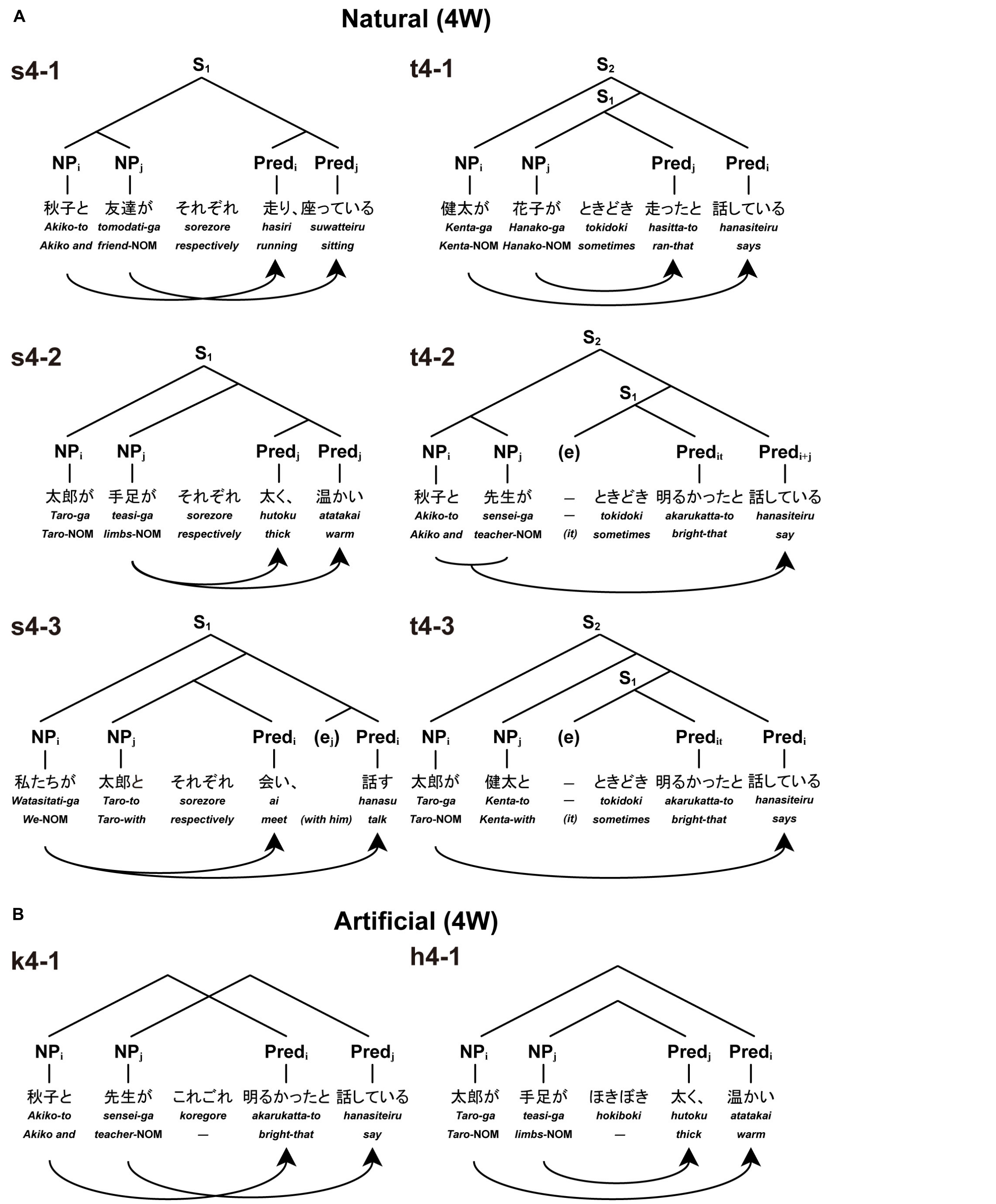


**FIGURE 1 |** Basic types of Natural and Artificial sentences. We tested six sentence types each under Natural or Artificial conditions. Below each example in Japanese, phrases in Romaji and word-by-word translations in English are shown (NOM = a nominative case marker). Each type was presented as three visual stimuli in the order of noun phrases (NPs), an adverb, and predicates (Preds). The same subscript letters stand for structurally bound correspondences between an NP and a Pred in the sentence (S): e.g., $NP_j$ and $Pred_j$ indicate that these two elements are paired ($Pred_{it}$ denotes the predicate of an indefinite subject "*it*"). Curved arrows also denote such NP-Pred pairings based on sentence structures. Each of tree structures represents unique structures for NPs and Preds. **(A)** There were six types of Natural sentences with four words. Left: three types of sentences with *sorezore*: e.g., "*Akiko and* [*her*] *friend are running and sitting, respectively*" (s4-1), "*As for Taro, [his] limbs are thick and warm, respectively*" (s4-2), and "*We meet with Taro and talk* [*with him*], *respectively*" (s4-3). Right: three types of sentences with *tokidoki*: e.g., "*Kenta says that Hanako sometimes ran*" (t4-1), "*Akiko and* [*her*] *teacher say that it was sometimes bright*" (t4-2), and "*Taro says with Kenta that it was sometimes bright*" (t4-3). **(B)** There were six types of Artificial sentences with four words, but only two of these are shown here. For the description of other four sentence types (k4-2, k4-3, h4-2, and h4-3), see the "Stimuli" section. Left: artificial cross-serial dependencies (pairing relations between NPs and Preds). Right: artificial nested dependencies. In these examples, pseudowords ("*koregore*" and "*hokiboki*") artificially forced dependencies without conforming to Merge-generable structures.

virtually ignoring strong generation; it is much easier and more straightforward to deal with weak generation than strong generation, because you can literally *see* and readily construct the word-string stimuli for online experiments, while abstract hierarchical structures associated with the strings await in-depth theoretical investigations. Further, the research trend toward weak generation is boosted by a well-known result from formal language theory/automata theory, namely that the weak generative capacity of human language lies somewhere *above* the context-free phrase-structure grammar in the so-called "Chomsky Hierarchy" (Chomsky, 1959, 1963; Joshi, 1985).

The formal properties that have been highlighted and widely discussed in the literature are nested dependencies and cross-serial dependencies. Briefly put, nested dependencies are dependencies that hold between $x_i$ and $y_i$ (i.e., $x$ and $y$ with the same subscript) in the configuration $x_1x_2 \ldots x_{n-1}x_n \ldots y_ny_{n-1} \ldots y_2y_1$, forming a "nested" dependency structure, while cross-serial dependencies are dependencies holding between $x_i$ and $y_i$ in the configuration $x_1x_2 \ldots x_n \ldots y_1y_2 \ldots y_n$, forming a "crossing" dependency schema. And it has been observed that human language exhibits nested dependencies in a great number of instances, while it also shows, *in very limited contexts*, cross-serial dependencies. Based on this difference, it has been argued that the generative power of human language is beyond the bounds of finite-state grammar and is beyond the scope of context-free phrase-structure grammar, but perhaps stays, in terms of its weak generation, within the bounds of a certain class of context-sensitive phrase-structure grammar (Joshi, 1985). This claim makes sense only insofar as we restrict our attention to weak generation, but recall that, as we pointed out above, the nature of human language has to do with strong generation – the generation of structural descriptions of linguistic expressions. If this is true, then the whole discussion about weak generative capacities of various generative systems (grammars) may in fact be beside the point, as far as the empirical inquiry into the nature of human language is concerned. Questions of real empirical interest arise only when strong generation is at stake, or more importantly, the problem of "explanatory adequacy" (see above) is in focus, a matter that goes beyond even strong generation (Chomsky, 1963, 1965).

In fact, if we shift our attention from dependencies defined on terminal strings to how abstract hierarchical structures behind them are formed by linguistic computations, the well-known fact mentioned in the preceding paragraph concerning mysterious distribution of the two types of dependencies in human language can be rightly addressed. Consider, for example, the subject-predicate pairing in languages such as Japanese, as in the upper row in sentence (2) below, resulting from the "SOV" (Subject-Object-Verb/Predicate) word order (see the topmost right panel of **Figure 1A** for a real stimulus of nested configurations).

(2) [*Taro-ga*$_1$ [*Hanako-ga*$_2$ [*Ziro-ga*$_3$ *odotta*$_3$*-to*] *hanasita*$_2$*-to*] *omotteiru*$_1$]

[*Taro*-NOM [*Hanako*-NOM [*Ziro*-NOM *danced-that*] *said-that*] *thinks*] (NOM, a nominative case marker)

"*Taro*$_1$ *thinks*$_1$ *that Hanako*$_2$ *said*$_2$ *that Ziro*$_3$ *danced*$_3$"

In this structure, which is a typical sentence embedding configuration in Japanese, the only possible linking pattern is to associate a subject with its corresponding predicate in the manner indicated by the subscript numbers (the same number for each subject-predicate pair), forming nested dependencies generated by iterative applications of Merge. The other linking patterns, including cross-serial dependencies, are simply impossible. For example, sentence (2) can never mean that *Ziro thinks that Hanako said that Taro danced*. Even though this interpretation is plausible either semantically or pragmatically, it is just not a possible interpretation provided by the grammar of Japanese. By contrast, the nested dependencies as exemplified by sentence (2) are readily – and widely – available in other human languages as well.

On the other hand, cross-serial dependency, which is generally argued to be one of the characteristic properties that require more powerful *context-sensitivity*, is only available in very limited contexts, as has been widely acknowledged in the linguistic literature (see above). One representative case is the "respectively" reading of coordination (Bar-Hillel and Shamir, 1960). Consider the following example from Japanese.

(3) [[*Taro*$_1$*-to Hanako*$_2$*-to Ziro*$_3$]*-ga* (*sorezore*) [*odori*$_1$, *hanasi*$_2$, *omotteiru*$_3$]]

[[*Taro and Hanako and Ziro*]-NOM (*respectively*) [*dancing*, *saying*, *thinking*]]

"*Taro*$_1$, *Hanako*$_2$, *and Ziro*$_3$ *are dancing*$_1$, *saying*$_2$, *and thinking*$_3$, *respectively*"

The subject-predicate pairings in the Japanese sentence (3) (or its English counterpart for that matter) can be seen as exemplars of cross-serial dependencies (see the topmost left panel of **Figure 1A**). If the adverb *sorezore* "respectively" is absent, the so-called "group reading" is also possible, where the interpretation is such that *the group of people consisting of Taro, Hanako, and Ziro are collectively dancing, saying, and thinking*. However, other dependency patterns are impossible to obtain here. Thus, the specific question that should be addressed based on these facts about linking patterns exemplified in sentence (2) and (3) is as follows. Why is it that in a configuration such as sentence (2), only nested dependencies are allowed, whereas in sentence (3), cross-serial dependencies as well as group reading are allowed, with nested dependencies being mysteriously excluded? Note incidentally that context-sensitive phrase-structure grammar easily generates all kinds of dependencies in these cases, including non-existent cross-serial dependency for sentence (2), and also non-existent nested dependency for sentence (3). Thus, it fails to distinguish "linguistically possible" dependencies from "linguistically impossible" ones. As we will discuss in detail later on in the Discussion, the problem just mentioned can be appropriately addressed and naturally resolved only insofar as abstract structures generated by Merge are seriously taken into account.

It is simply impossible to tackle the problem just mentioned if we only look at terminal strings, because the examples (2) and (3) represent the same sequential patterns, with three NPs on the left and three Vs (or Preds) on the right (NP NP NP . . . V V V; see the Stimuli section for relevant discussion). However, if we turn our attention to the *structures* of these sentences, a clear picture emerges. To see this, let us consider first the availability of the nested dependencies, which is available in a sentence embedding structure such as that of sentence (2) but never possible in a coordinate structure such as that of sentence (3). We argue that the nested dependencies between NPs and Vs in sentence (2) are straightforwardly obtained as a consequence of iterative applications of Merge, as it combines an NP and a V, going on to embed a sentence within another sentence, as illustrated roughly in (4). Note that we abstract away from all the technical details of clausal architecture that are not directly relevant for our present discussion. In particular, in order to avoid unnecessary complications in illustration, we refrain from depicting the "functional" portions of a clause structure. Those "functional heads" such as T(ense) and C(omplementizer) are – if they are indeed syntactic functional heads in Japanese, not an innocent assumption – undoubtedly incorporated into the central clausal structure by Merge. And to the extent that they are incorporated by Merge, their existence does not affect our discussion. Thus, for simplicity, we omitted them in our exposition below. Also, for the gloss and translation, see (2).

(4) a. Merge(*Ziro-ga*$_1$, *odotta*$_1$-(*to*))

= {*Ziro-ga*$_1$, *odotta*$_1$-(*to*)}

– A verb phrase $V(P)_1$ and $NP_1$ are combined by Merge, forming a sentence $S_1$

b. Merge({*Ziro-ga*$_1$, *odotta*$_1$-(*to*)}, *hanasita*$_2$-(*to*))

= {{*Ziro-ga*$_1$, *odotta*$_1$-(*to*)}, *hanasita*$_2$-(*to*)}

– $S_1$ and $V_2$ are combined by Merge, forming a $V(P)_2$

c. Merge(*Hanako-ga*$_2$, {{*Ziro-ga*$_1$, *odotta*$_1$-(*to*)}, *hanasita*$_2$-(*to*)})

= {*Hanako-ga*$_2$, {{*Ziro-ga*$_1$, *odotta*$_1$-(*to*)}, *hanasita*$_2$-(*to*)}}

– $V(P)_2$ and $NP_2$ are combined by Merge, forming an $S_2$

d. Merge({*Hanako-ga*$_2$, {{*Ziro-ga*$_1$, *odotta*$_1$-(*to*)}, *hanasita*$_2$-(*to*)}}, *omotteiru*$_3$)

= {{*Hanako-ga*$_2$, {{*Ziro-ga*$_1$, *odotta*$_1$-(*to*)}, *hanasita*$_2$-(*to*)}}, *omotteiru*$_3$}

– $S_2$ and $V_3$ are combined by Merge, forming a $V(P)_3$

e. Merge(*Taro-ga*$_3$, {{*Hanako-ga*$_2$, {{*Ziro-ga*$_1$, *odotta*$_1$-(*to*)}, *hanasita*$_2$-(*to*)}}, *omotteiru*$_3$})

= {*Taro-ga*$_3$, {{*Hanako-ga*$_2$, {{*Ziro-ga*$_1$, *odotta*$_1$-(*to*)}, *hanasita*$_2$-(*to*)}}, *omotteiru*$_3$}}

– $V(P)_3$ and $NP_3$ are combined by Merge, forming an $S_3$.

Since, this process is just a normal mode of applying Merge *recursively* (phase-by-phase, "phase" being a technical notion indicating a restrictive domain for rule applications), we say that such nested dependencies are totally Merge-generable. It therefore comes as no surprise that nested dependencies as exemplified in a sentence embedding structure such as that of sentence (2) are widely available in human language. Notice incidentally that the structures for the other linking patterns pointed out above in connection with example (2) cannot be generated by Merge in the way designated in (4), and thus are non-Merge-generable, which accounts for the unavailability of their associated interpretations.

Let us next consider the possibility of cross-serial dependencies between NPs and Vs in sentence (3). The crucial difference between sentences (2) and (3) in structure is that in the former sentence, neither the sequence of the NPs (*Taro*, *Hanako*, and *Ziro*) nor that of the Vs (*odotta*, *hanasita*, and *omotteiru*) form a *constituent* – a word or a group of words that function(s) as a single syntactic unit (i.e., a set) within a hierarchical structure, whereas in the latter sentence, the sequence of conjoined NPs or that of Vs each forms a constituent. A step-by-step derivation for sentence (3) is illustrated in (5) [see (3) for the gloss and translation].

(5) a. Merge(*Hanako-to*$_2$, *Ziro*$_3$-(*ga*))

= {*Hanako-to*$_2$, *Ziro*$_3$-(*ga*)}

b. Merge(*Taro-to*$_1$, {*Hanako*$_2$-(*to*), *Ziro*$_3$-(*ga*)})

= {*Taro-to*$_1$, {*Hanako*$_2$-(*to*), *Ziro*$_3$-(*ga*)}}

– $NP_1$, $NP_2$, and $NP_3$ are combined by iterative Merge.

c. Merge(*hanasi*$_2$, *omotteiru*$_3$)

= {*hanasi*$_2$, *omotteiru*$_3$}

d. Merge(*odori*$_1$, {*hanasi*$_2$, *omotteiru*$_3$})

= {*odori*$_1$, {*hanasi*$_2$, *omotteiru*$_3$}}

– $V_1$, $V_2$, and $V_3$ are combined by iterative Merge.

e. Merge({*Taro-to*$_1$, {*Hanako*$_2$-(*to*), *Ziro*$_3$-(*ga*)}}, {*odori*$_1$, {*hanasi*$_2$, *omotteiru*$_3$}})

= {{*Taro-to*$_1$, {*Hanako*$_2$-(*to*), *Ziro*$_3$-(*ga*)}}, {*odori*$_1$, {*hanasi*$_2$, *omotteiru*$_3$}}}

As shown in (5), the sequence of conjoined NPs and that of Vs in sentence (3) each forms a constituent (a set). This provides the grammatical basis for the group reading, which requires matching of the sequence of NPs and that of Vs as a whole. Thus, such a reading becomes readily available. In addition to this natural group reading, the cross-serial dependencies are also possible here. Merge forms the two constituents – the conjoined NPs and complex of Vs – and the interpretive mechanisms at the conceptual/thought interface apply in accord with an "isomorphy" condition which incorporates an insight of the "copying transformation" of Chomsky (1957) that requires parallel (isomorphic) hierarchical structures for the two constituents at hand, yielding the cross-serial interpretation. Thus, details of interpretive processes aside, it is clear that Merge sets out a necessary structural basis for cross-serial dependencies.

Needless to say, nested dependencies and other linking patterns are impossible in sentence (3), simply because Merge, as it applies to generate the structure of sentence (3), does *not* yield the structural basis for such dependencies and there is no other way to obtain these linking patterns. By contrast, in sentence-embedding constructions like sentence (2), neither the sequence of NPs nor that of Vs forms a constituent, and thus the group reading is impossible. Nor is the cross-serial dependency allowed in sentence (2), since there is no structural basis, i.e., constituency of the relevant elements, for such a dependency.

Thus, the generalization we can draw from these facts is that cross-serial dependencies in human language become possible only when the relevant terminal elements form a constituent. As we demonstrated above, Merge sets out the necessary structural condition, forming the relevant constituents in the coordinate structures such as that of sentence (3). However, Merge does *not* in and of itself provide a direct structural basis for cross-serial dependencies. This is probably why the interpretation requires a special device such as "*sorezore*" or "*respectively*" that effectively forces this interpretation, rather than the more natural (and apparently default) group reading, which is available only by virtue of Merge.

Summing up the discussion in this section, we have re-iterated the fundamental discovery of modern theoretical linguistics according to which the nature of human language critically depends on its mechanisms, particularly Merge – the basic and fundamental operation of (unordered) set-formation in syntax. Correspondingly, well-known results in formal language theory concerning the generation of dependencies defined over terminal strings (e.g., context-free vs. context-sensitive phrase-structure grammars) and the related discussion should be reconsidered and re-evaluated from the new theoretical point of view based on Merge. We have looked at two typical examples from Japanese, and we have suggested that these simple examples demonstrate important points about the nature of formal dependencies in human language. These points strongly suggest that dependencies are possible in human language only to the extent that they result from abstract structures generated by Merge, leading to the conclusion that it is Merge-generability that determines the availability of various dependencies in human language [Hypothesis (1)]. We will thus argue that in human language, the apparent generation of various "types" of dependency defined on terminal strings is rather illusory, emerging only as an epiphenomenon of linguistic computation.

# MATERIALS AND METHODS

## Participants

We recruited 25 native speakers of Japanese. They were undergraduate students who had not majored in linguistics or language sciences. Two participants were dropped from our analyses due to their health conditions. We also dropped four participants, who showed larger head movements (see below) in ≥75% of runs under one or more of the four conditions [Natural (4W), Natural (6W), Artificial (4W), and Artificial (6W)]. We excluded three more participants, whose accuracy on one or more sentence types (see **Figure 1**) was ≤60% (the chance level was at most 34% as shown below). The remaining 16 participants [six females; mean ± standard deviation (SD) age: 20.1 ± 1.1 years] showed right-handedness (laterality quotients: 81 ± 10) as determined by the Edinburgh inventory (Oldfield, 1971). None had a history of neurological or psychiatric diseases. Prior to participation in the study, written informed consent was obtained from each participant after the nature and possible consequences of the study were explained. Approval for the experiments was obtained from the Institutional Review Board of The University of Tokyo, Komaba Campus.

## Stimuli

As visual stimuli, we first prepared sentences under the Natural conditions, which were all grammatical and meaningful in Japanese. Under the Natural (4W) condition, there were 30 sentences in each of *six* sentence types (s4-1, s4-2, s4-3, t4-1, t4-2, and t4-3; see **Figure 1A**). Every sentence with four words (excluding an adverb) had two noun phrases (NPs, subjects), an adverb, and two predicates (Preds) in the form of NP-NP-Adverb-Pred-Pred. Under the Natural (6W) condition, there were 30 sentences in each of six sentence types (s6-1, s6-2, s6-3, t6-1, t6-2, and t6-3; see **Supplementary Figure 1**). Every sentence with six words (excluding an adverb) was in the form of NP-NP-NP-Adverb-Pred-Pred-Pred. Since Japanese lacks overt, semantics-free subject-predicate formal agreement, we chose another phenomenon in the language, namely, the subject-predicate linking, which in fact has been often utilized in the formal language/automata theory literature, and which, like most other linguistic dependencies, may not be immune from semantic, pragmatic, and other factors. We carefully examined the relevant phenomena to see if the nature of linking patterns is actually independent from those factors [*cf*. our discussion about example (2) above], and, as we will present below, we paid close attention to controlling non-syntactic factors as much as possible in our experiments.

For the nouns, we used common names of persons (e.g., "*Taro*"), (singular) animate nouns [e.g., "*sensei*" (teacher)], their plural forms [e.g., "*sensei-gata*" (teachers)], and part(s) of body [e.g., "*teasi*" (limbs)]. For the predicates, we used transitive verbs [e.g., "*kangae-ru*" (think)] (all of these select a clausal complement), intransitive verbs [e.g., "*odor-u*" (dance)], and adjectives [e.g., "*akaru-i*" (bright)]. Adjectives in Japanese act as Preds without copula verbs, and they have their own present and past forms {e.g., "*akaru-i*" [(is) bright]; "*akaru-k-atta*" [(was) bright]}. To avoid the undesirable possibility of default group-reading (which collectively relates all NPs to all Preds as a group) for the s4-1 (see **Figure 1A**) and s6-1 types (see **Supplementary Figure 1**), we selected at least two verbs indicating actions that cannot be collectively performed at the same time [e.g., "*hasiri*" (running) and "*suwatteiru*" (sitting)]. For these types, we also put a last predicate in progressive form, which was the case for all sentences with *tokidoki* (see below).

The adverbs under the Natural conditions were either "*sorezore*" (*respectively*; denoted here as "s" for such types) or "*tokidoki*" (*sometimes*; denoted here as "t" for such types), which were presented in *hiragana* (the basic Japanese syllabary that represents each mora in the Japanese language). While nested dependencies are created in sentence embedding constructions with or without an adverb, cross-serial dependencies are created only with the help of *sorezore* in coordinate configurations, in a way similar to English sentences with *respectively*: e.g., *Taro and Hanako sang and danced, respectively*. Note that the Merge-generable syntactic structures are naturally generated under these conditions.

We used three types of grammatical particles, which represent canonical case markings and syntactic information in Japanese: the nominative case marker *-ga* (which is realized as *-wa* when the subject represents the topic of the sentence; thus, we used *-wa* for s6-2, t6-1, and t6-2), a postposition *-to* (*with/and*), and a complementizer *-to* (*that*). In the sentences with *tokidoki*, the complementizer was placed at the end of the first Pred under 4W (**Figure 1A**), and of the first and second Preds under 6W. Each subject-predicate pair could not be made correctly, if rather rare and non-canonical usages of *-ga* – such as object marking and an external possessor – were employed. To correctly make each subject-predicate pair, the participants had to use *-ga* as a canonical nominative subject case marker. Since a Pred in past-tense form with a complementizer *-to* cannot be interpreted as a conditional clause like *-suru-to* containing a Pred in a present-tense form, we used, in an attempt to avoid the unwanted conditional clause interpretation, a past-tense form for all the Preds except for the last one in the sentences with *tokidoki*. In the sentences with *sorezore*, all the Preds except for the last one took an adverbial form, forming conjunctives for the Preds. In order to prevent participants from anticipating certain dependencies from particle patterns alone, we used NPs with the same particle patterns in two sentence types (with either *sorezore* or *tokidoki*) under 4W (e.g., an NP-*to*-NP-*ga*-Adverb-Pred-Pred pattern is used in s4-1 and t4-2). Due to syntactic characteristics of Japanese, this procedure was not possible under 6W.

Under the Artificial conditions, we used the same set of phrases as with the Natural conditions except that the adverbs *sorezore* and *tokidoki* were replaced with pseudo-adverbs, or phonotactically legal pseudowords, *koregore* (denoted here as "k") and *hokiboki* (denoted here as "h"). There were 30 different sentences for each of six types of Artificial sentences (for two representative types, see **Figure 1B**; for six types with six words, see **Supplementary Figure 2**). Using six examples for each condition, we instructed the participants to pay attention to the fact that each pseudo-adverb determined correspondence among the other four or six words (see the **Appendix** of **Supplementary Material**). As shown in **Figure 1B**, nested or cross-serial dependency was enforced depending on which of these pseudo-adverbs was used. More specifically, the pseudo-adverb *koregore* artificially imposed *cross-serial* dependency (see k4-1 which is made from t4-2), as shown in example (6) below, in which brackets and indices denote artificial reading. This linking pattern is impossible as a real Japanese sentence. The pseudo-adverb *hokiboki*, on the other hand, artificially imposed *nested* dependency (see h4-1 which is made from s4-2), as illustrated by example (7) below. Again, the linking pattern is prohibited as an actual Japanese sentence. Both examples (6) and (7) thus *deviate* from Merge-generable structures.

(6) [[*Taro-ga*$_i$ *inu-ga*$_j$ *Hanako-ga*$_k$] (*koregore*) [*aruita-to*$_i$ *kizuita-to*$_j$ *hanasiteiru*$_k$]]

[[*Taro*-NOM *dog*-NOM *Hanako*-NOM] (–) [*walked-that noticed-that says*]]

"*Taro*$_i$ *walks*$_i$, *the dog*$_j$ *notices*$_j$, *and Hanako*$_k$ *says*$_k$"

(7) [*Taro-to*$_i$ [*inu-to*$_j$ [*Hanako-ga*$_k$ (*hokiboki*) *kizuki*$_k$,] *aruki*$_j$,] *hanasiteiru*$_i$]

[*Taro and* [*dog and* [*Hanako*-NOM (–) *noticing*,] *walking*,] *saying*]

"*Taro*$_i$ *says*$_i$, *the dog*$_j$ *walks*$_j$, *and Hanako*$_k$ *notices*$_k$"

Here, the same indexed letters indicate each NP-Pred pairing. These examples became thus ungrammatical, due to the illegitimate linking patterns imposed by the artificial adverbs.

Under the Artificial (4W) condition, we prepared *six* sentence types (k4-1, k4-2, k4-3, h4-1, h4-2, and h4-3, which were made from *four* sentence types under the Natural (4W) condition: [k4-1 and h4-2 from t4-2], [h4-1 and k4-2 from s4-2], [k4-3 from s4-3], and [h4-3 from t4-3]. Note that the original sentences with cross-serial and nested dependencies (i.e., s4-1 and t4-1, respectively) were not used under the Artificial (4W) condition, because they were conflicting with each other. Thus, the Artificial condition included two types of cross-serial and nested dependencies for the task, as well as four types derived from the original sentences (i.e., s4-2, s4-3, t4-2, and t4-3). The examples (6) and (7), in which nested and cross-serial dependencies were switched with each other, are presented above for the purpose of explanation only. The same procedures were used for the Artificial (6W) condition as well (see **Supplementary Figure 2**).

The resultant artificial NP-Pred pairings were all meaningful in terms of selectional restrictions on the words we used. We assessed the plausibility of the NP-Pred pairs (typical 20 pairs each for those used under the Natural conditions alone, Artificial conditions alone, or both), by asking their likelihood (Likert or five-point scale) to participants ($n$ = 9), and the likelihood was not significantly different from the highest point ("definitely so") under both Natural and Artificial conditions (one sample $t$-test, corrected $p > 0.05$). The NP-Pred pairs were hence equally plausible; non-syntactic factors such as semantic and pragmatic knowledge, as well as frequencies of constructions, were strictly controlled between the conditions. Merge-generable and non-Merge-generable dependencies were thus expected to be realized under the Natural and Artificial conditions, respectively. Accordingly, we tested the participants first under the Natural conditions, and then under the Artificial conditions to compare *Merge-generability* (Natural vs. Artificial).

Each sentence was serially presented in three groups of NPs, adverb, and Preds. Each of these phrases was shown with two to six yellow characters in *hiragana* and *kanji* (the adopted logographic Chinese characters used in written Japanese) for

2.5 s (4W) or 3.5 s (6W) with an interval of 0.2 s after each group. The participants were instructed to read each sentence including particles like *-wa*, *-ga*, or *-to*. After the presentation of the sentence, a "question-set" was presented, which contained one of the Preds in its upper row, as well as three (4W) or four (6W) NPs in its lower row. The NPs in a question-set were chosen from those contained in the sentence, together with a conjunction of two NPs with *-to*, or an NP which was *not* contained in the sentence; these possibilities were informed to the participants. In the question-set, the NPs were always presented without any particle, and the Pred in the present form in order to avoid the use of particles or verb forms as cues. Question-sets were presented for 2.0 s (4W) or 3.0 s (6W) with a post-trial interval of 1.9 s; each trial lasted for 12.0 s (4W) or 16.0 s (6W).

The stimuli were presented against a dark background at the center of an eyeglass-like MRI-compatible display (resolution, 800 × 600; VisuaStim XGA, Resonance Technology Inc., Northridge, CA, United States), and the participants wore earplugs. For fixation, a red cross was always displayed at the center of the display, and the participants were instructed to keep their eyes on this position. The stimulus presentation and the collection of behavioral data [accuracy and reaction times (RTs)] were controlled using Presentation software (Neurobehavioral Systems, Albany, CA, United States).

## Tasks

Under both Natural and Artificial conditions, we used a task of NP-Pred matching, in which the participants were instructed to note *all* of the two (4W) or three (6W) NP-Pred pairs based on dependencies. NP-Pred matching under the *Natural* conditions imposed building syntactic structures of a given sentence (see **Figure 1**), rather than "word-to-word correspondence," and thus required syntactic judgment at the sentence level; the task cannot be solved correctly by semantic or pragmatic judgment (see above). The participants then chose one of the three (4W) or four (6W) NPs corresponding to the Pred on the question-set (see above), by pressing a button on a handheld controller (see the **Appendix** of **Supplementary Material**). After these instructions were given to the participants, the participants were trained on each condition (4W or 6W) outside the scanner, until they confidently performed the task for two consecutive runs (at least four correct trials out of six trials per run). The condition of 6W was always tested after that of 4W, with a short break. During the MR scanning, no feedback on each trial's performance was given to any participant.

The sentences of six types were presented randomly in the same frequency. A single run of MR scans contained 19 (4W) or 13 (6W) trials of either task. For every participant, the task with eight runs for 4W and nine for 6W under the Natural conditions were first conducted, and then the task under the Artificial conditions were tested in another day. By separating the task trials under the Natural and Artificial conditions in this order, we imposed the participants to read sentences in a natural way while performing the task under the Natural conditions. On the other hand, the participants might perform the task with a strategy like puzzle-solving under the Artificial conditions.

## MRI Data Acquisition

For the MRI data acquisition, a participant was in a supine position, and his or her head was immobilized inside the radio-frequency coil. The MRI scans were conducted on a 3.0 T MRI system equipped with a bird-cage head coil (GE Signa HDxt 3.0T; GE Healthcare, Milwaukee, WI, United States). During the fMRI session, we scanned 30 axial 3-mm thick slices with a 0.5-mm gap, covering the volume range of –38.5 to 66 mm from the anterior to posterior commissure (AC-PC) line in the vertical direction, using a gradient-echo echo-planar imaging (EPI) sequence [repetition time (TR) = 2 s, echo time (TE) = 30 ms, flip angle (FA) = 90°, field of view (FOV) = 192 × 192 mm$^2$, resolution = 3 × 3 mm$^2$). In a single scan, we obtained 114 [Natural (4W) and Artificial (4W)] or 104 [Natural (6W) and Artificial (6W)] volumes, in which the first six or eight images (the first dummy trial in each scan), for the rise of the MR signals were discarded. High-resolution T1-weighted images of the whole brain (192 axial slices, 1.0 × 1.0 × 1.0 mm$^3$) were acquired from all participants with a three-dimensional fast spoiled gradient recalled acquisition in the steady state (3D FSPGR) sequence (TR = 8.4 ms, TE = 2.6 ms, FA = 25°, FOV = 256 × 256 mm$^2$). These structural images were used for normalizing the fMRI data.

## fMRI Data Analyses

The fMRI data were analyzed by using SPM12 statistical parametric mapping software (Wellcome Trust Centre for Neuroimaging)[1] (Friston et al., 1995) implemented on MATLAB software (MathWorks, Natick, MA, United States). We confirmed that all available fMRI data were free from large head movements, with a translation of <3 mm in the three directions and with a rotation of <2° around the three axes. The acquisition timing of each slice was corrected using the middle slice (the 15th slice chronologically) as a reference for the fMRI data. The time-series data in multiple runs were then realigned to the first volume in all runs, and resliced using seventh-degree B-spline interpolation, so that each voxel of each functional image matched that of the first volume.

The T1-weighted structural image of each participant was aligned to the AC-PC line, and coregistered to the mean functional image generated during the realignment of the fMRI data. Each T1-weighted image was bias-corrected with light regularization, and segmented to the gray matter, white matter, cerebrospinal fluid, bone, other soft tissues, and air by using default tissue probability maps and a standard tool in the SPM12 that uses an affine regularization to warp images to the International Consortium for Brain Mapping East Asian brain template (Ashburner and Friston, 2005). The realigned functional images were also spatially normalized to the standard brain space as defined by the Montreal Neurological Institute (MNI), which converted voxel sizes to 3 × 3 × 3 mm$^3$ and smoothed images with an isotropic Gaussian kernel of 9-mm full-width at half maximum.

[1] https://www.fil.ion.ucl.ac.uk/spm/

In a first-level analysis (i.e., the fixed-effects analysis) for each participant, hemodynamic responses induced by the correct-response trials for each session were modeled with a boxcar function with a duration of 7.9 s (4W) or 10.9 s (6W) from the onset of each visual stimulus, i.e., the length of the time for the five/seven words, as well as with a duration of 2 s (4W) or 3 s (6W) from the onset of a question. The boxcar function was then convolved with a hemodynamic response function, and low-frequency noises were removed by high-pass filtering at 1/128 Hz. To minimize the effects of head movement, the six realignment parameters obtained from preprocessing were included as a nuisance factor in a general linear model. The images of the six conditions were then generated in the general linear model for each participant and used for our intersubject comparison in a second-level analysis (i.e., the random-effects analysis).

In the second-level analysis, we performed a repeated measures analysis of variance (rANOVA) with a $t$-test, the results of which were thresholded at uncorrected $p < 0.001$ for the voxel level, and at corrected $p < 0.05$ for the cluster level, with topological false discovery rate (FDR) correction across the whole brain (Chumbley and Friston, 2009). For the anatomical identification of activated regions, we used the Anatomical Automatic Labeling method[2] (Tzourio-Mazoyer et al., 2002) and the labeled data as provided by Neuromorphometrics Inc.[3], under academic subscription.

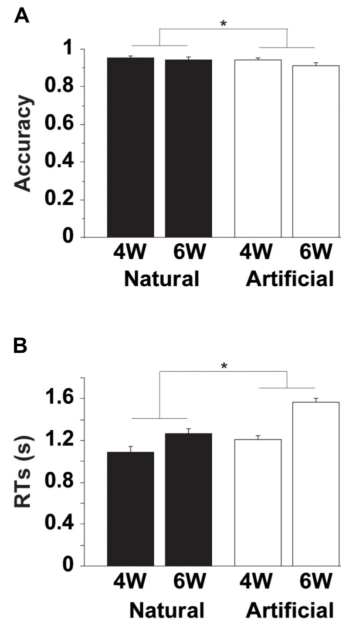


**FIGURE 2 |** Behavioral data. **(A)** Accuracy for an NP-Pred matching task. Filled and open bars represent Natural and Artificial conditions, respectively, each with either 4W (two NPs and two predicates) or 6W (three NPs and three predicates) conditions. Error bars denote the standard error of the mean (SEM) for the participants. *Corrected $p < 0.01$. **(B)** Reaction times (RTs) from the onset of a question-set for judgment. Only correct trials were included for RTs.

# RESULTS

## Behavioral Data

The accuracy and RTs are shown in **Figure 2**. For the accuracy, an rANOVA with two factors [Merge-generability (Natural, Artificial) × word numbers (4W, 6W)] showed that both main effects of Merge-generability [$F(1, 15) = 10$, $p = 0.006$] and word numbers [$F(1, 15) = 6.4$, $p = 0.02$] were significant, without the interaction between them [$F(1, 15) = 1.7$, $p = 0.2$] (**Figure 2A**). The main effect of Merge-generability was due to lower accuracy under the Artificial conditions, while the main effect of word numbers may be simply caused by processing loads (see **Supplementary Figures 1, 2**).

Regarding RTs, there were significant main effects of Merge-generability [$F(1, 15) = 26$, $p = 0.001$] and word numbers [$F(1, 15) = 119$, $p < 0.0001$], as well as the significant interaction between them [$F(1, 15) = 18$, $p < 0.001$] (**Figure 2B**). In addition to consistent results with the accuracy, the significant interaction suggests that general cognitive loads under the Artificial conditions became more demanding for the increased number of words.

## Modulation of the Cortical Activation by Natural and Artificial Conditions

As shown in **Figure 3A**, the most prominent activation under the Natural (4W) condition was mostly localized in the left frontal cortex, spanning most of the L. LPMC, L. F3op/F3t, and the orbital part of the inferior frontal gyrus (L. F3O), together with the left middle temporal gyrus (L. MTG). In addition to these language-related regions, additional activation was observed in the right hemisphere, such as the right LPMC (R. LPMC) and parietal cortex, together with medial regions including the pre-supplementary motor area (pre-SMA), anterior cingulate cortex (ACC), cuneus, caudate nucleus, and tegmentum/tectum. Under the Artificial (4W) condition, in contrast, the left frontal activation was greatly reduced to the dorsal portion (**Figure 3B**), and the left temporal activation was also decreased. The other right and medial regions were mostly consistent with those under the Natural (4W) condition. Regarding the 6W conditions, the overall activation patterns were similar to those under the 4W conditions, and left frontal activations were not enhanced as expected. Therefore, we combined the 4W and 6W conditions for subsequent analyses.

We then examined the [Natural (4W and 6W) – Artificial (4W and 6W)] contrast (**Figure 3C**), and found clearly localized activation in the ventral portion of the left frontal cortex, including the L. F3op, L. F3t, and L. F3O, as well as the L. MTG and the left angular gyrus (L. AG) (**Table 1**). On the other hand, the [Artificial (4W and 6W) – Natural (4W and 6W)] contrast resulted in a completely different pattern of activation (**Figure 3D**). As mentioned above, the left frontal activation was greatly reduced to the dorsal portion of the L. LPMC and L. F3op. Moreover, activated regions were more wide-spread in such regions as the R. LPMC, pre-SMA/ACC, left supramarginal gyrus (L. SMG), bilateral inferior parietal lobule (IPL), bilateral

[2]http://www.gin.cnrs.fr/en/tools/aal/
[3]http://www.neuromorphometrics.com/

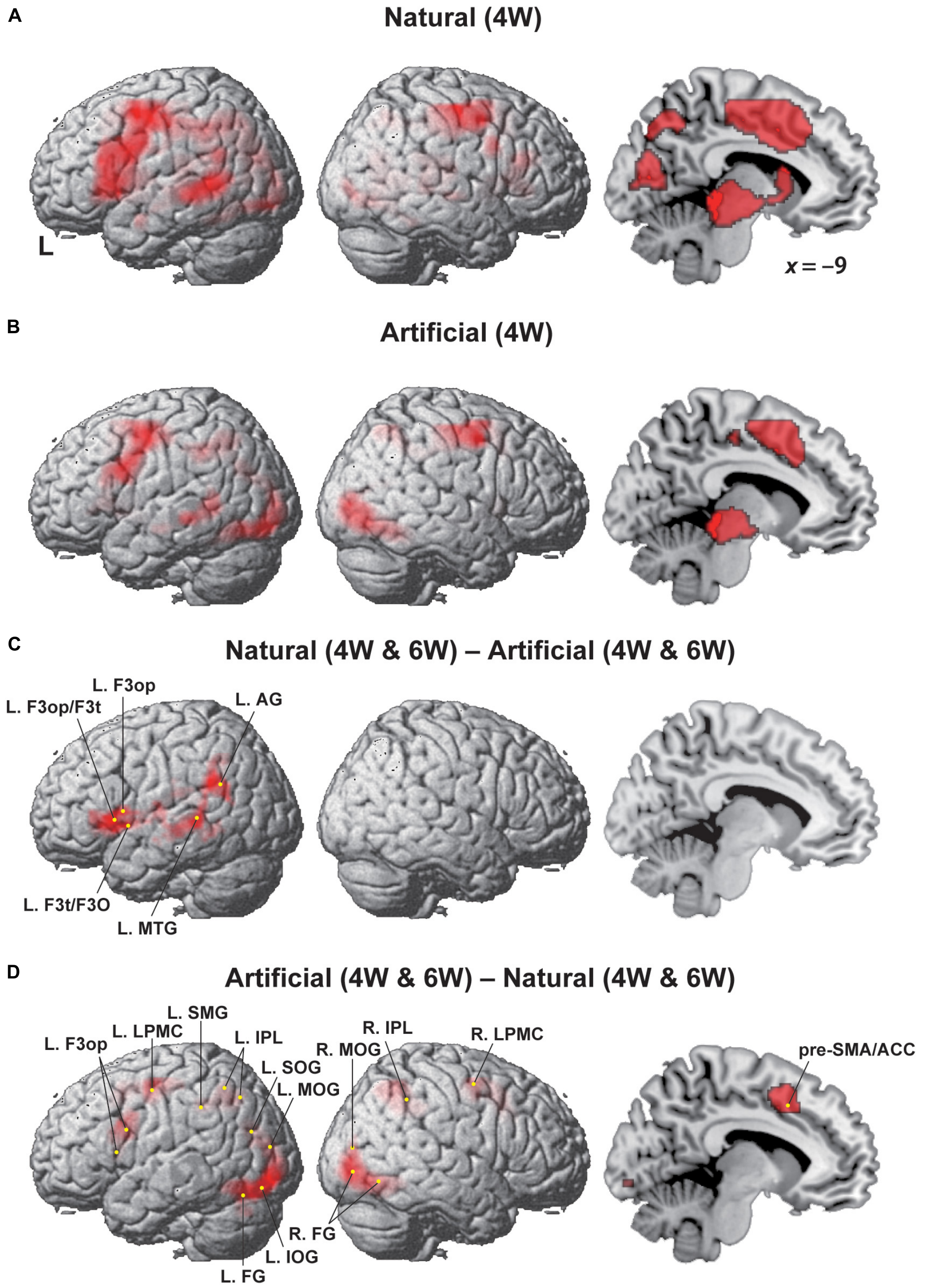


**FIGURE 3 |** Modulation of the cortical activation by Natural and Artificial conditions. Regions identified by **(A)** Natural (4W), **(B)** Artificial (4W), **(C)** [Natural (4W and 6W) – Artificial (4W and 6W)], and **(D)** [Artificial (4W and 6W) – Natural (4W and 6W)]. Exclusive masks of [– Artificial (i.e., negative activation)] and [– Natural] (uncorrected $p < 0.001$) were applied to the comparisons of **C** and **D**, respectively. Activations were projected onto the left (L) and right lateral surfaces, and medial section ($x = -9$) of a standard brain (FDR-corrected $p < 0.05$). Each yellow dot indicates the local maxima of activated regions. See **Table 1** for the stereotactic coordinates of activation foci.

middle occipital gyrus (MOG), left superior/inferior occipital gyrus (L. SOG/IOG), and bilateral fusiform gyrus (FG). The pre-SMA/ACC activation was much stronger under the Artificial (6W) condition than under the Natural (6W) condition, although this tendency was reversed under the Natural (4W) and Artificial (4W) conditions. These results indicate that the ventral portion of the grammar center was critically activated under the Natural conditions, providing clear evidence that the Natural (Merge-generable) and Artificial (non-Merge-generable) sentences were differentially processed in the brain.

**TABLE 1 |** Regions with enhanced activations under the Natural or Artificial condition.

| Brain regions | BA | Side | *x* | *y* | *z* | *Z* | Voxels |
|---|---|---|---|---|---|---|---|
| **Natural (4W and 6W) – Artificial (4W and 6W)** | | | | | | | |
| F3op | 44 | L | −60 | 11 | 8 | 4.9 | 653 |
| F3op/F3t | 44/45 | L | −54 | 14 | 5 | 4.8 | * |
| F3t/F3O | 45/47 | L | −42 | 8 | −1 | 4.7 | * |
| MTG | 21 | L | −66 | −34 | 2 | 4.6 | * |
| AG | 39 | L | −51 | −52 | 26 | 5.8 | * |
| **Artificial (4W and 6W) – Natural (4W and 6W)** | | | | | | | |
| LPMC | 6/8 | L | −33 | −7 | 47 | 4.9 | 785 |
| | | R | 21 | −7 | 53 | 4.6 | * |
| pre-SMA/ACC | 6/8/32 | M | −9 | 11 | 47 | 5.9 | * |
| | | M | 12 | 14 | 41 | 6.1 | * |
| | | M | 12 | 5 | 59 | 4.4 | * |
| LPMC | 6/8 | L | −54 | 8 | 35 | 4.3 | 165 |
| F3op | 44 | L | −45 | 8 | 23 | 5.7 | * |
| | | L | −33 | 14 | 8 | 3.9 | * |
| IPL | 7/40 | L | −27 | −55 | 50 | 4.6 | 176 |
| | | L | −18 | −67 | 47 | 4.1 | * |
| SMG | 40 | L | −36 | −40 | 41 | 4.1 | * |
| IPL | 7/40 | R | 27 | −52 | 44 | 7.2 | 274 |
| SOG | 7/19 | L | −27 | −73 | 26 | 5.3 | 592 |
| MOG | 18/19 | L | −27 | −82 | 14 | 4.9 | * |
| IOG | 18/19 | L | −39 | −79 | −13 | 7.2 | * |
| FG | 19 | L | −42 | −70 | −16 | 6.8 | * |
| MOG | 18/19 | R | 30 | −85 | 14 | 4.9 | 417 |
| FG | 19 | R | 30 | −85 | −4 | Inf | * |
| | | R | 39 | −67 | −10 | 6.2 | * |

*Stereotactic coordinates (x, y, z) in the MNI space (mm) are shown for each activation peak of Z values. The threshold was set at FDR-corrected p < 0.05 for the cluster level. BA, Brodmann's area; L, left; R, right; M, medial; F3op/F3t/F3O = opercular/triangular/orbital part of the inferior frontal gyrus; LPMC, lateral premotor cortex; pre-SMA, pre-supplementary motor area; ACC, anterior cingulate cortex; AG, angular gyrus; SMG, supramarginal gyrus; IPL, inferior parietal lobule; MTG, middle temporal gyrus; FG, fusiform gyrus; SOG/MOG/IOG, superior/middle/inferior occipital gyrus. The region with an asterisk is included within the same cluster shown one row above.*

# DISCUSSION

By employing a novel paradigm to manipulate Merge-generability (Natural or Artificial), we obtained the following three striking results. Firstly, the behavioral data clearly showed that the NP-Pred matching task became more demanding under the Artificial conditions than under the Natural conditions (**Figure 2**), reflecting cognitive loads that could be covaried with the increased number of words. Secondly, localized activation in the L. F3op, F3t, and F3O, as well as in the L. MTG and L. AG, was observed for the [Natural (4W and 6W) – Artificial (4W and 6W)] contrast (**Figure 3C**), indicating specialization of these left regions in syntactic processing. Any activation due to task difficulty was completely excluded from activations in these regions, because the Natural conditions were always easier than the Artificial ones (see **Figure 2**). And finally, the [Artificial (4W and 6W) – Natural (4W and 6W)] contrast resulted in the dorsal portion of the L. LPMC and L. F3op (**Figure 3D**), together with wide-spread regions required for general cognitive demands, such as visual attention (in the bilateral MOG and L. SOG/IOG), error detection (in the pre-SMA/ACC), and cognitive conflict (just as during a Stroop task) (Bush et al., 2000). These results indicate that Merge-generable sentences are processed in these specific regions in contrast to non-Merge-generable sentences, demonstrating that Merge is indeed a fundamental operation, which comes into play especially under the Natural conditions.

As explained in the Introduction, Merge is the fundamental local structure-building operation proposed by modern linguistics (Chomsky, 1995), which reflects a formal property of the competence system. Merge itself would be theoretically "costless," requiring no driving force for its application (Saito and Fukui, 1998; Chomsky, 2004; Fukui, 2011; Chomsky et al., 2019). In addition to Merge, an indispensable operation in any language-like symbolic system, the DoM also seems to play a role in accounting for enhanced activation under the Merge-generable Natural conditions (**Figure 3C**); note that the DoM remained at a minimum (one) for *artificially* forced dependencies without conforming to Merge-generable structures (see **Figure 1B**). As we noted in the Introduction, further experimental studies are required to clarify whether totally Merge-generable (e.g., nested) and partially Merge-generable (e.g., cross-serial) dependencies are analyzed differently in the brain, i.e., in terms of differential sub-regions and/or activation levels.

Neuroimaging studies have established that syntactic processing selectively activates the L. F3op/F3t and L. LPMC (Stromswold et al., 1996; Dapretto and Bookheimer, 1999;

Embick et al., 2000; Hashimoto and Sakai, 2002; Friederici et al., 2003; Musso et al., 2003), indicating that these regions have a critical role as grammar centers (Sakai, 2005). We also observed activations in the L. F3op/F3t and L. LPMC in our studies using sentences with non-canonical word orders, which contained filler-gap dependency and operator-variable relations in movement (created by the "Internal Merge") (Kinno et al., 2008; Ohta et al., 2017; Tanaka et al., 2017). Moreover, our magnetoencephalography studies revealed a significant increase in the responses in the L. IFG, which reflected predictive effects on a verb caused by a preceding object in a short sentence (Iijima et al., 2009; Inubushi et al., 2012; Iijima and Sakai, 2014). In the present study, we observed selective activation in the L. F3op, L. F3t, and L. F3O in the [Natural (4W and 6W) – Artificial (4W and 6W)] contrast, which is consistent with these previous findings. Our present findings provide further and significant experimental evidence to support the hypothesis that the concept of Merge-generability plays a critical role in the processes subserved by the grammar centers.

Compared with the ventral portion of the grammar centers (i.e., the L. F3op, L. F3t, and L. F3O), the dorsal portion (the L. LPMC, or the left dorsal prefrontal cortex) has been shown to be involved in more automatic or implicit aspects of syntactic processing (Hashimoto and Sakai, 2002), while the R. LPMC was supportively required for syntactic processing (Kinno et al., 2014) or for memorizing mere strings (requiring memory span) (Ohta et al., 2013b). Moreover, the L. LPMC activations were particularly enhanced for scrambled, i.e., object-initial sentences (Kinno et al., 2008), which were also confirmed by lesion studies (Kinno et al., 2009, 2014). In the present study, L. LPMC activations were enhanced under the Artificial conditions (see **Figure 3D**), which required more pattern-based or procedural strategy – just as in the case of puzzle-solving – for artificially matching an NP-Pred pair. The left frontal activations were not enhanced as expected under the Natural (6W) condition in our experiment. This is probably because the task became more "mechanical," requiring less conscious efforts and thus inducing less activations to process, as the number of words in the sentences increases.

It is instructive to note in this connection that while there has been much discussion on nested constructions/structures in the literature, there has been virtually no reference, as far as we are aware, to cross-serial constructions/structures; rather, only cross-serial dependencies defined on terminal strings have been discussed. Treating nested and cross-serial dependencies on a par may in fact mean that we are mixing apples and oranges, because nested dependency (as well as filler-gap/movement dependency and operator-variable dependency) is, as we have seen, a direct consequence of Merge (totally Merge-generable), whereas cross-serial dependency is a result of some interpretive mechanisms, with Merge only providing the necessary structural basis for the process (partially Merge-generable). We are of course aware that there are cross-serial dependency phenomena, typically in West Germanic languages [see Wurmbrand (2006) for an extensive review], reported and discussed in the literature. Although we cannot go into the details in this paper, and the definitive analyses of those phenomena surely remain to be properly formulated, it seems clear to us that those "cross-serial phenomena" can – and should – be naturally treated in terms of externalization mechanisms [see Huybregts (1984), Haegeman and Riemsdijk (1986), and subsequent works for much relevant discussion]. The generation of cross-serial dependencies, which requires the specification of linear (left-to-right) order, cannot be directly carried out by the core component of human language (Merge). Thus, those cross-serial phenomena, as well as, perhaps, the famous crossing case of "Affix Hopping" discussed in Chomsky (1957), ought to be handled in the externalization process.

Mainstream cognitive or neuroscientific investigations into human language have been centering around the Chomsky Hierarchy of weak generation. In their discussion, nested dependencies are treated as a hallmark of context-free grammars as distinguished from finite-state grammars, and cross-serial dependencies are used as testing grounds for context-sensitive grammars. However, these dependencies are usually characterized on the basis of terminal strings, and if we adopt the contemporary theory of Merge, we are instead led to an entirely different conception of the relevant dependencies. As we discussed above, nested dependencies naturally arise as a result of unbounded Merge, whereas cross-serial dependencies may appear in human language only insofar as the relevant structure is generated by Merge, and some other mechanisms/conditions are also fulfilled.

This conclusion may lead to an entirely new interpretation of the question of why nested dependencies abound, whereas cross-serial dependencies are severely limited in natural languages (see the discussion in section "Theoretical Background"). This is *not* because human language requires a characterization at the complexity of context-sensitive grammars or Turing machines (type-0 grammars), but because human language is so simple that it only avails itself of a minimal apparatus for strong generation, i.e., Merge. Merge-based phrase structures provide a direct basis for various nested dependencies, and also a rather partial (but necessary) means for characterizing limited kinds of cross-serial dependencies. In contrast, the human language faculty becomes rather extraneous whenever the task goes beyond the narrow channel of Merge-generability, such as when dealing with artificial nested/cross-serial dependences within terminal strings. Thus, dependencies defined on terminal strings are processed even if they are artificially imposed, but those processes are significantly enhanced when dependencies are Merge-generable. Ultimately, then, a weak generation of terminal strings is reduced to just a secondary effect of Merge-based strong generation. Consequently, our results also shed fresh light on another long-standing question, namely why the classical Chomsky Hierarchy does not constitute an entirely adequate scale along which human language is to be characterized and evaluated (cf., the notion of "mild" context-sensitivity). The Chomsky Hierarchy is typically a measure of weak generative capacity, and it is thus more or less orthogonal to the empirical study of human language (Chomsky, 1963, 1965).

Our conclusion should not be underestimated, since there are numerous studies that center on the relation between human language and the Chomsky Hierarchy. For instance, it has been reported that the computation of "regular-grammatical" dependencies of the form $(AB)^n$ ($n$ = 2, 4) and "context-free" dependencies of the form $A^nB^n$ ($n$ = 2, 4) selectively activated different brain regions (the left frontal operculum and L. IFG, respectively) (Friederici et al., 2006). However, finite sequences of artificial symbols are a matter of weak generation at best, and there is little evidence that their participants were truly computing finite $A^nB^n$ (where $n$ = 2, 4) sequences in terms of hierarchical structures, i.e., phrase-structure grammars, let alone Merge-based human syntax. The literature on non-human animals' capacities for computing finite $(AB)^n$ versus $A^nB^n$ patterns are equally misguided (Gentner et al., 2006; Abe and Watanabe, 2011), if not only due to the unresolvable finiteness limitations.

We emphasize that the real novelty of our present experiments lies in its focus on Merge-generability, not merely phrase structures. Of course, there are quite a few neuroscientific studies that do try to discuss the relevance of phrase structures, but few have spoken to the Merge-generable versus non-Merge-generable distinctions [but see Ohta et al. (2013a,b) for notable exceptions]. For example, it has been reported that a selective cortical activation of the L. IFG for two-word phrase formation is enhanced compared to an unstructured list of two words (such as *this ship* vs. *stone, ship*) (Zaccarella and Friederici, 2015). This is a finding of importance, also consistent with our results, but the relevant dependencies between two adjacent words are so elementary that they may be characterized by *any* theory of strong generation. Another notable study provided an interesting set of data that support the primacy of structure-dependent computations in human language (Musso et al., 2003). Those authors asked German native speakers to learn two sets of transformational or pseudo-rules of Italian and Japanese (passive, negative construction, etc.). The first set of learned rules are real rules of the respective languages and thus consistent with the structure-dependence principle of human language, which holds that the applicability of transformational rules must be defined in terms of abstract phrase structures, not terminal strings. The second set of learned rules are unreal or artificially manipulated pseudo-rules that use the same lexicon as the respective languages but systematically violate the principle of structure-dependence, defined just on terminal strings (for example, putting the negation after the third word counting from the left). The results obtained in that study indicate that an increase of cortical activation in L. IFG was observed only for the acquisition of real structure-dependent rules, irrespective of the types of language. This work is significant in that it points to the primacy of phrase structures over terminal strings in the acquisition of transformational rules. It can thus be interpreted as constituting another empirical support for our broader hypothesis that abstract hierarchical structures generated by Merge are critical, not just for the formulation of transformational rules, but for possible dependencies in human language in general.

## CONCLUSION

In sum, our discussion points to the broad conclusion that all natural dependencies admissible in human language are Merge-generable, including certain types of nested, cross-serial, and transformational (such as filler-gap/movement) dependencies, and that non-Merge-generable dependencies of any type are extraneous to the human language faculty. There are only abstract hierarchical phrase structures in human language, generated all the way through via Merge. Here, we provided a novel set of neuroimaging data that confirm this general picture, thus corroborating the overarching hypothesis that human language at its core is a surprisingly simple system of unbounded Merge, and that Merge is the single generative engine underlying every aspect of linguistic computations.

## DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Institutional Review Board of The University of Tokyo, Komaba Campus. The patients/participants provided their written informed consent to participate in this study.

## AUTHOR CONTRIBUTIONS

All authors contributed to the designing of the study and writing of the manuscript. KT, IN, SO, and KS conducted and analyzed the experiments.

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## SUPPLEMENTARY MATERIAL

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MINI REVIEW
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# Languagelike-Specificity of Event-Related Potentials From a Minimalist Program Perspective

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In this mini-review, I use event-related potential (ERP) studies to test the minimalist program (MP) prediction that organisms with the faculty of language cognitively process languagelike systems in a qualitatively distinct manner. I first discuss "languagelike" as a technical term defined by recursion criteria. From this definition and using a generative perspective, I show that certain domains of math and music can be considered languagelike. These domains are then used as case studies to test whether or not different languagelike systems are cognitively processed in a similar manner. This is done by investigating the elicitation of common language-related ERPs (namely, the left-anterior negativity (LAN), N400, and P600) in these languagelike systems. I show that these systems do indeed elicit the same language-related ERPs, supporting the claim that different languagelike systems are processed similarly. I then discuss discrepancies between these systems, as exemplified by the P3, and I provide plausible accounts for interpreting those results. I ultimately conclude that present data on the LAN, N400, and P600 disprove language-specificity but that languagelike-specificity remains plausible, and as yet there is no reason to reject MP's prediction that languagelike systems are processed in a qualitatively distinct way.

**Keywords: minimalist program, faculty of language, event-related potentials, math, music**

## INTRODUCTION

As a research program with its foundation in the biolinguistics framework, the Minimalist Program (MP) "seeks the simplest formulation of Universal Grammar (UG)," which is "the theory of the biological endowment of the relevant components of the faculty of language (FL)" (Chomsky, 1995, p. viii). Thus, though each exists as its own object of inquiry, any prediction of FL is a prediction of UG, which is a prediction of MP (though not necessarily vice versa).

Hauser et al. note that "investigations of [FL] should include domains other than communication" (Hauser et al., 2002, p. 1571). In this mini-review, I use functional neuroimaging studies to test the MP prediction that there is "a qualitative difference in the way in which organisms with [FL] approach and deal with systems that are languagelike and others that are not" (Chomsky, 1965, p. 56)[1].

To that end, I first precisely define what constitutes a languagelike system and establish some testable systems that meet this definition. I then test for specificity to languagelike systems ("languagelike-specificity") by reviewing event-related potential (ERP) studies and demonstrating similarities of cognitive processes ("cognitive overlap") across different languagelike systems.

It should be said at the outset that it is not possible to comprehensively cover the abundance of language-related ERP studies within this mini-review. I have therefore carefully selected only those studies most relevant to the discussion herein, and I recommend that the interested reader check Kutas and Federmeier (2011), Brouwer and Crocker (2017), and Nieuwland (2019) for comprehensive reviews on language-related ERPs.

## LANGUAGELIKE SYSTEMS

According to Chomsky et al., there are two empirical, non-negotiable characteristics of language: discrete infinity and displacement (Chomsky et al., 2017, p. 3). Discrete infinity refers to the infinite generative capacity of grammatical sentences from a finite set of symbols, or the ability to "make infinite use of finite means" (Chomsky, 1965, p. 8). Displacement refers to the maintaining of a noun phrase's thematic relation to a verb, while displacing it from its base position, such as is found in active/passive voice alternation (Chomsky et al., 2017, p. 3). Note, however, that these two characteristics are simply the consequence of an underlying computational mechanism. We call this mechanism Merge, a fundamental set-formation operation that produces a new syntactic object *K* from two syntactic objects X and Y, such that *K* = {X,Y}. Importantly, it is the *recursive* application of Merge that is considered sufficient to account for both discrete infinity and displacement (Chomsky et al., 2017, pp. 3–4). Thus, FL is characterized by recursion[2], which is often regarded as the most fundamental feature of language and consequently gives us a suitable working definition: a languagelike system is one that utilizes recursion.

### Recursion

To move further, we must understand recursion. It is tempting to equate recursion with embedding, for example in the use of recursive possessives (as in "my father's father's father's..."), in the use of recursive relative clauses (as in "the boy that wore the shirt that got dirty at the game that..."), and so on. However, this oversimplification is a mischaracterization that has led to confusion over whether or not recursion exists in all human language (see Everett, 2005 and Nevins et al., 2009, for the famous debate on Pirãha exceptionality). In fact, embedding is a property and evidence of recursion, but recursion is not limited to embedding. Watumull et al. formally describe recursion by three criterial properties: computability, definition by induction, and mathematical induction (Watumull et al., 2014, p. 1). Computability refers to output being generated deterministically by conditional branching, as in a Turing machine: "IF in state $q_i$ reading symbol $x_i$ on the tape, THEN write $y_i$, move one space, transition to state $q_j$" (Watumull et al., 2014, pp. 1–2). A function is computable if its deterministic rules are finitely specified. Definition by induction allows strong generation of increasingly complex structures through stepwise computation (Watumull et al., 2014, p. 2). Lastly, mathematical induction results in an unbounded (i.e., infinite) computable generation of structured expressions. An important distinction is that *generation* can be infinite while *production* is finite due to some arbitrary constraint (Watumull et al., 2014, p. 3). In a Turing machine, such a constraint might be tape length, while in human language, it could be memory limitations, lack of cultural utility (e.g., counting above a certain number), etc. In summary, recursion requires that three criteria are met: (1) computability gives finitely specified rules, (2) definition by induction allows stepwise computation, and (3) mathematical induction provides infinite generative capacity.

### Math and Music

With this definition of a languagelike system, let us take arithmetic sequences and musical prolongation as two case studies. First, consider the famous Fibonacci sequence, defined $F_n = F_{n-1} + F_{n-2}$ for each $n \in \mathbf{N}$, with $F_0 = 0$ and $F_1 = 1$. This yields $\{0,1,1,2,3,5,8,13\ldots\}$, *generating* integers infinitely, and without arbitrary constraints (e.g., "for $n < 10$"), it will also *produce* integers infinitely. Thus, the three conditions are satisfied: computability is achieved by the finitely specified formula $F_n$, definition by induction is satisfied by stepwise computation of the formula, and the sequence is generatively unbounded, satisfying mathematical induction. This same procedure can be used to show any arithmetic sequence to be recursive.

Superficially, music and language have many similarities (expressive communication, cultural significance, local variation, etc.), but it is not straightforward whether music is a languagelike system. In their book *A Generative Theory of Tonal Music* (GTTM), Lerdahl and Jackendoff developed a formal grammar for music. The authors first note that a generative theory of music is "a formal description of the musical intuitions of a listener who is experienced in a musical idiom" (Lerdahl and Jackendoff, 1983, p. 1). Let us consider musical prolongation. In music theory, the highest hierarchical level is the tonic (i.e., the resolving pitch) of the key (e.g., in the key C Major, the tonic is C). The tonic is said to *prolongate,* governing all parts of the piece played in relation to it (Lerdahl and Jackendoff, 1983, p. 179). Consider ending "Mary had a Little Lamb" on "it's fleece was white as." The omission of "snow" leaves the piece melodically unresolved, illustrating that note's function as the prolongational head.

Regarding prolongation, GTTM provides four "prolongation reduction well-formedness rules" (PRWFR). Though I will only use the first rule, I include all four (greatly simplified) both

[1]The astute reader may notice that the claim predates MP. This does not, however, lessen its pertinence to MP, which is "simply a continuation of what has been undertaken from the earliest years [of generative grammar]" (Chomsky, 2011, p. 263). The concept is salient throughout MP literature, but wording tends to be less succinct (for purposes here), and more evolution-centric than predictive (see Pinker and Jackendoff, 2005, p. 229; Ott, 2007, p. 7; etc.).

[2]Precisely, it is FL in the narrow sense (FLN) that is characterized by recursion. This is described in contrast to FL in the broad sense (FLB), which includes interface systems (Hauser et al., 2002, p. 1569). The distinction is important but not relevant here, hence the simplified use of FL instead of FLN.

for reference and to adequately demonstrate that prolongation satisfies languagelike criteria:

**PRWFR 1:** Every (section of a) piece has a single prolongational head.
**PRWFR 2:** A pitch event $e_i$ can be a direct elaboration[3] of event $e_j$ in the following ways:
1. $e_i$ is a strong prolongation of $e_j$ if its notes are identical;
2. $e_i$ is a weak prolongation of $e_j$ if the roots are identical but some notes differ;
3. $e_i$ is a progression to or from $e_j$ if the roots differ.

**PRWFR 3:** Every event is either the prolongational head or a recursive elaboration of it.
**PRWFR 4:** (No Crossing Branches) If $e_i$ is a direct elaboration of $e_j$, every event between them, must be a direct elaboration of $e_i$, $e_j$, or some event between them (Lerdahl and Jackendoff, 1983, pp. 214–215).

Here, we have finitely specified generative rules (computability), applied through stepwise computation (definition by induction), and with infinite generative capacity through recursive elaboration (mathematical induction). Thus, musical prolongation satisfies recursion criteria and is indeed a languagelike system.
Note, not all musical structures are languagelike, just as not all mathematical disciplines are, just as not all vocal utterances are. However, this does not preclude their use as empirical tests for languagelike-specificity, since we only consider languagelike subsets of each domain.

**TABLE 1** | A simplified summary of ERPs elicited by violations of language and languagelike systems.

| Domain | Violation type | Violation example | ERPs | Source |
|---|---|---|---|---|
| Language | Semantics | "The cat will bake." | N400 | Federmeier et al. (2002), Osterhout et al. (2004), Lau et al. (2008) |
| Language | Syntax | "The blouse was on ironed." | P600 | Osterhout and Holcomb (1992), Kutas et al. (2006), Brouwer and Crocker (2017) |
| Language | Morphosyntax | "The clerk were severely underpaid." | LAN, P600 | Barber and Carreiras (2005), Molinaro et al. (2011) |
| Math | Arithmetic sequence | "7 10 13 16 19 22 24" | LAN, P600 | Núñez-Peña and Honrubia-Serrano (2004) |
| Math | Arithmetic operation | "7 × 4… 24" | N400, P3 | Niedeggen et al. (1999) |
| Music | Prolongation | [out-of-key chord] | RATN, P600 | Besson and Faïta (1995); Patel et al. (1998) |
| Music | Meter | [deviant accent]; [empty beat] | MMN, P3 | James et al. (2012), Bouwer et al. (2014) |

*In each example provided, words/numbers were presented visually one at a time, except for musical stimuli, which were presented aurally. Underlined words/numbers represent the critical stimulus, whose onset (t = 0 ms) marks the point from which each ERP's latency is measured.*

## EVENT-RELATED POTENTIALS AND LANGUAGELIKE-SPECIFICITY

Event-related potentials (ERPs) are stimulus-induced, time-locked, averaged electric potentials in the brain measured by electroencephalography (EEG). EEG is a common neurolinguistic research method with high temporal resolution, well suited for studying the time-course of language processing (Stemmer and Rodden, 2015, pp. 477–478; see also Burle et al., 2015, for limitations). **Table 1** summarizes all ERPs reviewed henceforth.

### Language-Related Event-Related Potentials

Typically, language processing experiments expose participants to semantically or syntactically violated ("critical") stimuli (e.g., *"the blouse was on ironed."), which is compared against unviolated ("control") stimuli ("the blouse was ironed."). Syntactic/morphosyntactic violations elicit the P600, a long-lasting positive deflection of voltage that peaks over centro-parietal areas of the brain around 600 ms post-stimulus (Osterhout and Holcomb, 1992; Kutas et al., 2006; Brouwer and Crocker, 2017). The P600 is often interpreted as an index of structure-related difficulties or reanalysis (Kutas et al., 2006, 693). It therefore stands to reason that the same P600 will be elicited by non-linguistic stimuli of languagelike systems.

Similarly, the N400—a centro-posterior negativity at 400 ms post-stimulus—and the LAN—a left anterior negativity, which also peaks around 400 ms post-stimulus—are of linguistic interest. The N400 is elicited by semantic anomalies (e.g., "the cat will bake.") (Federmeier et al., 2002; Osterhout et al., 2004), and is interpreted as reflecting semantic integration in a combinatorial process, evidenced by a correlation between N400 amplitude and degree of semantic incongruence (Lau et al., 2008). The LAN often precedes the P600 elicited by morphosyntactic violations (e.g., *"the clerk were severely underpaid.") (Barber and Carreiras, 2005; Molinaro et al., 2011; see also Friederici, 2002 for review).

### Arithmetic Sequence Violation Event-Related Potentials

Turning to recursive arithmetic sequences, consider an experiment where numbers in a series are presented one at a time. If the generating formula is simple, participants will deduce the formula and predict subsequent numbers. Then, MP predicts that a violation in this sequence would elicit some combination of the LAN, N400, and P600. This was indeed shown to be the case. While recording EEGs, experimenters showed participants seven numbers in sequence, each computed by the simple recursive formula $x_{i+1} = x_i + c$, where $c$ took the value ±2,

[3]GTTM defines direct and recursive elaboration such that event $e_i$ is a *direct elaboration* of $e_j$ if $e_i$'s hierarchical branch terminates on $e_j$'s branch; and $e_i$ is a *recursive elaboration* of $e_j$ if it is a direct elaboration of $e_i$ or if a series of direct elaborations lead to $e_j$'s branch (Lerdahl and Jackendoff, 1983, p. 214).

3, or 4 (e.g., "7 10 13 16 19 22 25") and the final number was either correct ("...19 22 25"), widely incorrect ("...19 22 50"), or narrowly incorrect ("...19 22 24") (Núñez-Peña and Honrubia-Serrano, 2004, pp. 132–133). The results showed an early left anterior negativity peaking around 250–300 ms (LAN), and a centro-parietal positivity peaking around 500–600 ms (P600). Furthermore, the P600 amplitude increased with widely incorrect endings, compared to narrowly incorrect endings (Núñez-Peña and Honrubia-Serrano, 2004, pp. 134–138).

For comparison, single arithmetic operation violations (e.g., "7 × 4..." "24") are shown to elicit an N400 and a P3 (see section "Making Sense of the P3") (Niedeggen et al., 1999, pp. 311–312). Structural differences may explain the N400. A single arithmetic operation corresponds to a single instance of Merge, while arithmetic sequences require a greater maximum depth of Merged subtrees (Degree of Merger) and employ an additional operation, Search (Ohta et al., 2013, p. 2), which refers back to previous elements in the hierarchical tree. This Search operation could explain the elicitation of the P600 by sequence violations and its absence by single operation violations, although further research is required to test this hypothesis.

### Musical Prolongation Violation Event-Related Potentials

Recall that GTTM's PRWFR 1 states that there exists a single prolongational head, which governs all subordinate pitch events. In contradiction to this rule, a prolongation violation is a pitch event that disagrees with its prolongational head (i.e., an out-of-key note/chord). Such a pitch event would cause a breakdown and/or reanalysis of the prolongational hierarchy, and by MP prediction should elicit a languagelike neural response.

As with the arithmetic sequence, this turns out to be the case. Patel et al. played musical phrases to musically trained participants while recording EEG data (Patel et al., 1998, p. 718). Each phrase consisted of block chords in an established key, at the end of which a target chord was presented as an in-key chord (control), a nearby-key chord, or a distant-key chord (Patel et al., 1998, p. 722). EEG results showed a late, centro-parietal positivity peaking at 600 ms post-stimulus (i.e., P600) (Patel et al., 1998, p. 723). Moreover, the strongly violated distant-key condition elicited a greater P600 amplitude compared with the weakly violated nearby-key condition (Patel et al., 1998, p. 724). Finally, an anterior negativity was found 300–400 ms post-stimulus, though in contrast to the LAN, its distribution was right-lateralized and maximized over anterior-temporal areas (termed RATN) (Patel et al., 1998, p. 726). These results agree with other musical ERP studies (see, e.g., Besson and Faïta, 1995) and with the arithmetic sequence violation ERP whose amplitude was also modulated by degree of violation.

Jackendoff claims that in music, meter is the most consistent with language in terms of hierarchical structure (Jackendoff, 2009, p. 203). Thus, we might expect metric violations to elicit the P600. However, ERP studies on metric deviance report the mismatch negativity (MMN)—a fronto-central negativity peaking around 150–250 ms that is sensitive to infrequent change in repetitive auditory sequences—and a P3 (see section "Making Sense of the P3") (see James et al., 2012, pp. 2762–2765; Bouwer et al., 2014, pp. 5–8). Here, experimental design dictated that deviant stimuli were constructed by omitting beats or by changing the accent pattern (Bouwer et al., 2014, p. 2). With constant tempo and time signature, such deviations may be interpreted as metric elaborations (analogous to prolongational elaborations) rather than metric violations, thus eliciting the simpler MMN. In other words, metric elaboration may not cause listeners to reanalyze the underlying hierarchical structure.

The results of the arithmetic sequence violation and musical prolongation violation studies show that these violations are, in essence, processed as or very similarly to morphosyntactic violations and that the LAN and P600 are not language-specific, but may instead have languagelike-specificity.

## MAKING SENSE OF THE P3

The P3 is a centro-parietal positivity around 300 ms, elicited by related but improbable or infrequent events and consists of two subcomponents, P3a and P3b. P3a is an earlier component with a central maximum, related to attentional mechanisms, while P3b is a later component with a parietal maximum, related to attention and memory processing, and modulated by difficulty (Polich, 2007, pp. 2128–2135).

Bouwer et al.'s metric violation elicited a P3a (Bouwer et al., 2014, p. 4), which is consistent with the interpretation that the metric violation requires attention but no deeper reanalysis of the underlying hierarchical structure.

On the other hand, some researchers propose that the P600 belongs to the P3 "family," evidenced by the observation that both P3b and P600 amplitudes are modulated by difficulty and latencies are modulated by reaction time (Sassenhagen et al., 2014, pp. 32–33). Under this interpretation, MP would predict that any P3b-eliciting stimulus is languagelike, or else the P3b/P600 cannot be languagelike-specific. Consider one experiment where viewing a video of a man attempting to cut bread with an iron was shown to elicit (a rather late) P3b (as well as an N400) (Sitnikova et al., 2008, pp. 2047–2054). If the P3b is languagelike-specific, that implies that this and similar stimuli are processed in a recursive, hierarchical languagelike way (e.g., through combinatorial processes of semantic information contained in the video). It is easy to extend this to the argument that nearly all complex systems are hierarchical in nature. In fact, Pinker and Jackendoff argue that the problem is not that too few systems are languagelike, but rather too many are (Pinker and Jackendoff, 2005, p. 230). This does not render FL meaningless, but rather demonstrates how it uniquely equips us to approach many different complex systems in a way that organisms without FL cannot.

## CONCLUSIONS

In this mini-review, I have treated "languagelike" as a technical term defined by recursion criteria. I have shown that ERP studies demonstrate cognitive overlap (LAN, N400, and P600) between language and subdomains of math, and music, supporting MP prediction that cognitive processing of different languagelike systems is qualitatively distinct. I have also suggested that since some languagelike systems do not elicit languagelike ERPs, if MP prediction is true, then these discrepancies must be accounted for, for example, by structural inconsistencies or by reinterpreting the P600 as belonging to the P3 family.

It is outside the scope of this mini-review to dissociate languagelike ERPs from general cognitive function, and until such dissociation is made, languagelike-specificity cannot be indisputably confirmed. To that end, it is important that future research explore this and similar issues by framing hypotheses in light of current linguistic theory. It is also important that greater efforts be made for cross-communication between linguistic and non-linguistic neuroscientific areas of research.

Regardless, it is clear that the data considered here are compatible with the interpretation that the LAN, N400, and/or P600 have languagelike-specificity and that their elicitation from different languagelike systems indicates a qualitatively distinct processing mechanism for languagelike systems, as predicted by MP.

## AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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# The Evolvability of Words: On the Nature of Lexical Items in Minimalism

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Work within the minimalist program attempts to meet the criterion of evolvability: "any mechanisms and primitives ascribed to UG rather than derived from independent factors must plausibly have emerged in what appears to have been a unique and relatively sudden event on the evolutionary timescale" (Chomsky et al., 2017). On minimalist assumptions the evolution of the language faculty must have involved at least three major developments: (i) the evolution of computational atoms, lexical items, understood as bundles of features, (ii) the evolution of a single, simple recursive operation that glues together lexical items and complexes of lexical items, and (iii) externalization linking the syntactic component of the language faculty to the cognitive systems that humans use for sound and gesture. The first development, the evolution of lexical items and the lexicon, is especially poorly understood. A complete account of the evolution of lexical items will state what evolved, how, and why. The focus of this article is the first question: what evolved. What properties do lexical items have, what determines these properties, and what is the internal structure of lexical entries? The article identifies what the key open problems are for a minimalist account of the evolution of words that strives to meet the criterion of evolvability.

**Keywords: lexical semantics, language evolution, words, lexical items, anti-individualism, individualism, internalism/externalism**

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## 1. INTRODUCTION

The minimalist program (henceforth, *minimalism*; see Chomsky, 1995b, 2016; Marantz, 1995; Belletti and Rizzi, 2002; Boeckx, 2006; Hornstein, 2009; Berwick and Chomsky, 2016)[1] developed out of the Principles and Parameters approach to syntax. Minimalism explores the idea that the basic operations of the human language faculty are simple and few, and that the attested complexities of natural language (such as unbounded dependencies) are a byproduct of the interactions of subsystems. This view of the language faculty attempts to meet what some have called the *criterion of evolvability*: "any mechanisms and primitives ascribed to UG rather than

[1]My use of the term *minimalism* throughout this article should be distinguished from the use of *minimalism* to refer to minimal semantics (Borg, 2004, 2012), a particular approach to semantic theorizing. Minimal semantics is, very roughly, committed to the view that well-formed (declarative) sentences express truth-evaluable content and that content is fully determined by syntactic structure and lexical content. Although minimal semantics assumes that there are (a limited number of) context-sensitive expressions, the input of context to literal content is taken to be severely constrained (Borg, 2012, p. 4, 5). The tenets of minimal semantics intersect in an interesting way with the goals of the minimalist program. I will not explore this intersection here, but I return to Borg's work in my discussion below of the structure of lexical entries.

derived from independent factors must plausibly have emerged in what appears to have been a unique and relatively sudden event on the evolutionary timescale" (Chomsky et al., 2017).

On minimalist assumptions the evolution of the language faculty must have involved at least three major developments (see, e.g., Berwick, 2011; Berwick and Chomsky, 2016)[2]:

- evolution of lexical items understood as bundles of features
- evolution of a single, simple recursive operation, Merge, that glues together lexical items and complexes of lexical items, thus forming larger units
- externalization linking the syntactic component of the language faculty to the cognitive systems that humans use for sound and gesture.

Each of these developments must be part of any minimalist account of language evolution. One cannot be reduced to the other. Berwick (1998) states this explicitly: "Merge cannot tell us everything we need to know. **It does not say how words came to be**, and will have little to say about the word features particular to each language" [emphasis added–BC]. But these three developments are interdependent. For example, as Piattelli-Palmarini (2010, p. 160) argues, if lexical items are defined as mergeable form-meaning pairs, then there could not be any lexical items without syntax because "[w]ords are fully syntactic entities."

The evolution of lexical items (and the lexicon) is poorly understood. As Chomsky et al. (2017) put it, "[t]he evolutionary origins of . . . the lexicon and its atoms with all their semantic intricacy . . . remain a deep mystery." A complete account of the evolution of lexical items will state what evolved, how, and why. Here I focus primarily on the first issue: what evolved. What properties do lexical items have, what determines these properties (factors entirely internal to the individual?, extramental factors?, some of both?), and what is the internal structure of lexical entries? After a brief discussion of, in very broad strokes, how lexical items are treated in (some varieties of) minimalism, I focus my attention on just one aspect of lexical items: their semantic properties.

Any account of the evolution of words within minimalism needs to address a large number of issues, even if we restrict our attention to just the semantic properties of lexical items. Some of these issues are fairly abstract ones involving the nature of lexical semantic features and their interrelationship; others are more specific issues that pertain to the particular psychological mechanisms that ground the relation between semantic features and the extramental world. I try to get clear on what the core issues are and what tools and evidence we need to address them. The implications of this investigation for a minimalist account of language evolution that strives to meet the criterion of evolvability are severe. Much needs to be clarified about the nature of lexical items and their relationship to other cognitive structures before we can make progress on understanding how words evolved and why. (Noam Chomsky (p.c.) observes correctly that many of the issues that I raise below are not particular to minimalism. While the context for the discussion that follows is minimalist conceptions of lexical items and the lexicon, the issues that I discuss are issues for many other frameworks as well.)

A few caveats. (i) In what follows, I do not present or advocate for (as far as I can tell) a novel account of lexical items within minimalism. (ii) For the most part, I describe some characterizations of lexical items that have appeared in the minimalist literature to get a handle on what evolved in the evolution of words. I review ideas from various accounts, but draw primarily from the expositions of the lexicon and lexical items that have appeared in Chomsky's work (e.g., Chomsky, 1995b, 2000, 2003b, 2016). I make no attempt to be exhaustive, even of Chomsky's work on the topic, nor do I go into much detail about the empirical consequences of various views of the lexicon. These consequences are explored in detail in the work cited throughout this article. (iii) I do not discuss theories of the lexicon, features, or feature structures that have appeared in frameworks embedded within traditions other than the Principles and Parameters approach (e.g., Head-driven Phrase Structure Grammar; see, e.g., Pollard and Sag, 1994).

## 2. LEXICAL ITEMS AND THEIR FEATURES

As noted in the previous section, minimalist discussions of language evolution have proposed that there were three key developments in the evolution of the language faculty. One development was the emergence of a capacity to construct an infinite range of hierarchically structured expressions through an operation, Merge. This capacity is what (Chomsky, 2016, p. 4) calls the *Basic Property*. Another was the development of the atoms of computation that, when combined, yield those hierarchically structured expressions. I call these computational atoms, when associated with phonological properties, *lexical items* (henceforth, LIs).

The third development is externalization. Chomsky (2016, p. 41), among others, says we should distinguish the emergence of "word-like objects" without phonological properties from the evolutionary development of externalization. Externalization is the mapping of the expressions generated by the syntactic component of the language faculty to the cognitive systems that humans use for sound and gesture (the sensorimotor interface): "When the beneficial mutation [giving rise to Merge—BC] has spread through the group, there would be an advantage to externalization, so the capacity would be linked as a secondary process to the sensorimotor system for externalization and interaction, including communication as a special case" (Berwick and Chomsky, 2011, p. 36).

Characterizations of externalization typically assume that the sensorimotor systems linked to the language faculty are evolutionarily ancient, systems that were largely (perhaps entirely) in place before the development of Merge and the development of LIs. The sensorimotor systems, it is claimed, have little to do with language and have not evolved in any significant way subsequent to the emergence of the faculty of language (Chomsky, 2017, p. 298; Huybregts, 2017). On this

[2]The order of presentation here of these developments is not intended to indicate a claim about their relative ordering during human evolution.

view, the articulation of language, through sound, gesture, etc., is considered to be an ancillary aspect of language. Huybregts (2017) presents conceptual and empirical arguments in favor of the view that externalization occurred subsequent to the development of Merge.

Huybregts (2017, p. 292) claims that "externalization may not have required much, or any, further evolution of language." Externalization is typically characterized as a single evolutionary development. This is likely an oversimplification of this aspect of language evolution. Externalization involved at least the development of mental representations of phonological structure and the linkage of LIs (presumably comprising, prior to externalization, solely semantic and syntactic features) with these representations. There is much more to explore here, but, given the goals of this article, I set aside the issue of externalization. [Tallerman (2014) presents a thorough critique of the standard take on externalization; Jackendoff (2011, p. 616) argues against the notion of externalization presented in Chomsky (2010)].

I assume throughout what follows that the signals that characterize non-human animal communication systems (Hauser, 1996 for an overview) are different from LIs in many respects (see, e.g., Deacon, 1997; Hurford, 2007). (This is not to say that there is no relationship between the properties of non-human animal communicative behavior and the meanings associated with LIs. Bar-On (2018) argues that communicative expressive behaviors displayed by both humans and non-human animals play an important explanatory role in understanding the origins of linguistic meaning.) Consider alarm calls (e.g., vervet monkey alarm calls; see Cheney and Seyfarth, 1990). They are typically indexical (bound to the currently occurring situation): "Alarm calls are about the here and now—or the almost here and now" (Skyrms, 2010, p. 28, 29). The production of alarm calls involves little or no calculation of the attentive state of other animals. They are largely innate. Alarm calls are *functionally referential* (Hauser, 1996, p. 509)[3]. As Deacon (1997, p. 57) puts it: "Alarm calls refer to objects the way laughter does, not the way words do."

Further, there are a range of concepts that are expressed by LIs (and complexes of LIs) but, as far as we know, are not externalized by non-human animal signals:

> Other animals do not create external public representation of quantifiers, sortals, epistemic states, causality, and so on. Other animals may represent their world in terms of such concepts, but they do not communicate about such things (Carey, 2009, p. 464).

As Tallerman (2014, p. 208) observes, some of the externalized concepts that characterize human language may "have developed *through* the use of (externalized) language," subsequent to the externalization step in language evolution described above. As Hurford (2012, p. 153; cited in Tallerman, 2014) puts it: "public use affects private concepts."

Contrasts between LIs and non-human animal signals could probably be multiplied indefinitely. For example, some linguistic representations are merely objectual, others are purely objective (Taylor, 2019, p. 113–116). Objective representations stand for real properties and objects. Merely objectual ones (e.g., *Sherlock Holmes*) are "fit" for the job of standing for real existents or real properties but don't. There does not seem to be a robust counterpart to the objectual/objective distinction in non-human animal communication systems.

There is often a great deal of controversy surrounding any claim about non-human animal communication systems, especially with respect to meaning (see, e.g., Scott-Phillips, 2015; Moore, 2016, for a recent exchange regarding meaning in great ape communication). But I take the claim that LIs are vastly different from non-human animal signals to be an uncontroversial one.

Minimalism assumes that each LI comprises properties involved in form (sound, gesture, etc.) and meaning (Chomsky, 1995b, 2000, 2003b; Collins and Stabler, 2016 present a formalization of minimalist syntax). These properties are often referred to as *features*. Universal Grammar provides three sets of features: phonological features (such as VOICE), semantic features (such as CAUSE), and syntactic features (such as category information). Syntactic features are involved in the computational processes (e.g., applications of Merge) that yield hierarchical complexes of LIs. Each LI is a triple ⟨SEM, SYN, PHON⟩ (Collins and Stabler, 2016, p. 44). SEM and SYN are (possibly empty) subsets of the set of semantic features and the set of syntactic features provided by Universal Grammar. PHON is a string of segments, possibly null, where each segment is a bundle of features (like VOICE). A lexicon is a finite set of LIs[4].

The lexicon has a number of properties that distinguish it from the sets of signals (such as a set of alarm calls) that characterize non-human animal communication systems. Tallerman (2014, p. 209, 210) discusses some of these properties and their implications for accounts of language evolution. For example, unlike many non-human primate call systems, the lexicon is acquired entirely in ontogeny. Further, the lexicon is very large in size relative to the size of call systems. The capacity to acquire a lexicon presumably involved cognitive changes in the hominin lineage. These changes require an evolutionary account. In what follows, my focus will be LIs (their properties, how those properties are determined, etc.) rather than the lexicon *per se*. But any adequate model of the evolution of words in minimalism will need to incorporate an account of the evolutionary development of the lexicon.

Any minimalist characterization of LIs must answer the following questions:

[3] Marler et al. (1992) present two criteria that must be met for a signal to be functionally referential:

- Production criterion: all the stimuli that elicit the signal belong to one category, either a general category such as "aerial predators" or a more specific one such as "eagle".
- Perception criterion: the utterance of the referential signal is alone sufficient to elicit the same behavior as would be elicited by perceiving the referent.

[4] While features play a central, indispensable role in minimalism and a great deal of other work in linguistics, there is little agreement on what features there are and their key properties. For this reason, I make no attempt in what follows to present a complete inventory of lexical semantic features. My goal here, among others, is simply to try to get a handle on what kinds of lexical semantic features have been associated with LIs. Adger (2010) and Adger and Svenonius (2011) discuss many of the major issues concerning features and feature structures in minimalism.

- What sorts of properties are associated with LIs?
- How are these properties determined? What makes it the case that an LI in the lexicon of a particular individual is an LI with its particular properties?[5]
- What is the internal structure of lexical entries?

In what follows, I address each of these questions, focusing on lexical semantic properties and the internal structure of the semantic component of LIs. The goal will be to clearly articulate what minimalist accounts of the evolution of words must explain.

## 2.1. The Inventory of Semantic Features

As discussed in the introduction, most work in minimalism assumes that LIs have features and that some of these features are semantic ones. In what follows, I make a few (tendentious) assumptions about semantic features. As noted in the introduction to this section, a set of lexical semantic features is just one of several components of each LI, alongside a set of syntactic features and a set of phonological features. I assume that many semantic features (like CAUSE, CONTACT, MANNER OF MOTION, ANIMATE, etc.) correspond to concepts in cognitive faculties outside language cognition. (As noted below, some of these concepts, like BODY, may be shared by humans and non-human animals.) These semantic features are concepts that have been coopted for lexical representation, a claim that I return to below. (I use capitals throughout for the names of both semantic features and concepts.)

Following Glanzberg (2011), among others, I do not assume that LIs simply express concepts, though they are associated with them (in some fashion). The relationship between LIs, semantic features, lexical meanings, and concepts is a complex one. I do assume that concepts are mental representations that are not necessarily specific to language cognition. Following Fodor (1975, 1998; 2008, among many other publications), I take the concepts that humans externalize with language to be "composable mental symbols with which thinkers can think about things" (Pietroski, 2018, p. 348). There is overwhelming evidence that both humans and many non-human animal species have concepts (Hurford, 2007; Carey, 2009), but the conceptual repertoire varies from species to species and composability appears to be unique to human cognition.

There is widespread disagreement about the ultimate basis for concepts and their internal structure[6]. I don't take a strong position on either of these issues here, although I touch on them below. Tallerman (2014, p. 208) observes that in minimalism, "what is meant by 'conceptual atoms' is some set of basic concepts which either constitute, form a part of, or are precursors to lexical items"[7]. Tallerman points out that these are three distinct possibilities. Chomsky (2016, p. 41) distinguishes the atoms of computation (or, as he puts it, "atomic concepts") from words and lexical items, although these terms ("atoms," "words," "lexical items") are sometimes used interchangeably. Computational atoms are the elements that language uses, through Merge, to construct an infinite range of hierarchically structured expressions. These atoms connect to the conceptual-intentional interface for mental processes (Chomsky, 2016, p. 4) but they do not necessarily have phonological properties. LIs, in contrast, are computational atoms that have been assigned phonological properties through externalization, sound being just one possible modality. (Because I have set aside the issue of externalization, I do not attempt to systematically distinguish between LIs and computational atoms in what follows.)

Features alone determine the identity of LIs: "any feature change yields a different LI" (Chomsky, 2003b, p. 265). As I discuss below, according to minimalism, word meaning is determined by some combination of semantic features provided by Universal Grammar (many of which were ultimately coopted from other areas of cognition) and meaning-related properties drawn from cognitive structures outside of language cognition: "word meaning and the knowledge associated with it may include several sorts of structures"—conceptual, visual, auditory, etc.—each structure playing a role in thought (Jackendoff, 2012, p. 125). That word meaning is determined by some combination of linguistic and non-linguistic properties is an assumption shared widely by linguists (e.g., Chomsky, 1975; Jackendoff, 2012), philosophers (e.g., Glanzberg, 2014, 2018; Taylor, 2019), and psychologists (e.g., Rips, 2011).

Ultimately, according to minimalism, the meaning-related properties associated with linguistic expressions generated by the language faculty are "information that is used by conceptual-intentional systems to engage the world in different ways as the language user thinks and talks in terms of the perspectives made available by the resources of the mind" (Chomsky, 2003b, p. 273). These properties provide a certain constrained range of perspectives for referring to aspects of the world (Chomsky, 2000, p. 36, 2016, p. 50; see also Borg, 2012, p. 149; Stainton, 2006, p. 924 for related discussion). They "focus attention on selected aspects of the world as it is taken to be by other cognitive systems, and provide intricate and highly specialized perspectives from which to view them, crucially involving human interests and concerns even in the simplest cases" (Chomsky, 1995a, p. 20). For example, consider the complexities associated with the word *near*: if I text you *I'm near your house*, you will be surprised if you then turn around in your living room and find me standing right there (as opposed to learning that I'm just up the block).

[5]Focusing on semantic properties of LIs, I take this (the question of how the properties of LIs are determined) to be a question of foundational semantics, drawing on Stalnaker's (1997) distinction between descriptive semantic questions (e.g., what is the semantic value of the LI *Rihanna*?) and foundational semantic questions (e.g., what makes it the case that the lexical item *Rihanna* has the semantic properties that it has?). I return to this distinction below.

[6]Prinz (2002) argues that all human concepts have a perceptual basis. Rips (2011) presents a range of evidence that concepts include information that goes beyond what purely perceptual mechanisms afford and that non-perceptual modes of thought are central to basic cognitive notions such as numbers and causality. As I discuss below, Fodor argues in a number of publications (see, e.g., Fodor, 1998; Fodor and Lepore, 2002) for conceptual atomism, the view that most concepts have no internal structure (discussed below). Prinz (2002) argues against atomism, primarily on the grounds that atomic representations can't explain our capacity to categorize because these representations do not contain features. Fodor (1998, p. 63) observes that the claim that an element (a concept, an LI) has features is distinct from the claim that the element is a feature bundle or comprises multiple sets of features (as in minimalism). This distinction reduces the force of Prinz's argument.

[7]Many thanks to a reviewer for pointing me to Tallerman's article.

What meaning-related properties are typically assumed to be encoded by LIs? Most accounts of LIs assume that semantic features tell us something about "the worldly object, property, or event that is the assigned semantic value of the relevant expression" (Taylor, 2019, p. 29). But, as mentioned above, semantic features do not represent our total knowledge of the object, property, or event that correspond to the semantic value of individual LIs:"[l]inguistic theory is not the whole theory of human knowledge" (Higginbotham, 1989a, p. 470).

The semantic features of LIs that have been mentioned in the literature are eclectic. I will not attempt to survey them here. As I noted earlier, it would be premature to present a putatively complete inventory of lexical semantic features, given the lack of consensus within minimalism about the right theory of features or their key properties. I will instead point to some of the proposals in the literature to give a sense of the range of semantic features that have been introduced. Then I try to identify some generalizations about these features.

Collins and Stabler (2016, p. 44) list semantic features "pertaining to aktionsart, thematic roles, negation, focus, topic, tense, aspect, quantification, definiteness, plurality, causation." These features are a motley crew, relating to the internal structure of eventualities, the semantic roles of eventuality participants, discourse properties, and numerical notions. Throughout his work, Chomsky has emphasized the rich range of properties, both concrete and abstract, that can be involved in fixing word meaning—lexical features indicating semantic role (such as AGENT, INSTRUMENT, and GOAL)[8], semantic relations between words, and properties of quantifying determiners and anaphora. These meaning-related properties are "expressed in part on the level of semantic representation separate from extralinguistic considerations" (Chomsky, 1979, p. 141, 142)[9]. On this view, particular LIs will be associated with meaning-related properties that are some combination of intralinguistic properties and information about the semantic value of the expression. For example, the lexical entry for the common noun *book* indicates that it is a nominal (rather than verbal) expression used to refer to an artifact, rather than an expression used to refer to a substance like water or a pure abstraction like loyalty, with both material and abstract characteristics (Chomsky, 2000, p. 15, 16).

Semantic features encoded in lexical items are (like phonological features and syntactic features) assumed in minimalism to be part of our biological endowment. They are provided by Universal Grammar, but may be unrealized: individuals and languages differ in what semantic features are involved in fixing meaning (Chomsky, 2003b, p. 277).

The semantic features encoded in lexical entries are assumed to be innate but it is possible that not all lexical semantic properties are provided by the language faculty alone. Some may be drawn from other faculties of the mind such as a "non-linguistic system of common sense understanding" (Chomsky, 1975, p. 42), "a system of beliefs and expectations about the nature and behavior of objects" (Chomsky, 1975, p. 139). That is, lexical meaning is an interface phenomenon, pulling from multiple areas of cognition. Individual LIs are intersectional, "located in a 'semantic space' generated by the interaction of the language faculty and other faculties of the mind" (Chomsky, 1975, p. 42). For example, the semantic value of the common noun *tiger* is a "function of the place of the associated concept in the non-linguistic system of common-sense understanding... though the linguistic system may provide some more abstract semantic properties" (Chomsky, 1975, p. 42).

I take the claim in the previous paragraph (that the semantic properties associated with LIs are intersectional, drawing from a range of cognitive systems) to be an uncontroversial one, but one that makes the task of determining which semantic properties are encoded in LIs, and which are not, challenging. It has long been observed that it is very difficult to determine the line, if any, that separates knowledge of linguistic meaning (expressed as semantic features of LIs in minimalism), strictly speaking, from all-inclusive knowledge of the world, both mental and extramental (Chomsky, 1979, p. 142, 2000, p. 15; Fodor, 1998, p. 44–46; Higginbotham, 1989a, p. 470–471; Taylor, 2019, p. 31). Chomsky (2000, p. 15), discussing the word *book*, observes that there is no good way currently to determine whether a semantic property is part of the lexical meaning of the word (i.e., a semantic feature) or instead attached to the concept associated with the word[10]. In fact, we may be unable, in practice and in principle, to distinguish encyclopedic, worldly knowledge from strictly lexical semantic knowledge, if Quine is correct about our inability to separate convention from fact:

> The lore of our fathers is a fabric of sentences. In our hands it develops and changes, through more or less arbitrary and deliberate revisions and additions of our own, more or less directly occasioned by the continuing stimulation of our sense organs. It is a pale gray lore, black with fact and white with convention. But I have found no substantial reasons for our concluding that there are any quite black threads in it, or any white ones (Quine, 1956, p. 86, 87, quoted in Taylor, 2019, p. 31).

Language change, specifically semantic change (change in the meaning of words over time such as amelioration and pejoration), might give us a handle on the distinction between the lexical semantic features of LIs and encyclopedic,

[8]Harley (2010) presents an overview of different minimalist treatments of argument structure phenomena (i.e., linguistic phenomena that involve the morphosyntactic realization of the core participants in the eventuality an LI like *break* denotes). Some of these treatments dispense with argument structure (as a feature of LIs) entirely, while other treatments have preserved the traditional assumption that semantic roles (like AGENT) are associated with lexical features of some sort.

[9]For example, Chomsky (1975, p. 233) stresses that there might be analytic connections (for example, between *persuade* and *intend*: "*x* persuade *y* to *z*" entails "*y* intend to *z*") that can be accounted for "by virtue of the substructure of lexical features and their general properties", features such as CAUSE, BECOMING, AGENCY, and GOAL.

[10]Glanzberg (2011) distinguishes two sorts of concepts that run in parallel, the linguistic meaning of an LI (encoded representationally in the lexical entry for the LI) and the non-linguistic mental representations that are associated with the LI. He speculates "that a substantial amount of our most sophisticated thinking makes direct use of the meanings of lexical items, rather than the associated non-linguistic concepts." As noted above, certain apparent differences between the conceptual repertoires of human and non-human animals may be a byproduct of lexicalizing concepts as components of LIs, rather than differences in non-linguistic conceptual resources across species ("public use affects private concepts").

meaning-related properties associated with other cognitive faculties. While careful to point out that there isn't a sharp boundary between the different classes of properties associated with LIs, Taylor (2019, p. 167, 168) distinguishes lexical change (e.g., the development from a deontic/obligation interpretation, as in *you must do X*, of an epistemic interpretation, as in *X must be the case*, common to many modal verbs—like the English auxiliary *must*—cross-linguistically) from encyclopedic change, proposing that semantic properties provided by faculties of the mind other than the language faculty might include an evolving set of metaphysical details about the object, property, or event expressed by a particular LI such as *book*. In contrast, semantic features encoded by the lexicon are "to some degree insulated from pressure to change merely as a consequence of our ever-increasing knowledge of the world" (Taylor, 2019, p. 167). If this is on the right track, the way in which different lexical semantic properties behave during language change might help us pinpoint the semantic features encoded in LIs.

Another factor that might help us distinguish encyclopedic knowledge from strictly lexical semantic knowledge when examining a meaning-related property of a linguistic expression is the interaction between that property and other areas of grammar, particularly morphosyntax. An assumption of most work on lexical semantics (see Glanzberg, 2018, p. 205 for references) is that what is crucial to language design and linguistic theory is not so much the distinction between knowledge of (linguistic) meaning and non-linguistic encyclopedic knowledge, but rather a distinction between semantic properties that have systematic morphosyntactic effects and semantic properties that do not (Higginbotham, 1989a, p. 470; Borg, 2012, p. 199)[11]. For example, a condition on middle formation (a construction in which the patient argument of a verb is realized as the subject and the agent is unexpressed) appears to be that the affected argument is construed as physically altered by the action expressed by the verb (Higginbotham, 1989a, p. 471). Compare (1) and (2):

(1) That bread cuts easily

(2) #That bread taps easily

Why certain concepts but not others are co-opted as morphosyntactically potent semantic features (like AGENT or CAUSE) of LIs is unclear, but the recruitment of these concepts as semantic features within the lexicon is taken to explain how and why they impact the morphosyntactic distribution of the LIs they are associated with. As noted above, most accounts of lexical semantics assume that meaning-related information that does not appear to have any impact on the morphosyntactic distribution of LIs is not encoded as a semantic feature. For example, that bread is often made with flour is somehow related to the non-linguistic mental representations (concepts) associated with bread but this information is not enshrined in the lexical entry for *bread* as a morphosyntactically potent semantic feature.

There are many ways to encode morphosyntactically relevant semantic features in LIs[12]. For example[13], Higginbotham (1989a; see also Glanzberg, 2014, p. 278; Higginbotham, 1989b, p. 167; Ludlow, 2014, p. 99 for discussion) proposes that lexical entries include information concerning what the LI is *true of*; he calls this an *elucidation* of the meaning of a word. For example, the lexical entry for the verb *cut* might include the information in (3), from Higginbotham (1989a, p. 467), a combination of information about thematic structure (the semantic roles patient and agent) and properties related to the action of the verb (i.e., an action that impacts the material integrity of the patient) that appear to have systematic grammatical effects, as illustrated by the middle formation example in (1) above.

(3) "cut" is a V that applies truly to situations *e*, involving a patient *y* and an agent *x* who, by means of some instrument *z*, effects in *e* a linear separation in the material integrity of *y*.

Ludlow (2014, p. 99) observes that some aspects of this lexical entry for *cut* might be stable (such as the thematic structure involving an agent, instrument, and patient), while others (e.g., the notion of linear separation) might be modulated by discourse participants in context. I return to this observation in section 2.3 below.

Summing up the discussion so far, within minimalism LIs are associated with a range of meaning-related properties drawn from multiple areas of cognition. Some but not all meaning-related properties are actually encoded in the lexical entries for LIs as semantic features. An assumption within much of the lexical semantics literature is that semantic features are meaning-related properties that have systematic morphosyntactic effects. An account of the evolution of LIs and the lexicon will need an explicit characterization of what those semantic features are. Without that, we have no foundation for an evolutionary account. Further, accounts of language evolution within minimalism will need to explain the human-unique profile of LIs with respect to meaning. Why do LIs have the semantic features they do? That is the topic of the next section.

[11] Fodor and Lepore (2002, p. 99–102) dispute the claim that there are semantic determinants of morphosyntactic distribution; see Fodor (1998, p. 56–64) for related discussion.

[12] In a number of publications, Fodor (e.g., Fodor, 1998, p. 59, Fodor, 2008, p. 28; Fodor and Lepore, 2002, p. 99; see Borg, 2012, p. 187 for an overview of Fodor's critique) criticizes the use of theoretical vocabulary like CAUSE by lexical semanticists because, among other things, the semantics of this vocabulary is typically unspecified: "It is ... notoriously difficult to assess the claimed correlations between lexical semantics and syntactic distribution, because one is never told what the semantic representations themselves mean" (Fodor and Lepore, 2002, p. 99). According to this argument, without a specification of what CAUSE, AGENT, ACT, etc. denote it is not possible to assess whether a particular proposal involving this sort of vocabulary explains the morphosyntactic phenomenon in question (e.g., the middle construction). Although the features that populate semantic representations in lexical semantics work are frequently left undefined, the claim that "one is never told what the semantic representations themselves mean" [emphasis added—BC] is false, though, as Glanzberg (2014, p. 278) points out. For two exceptions (among others) to Fodor and Lepore's claim, see Dowty (1979), who presents an explicit semantics for CAUSE and BECOME (and much else), and Rothstein (2004), who also presents an analysis of BECOME (and much else).

[13] Levin and Hovav (2005) is a comprehensive survey of different approaches to lexical semantic representation. Glanzberg (2018, p. 207, 208) provides further references to a variety of approaches to lexical semantics.

## 2.2. The Determination of Semantic Properties

The previous section tried to get a handle on the range of meaning-related properties associated with LIs within minimalism and which of those properties are encoded in the lexicon as semantic features. Different categories of expressions (nominal, verbal, etc.) tend to be associated with different meaning-related properties. Consider the LI *Rihanna*. According to Chomsky (1975, p. 47), from the fact that *Rihanna* is a proper name, it follows that the entity so designated is assigned to "the natural kind Person (hence Animate)." Consequently, the apparent necessity of statements like *The person Rihanna is an animate object* "follows without any attribution of necessary properties to individuals apart from their designation" (Chomsky, 1975, p. 47). Assuming that this claim has some weight to it, we must address the following question: What ultimately determines the semantic features of proper names like *Rihanna*?

This sort of question is what Stalnaker (1997) refers to as a *foundational semantic* question (mentioned in footnote 5 above). Foundational semantic questions are "about what the facts are that give expressions their semantic value" (Stalnaker, 1997, p. 166, 167). In contrast, a *descriptive semantic* question asks what semantic properties expressions have. Kripke (1972) addresses both types of questions with respect to proper names (see Stalnaker, 1997 for discussion). According to Kripke, the semantic value of a proper name like *Rihanna* is its referent (the individual Rihanna), answering the descriptive question *What is the semantic value of "Rihanna"?* This proper name, *Rihanna*, has the semantic value it does because of a particular sort of causal relation between the name and the referent. The identification and description of this causal relation will be part of an answer to the foundational question *Why does "Rihanna" have as its semantic value the individual Rihanna?*

Taylor (2019, p. 43) discusses the transition from descriptive semantic considerations about semantic values and properties to metaphysical considerations about the natures of those values. In a number of publications, Ludlow (1999, 2003, 2011, 2019) has argued that meaningful use of language involves ontological commitments and that there is a strong connection between semantics and metaphysics, proposing that we can use our knowledge of language to "gain insight into the nature of reality" (Ludlow, 1999, p. 179). On Ludlow's view (and many others; see, e.g., Kennedy and Stanley, 2009), semantic theory is about language-world relations; "semantics and metaphysics have to take place hand in hand" (Ludlow, 2019, p. 16). In contrast, Chomsky has argued (see, for example, Chomsky, 1975, 2003b) that study of how expressions of human language relate to extramental individuals, properties, and events will not yield substantive metaphysical theses (except for theses about the language faculty itself), at least in terms of "the enterprise of natural science" (Chomsky, 2003b, p. 289). (Ludlow, 1999, 2003 replies to some of Chomsky's arguments.) Taylor (2019) argues that natural languages are not "fully metaphysically transparent" (p. 30), providing "only shallow initial knowledge into the ultimate metaphysics of the assigned semantic values" (p. 107) and advocates for "metaphysical modesty" in semantics, although he does not claim that language is "completely metaphysically opaque" (p. 30).

Stalnaker (1997, p. 168, 169), in a helpful discussion of the relationship between semantic frameworks and ontology, argues that "the motivation and commitments of [e.g., the possible worlds framework–BC] are more methodological and conceptual than they are metaphysical" (p. 168). Hobbs (1985) argues for ontological promiscuity on the basis that a less plausible (but linguistically faithful) ontology might have theoretical simplicity as a happy byproduct. Similarly, Gross (2015) observes that supposing semantic features of all sorts "might facilitate the modeling and computation of semantic properties and relations." It doesn't follow from this that the speaker (or the semanticist) is actually committed to the existence in the external world of objects, properties, or events with those properties or involved in those relations. There's much more to be said here, some of which is likely relevant to our understanding of the evolution of words, but I'll set aside questions regarding the relationship between semantics and metaphysics for the remainder of this article.

The goal of semantic theory is typically understood as descriptive (Borg, 2012, p. 160): assign semantic values to LIs and account for how the semantic values of complex expressions are a function of the semantic values of their parts and the way in which those parts are combined (Stalnaker, 1997, p. 166). Semantic theory itself is not (typically understood as being) required to account for the metaphysical character of the semantic properties of LIs. On this conception, semantic theory is required to explain why *Sam smokes* means Sam smokes as a consequence of the semantic value of *Sam* and *smokes*, and the way in which they are combined; it is not expected to tell us why the proper name *Sam* denotes Sam and not Kris or why the verb *smokes* means smokes and not dances.

In contrast, a complete account of language evolution, assuming some form of minimalism, might reasonably be expected to say something about how the meaning-related properties associated with LIs are determined. What makes it the case that certain meaning-related properties of LIs obtain, particularly those properties that are encoded in LIs as morphosyntactically potent semantic features, and not others? Some of the meaning-related properties associated with LIs discussed in the previous section (such as those corresponding to semantic features like CAUSE and AGENT) may have been determined (at least in part) by repeated causal interactions with attributes in the environment during our evolutionary history[14]. Other properties might instead have been fixed primarily by the internal properties of language users or their progenitors, rather than mainly through interactions with features of the extramental environment. Meaning-related lexical properties must be investigated on a case-by-case basis. No single type of account is likely to be explanatory for all semantic features. In the remainder of this section I discuss issues surrounding how to frame foundational semantic questions related to lexical semantics. Let me say up front that while answering these

[14]But Rips (2011) presents evidence that perceptual information alone is not enough to ground notions like causality. (See footnote 6 above.)

questions may be key to understanding the evolution of words they may not be answerable, directly or indirectly, at least with the evidence available and our current methodological toolkit for addressing language evolution.

Chomsky (see, for example, Chomsky, 1995a, 2000, 2003a,b, 2016) has taken a "strictly internalist, individualist approach to language" (Chomsky, 1995a, p. 13), both foundational and descriptive. Individualist[15] inquiry of the sort that Chomsky advocates seeks to understand the internal states of an organism, cognitive structures such as the human language faculty (Chomsky, 1995a, p. 27). The individualist approach involves the postulation of mental entities, representations, but individualist inquiry "need not ponder what is represented, seeking some objective construction from sounds or things" (Chomsky, 1995a, p. 53).

Chomsky's position on semantic properties, in particular, is firmly individualistic. Meaning-related lexical properties enter into "interpretation, thought, and action, but there is no reason to seek any other relation to the world" (Chomsky, 1995a, p. 53). The context for Chomsky's individualism is his long-running opposition to what he has called the *referentialist doctrine* (Chomsky, 2016, p. 42). The central tenet of this doctrine, as Chomsky characterizes it, is that there is a direct relation between LIs and extramental entities (e.g., *London* refers to London), as opposed to "things in some kind of mental model, discourse representation, and the like" (Chomsky, 1995a, p. 24). Chomsky has argued that, in contrast to non-human animal communication systems, "natural language has no referential semantics in the sense of relations between symbols and mind-independent entities" (Chomsky, 2016, p. 48). I will not summarize Chomsky's arguments (Chomsky, 2000, 2016, p. 43f.) against the referentialist doctrine, as they have been nicely summarized elsewhere[16]. (Among other things, Chomsky argues that the referentialist doctrine commits us to implausible individuals like *Joe Sixpack* and *John Doe*.) Borg (2012, p. 155; discussing Collins, 2009) observes that it is "the explanatory redundancy of the external dimension to meaning, from the point of view of semantics, which is at the heart of arguments for internalism."

Looking at the range of properties, such as CAUSE, discussed in the previous section, the meaning-related properties associated with LIs vary in how much of their nature depends constitutively on environmental factors, at least they appear to do so superficially. The determination of at least some of these properties likely involved aspects of the environment of our evolutionarily distant progenitors. Many meaning-related properties externally expressed by linguistic representations appear to be internally represented by some non-human animals. These include the kind BODY, abstract relations like transitivity seemingly grounded in hierarchical social knowledge (e.g., who dominates who), categories and properties of objects (e.g., quality of food and specific predators), discrete numerosities, temporal notions, and spatial notions (see, e.g., Cheney and Seyfarth, 2007; Hurford, 2007; Camp, 2009; Carey, 2009; Burge, 2010).

With the considerations in the previous paragraph in mind, it seems wrong to assume that foundational semantic questions concerning the meaning-related properties associated with LIs, including those enshrined in LIs as morphosyntactically potent semantic features, can and should be given only individualist answers, as Chomsky (1995a, 2000, 2003b, 2016) appears to. As Burge (1989, p. 187; emphasis added—BC) puts it:

> Most empirically applicable concepts are fixed by three factors: by actual referents encountered through experience—one's own, one's fellows', or **one's species ancestors'**, or indirectly through theory; by some rudimentary conceptualization of the examples—learned or innately possessed by virtually everyone who comes in contact with the terms; and by perceptual information, inferential capacities, and kind-forming abilities, that may be pre-conceptual.

The individuation of many of the concepts (such as CAUSE, BODY, and ANIMATE) that underpin the semantic properties (both encyclopedic properties and morphosyntactically-relevant ones) that we associate with linguistic expressions likely depend on direct or indirect relations to the extramental environment, by us or our progenitors. An anti-individualist perspective might help us address foundational lexical semantic questions.

The central claim of anti-individualism is that:

> The natures of mental states that empirically represent the physical environment depend constitutively on relations between specific aspects of the environment and the individual, including causal relations, which are not in themselves representational; the relevant environment-individual relations help determine specific natures of the states (Burge, 2010, p. 61).

Anti-individualist explanations play a large role in a number of cognitive domains; e.g., visual perception (Burge, 2007a, 2010). The study of visual perception involves the development of empirical theories that are concerned with how visual perception works, seeking to uncover psychological laws. Discussing work on the nature of visual representations and the processes by which they are derived, Chomsky (1995a, p. 52) argues that "the account is completely internalist." Visual representations, according to Chomsky, are not to be understood relationally, as "representation of" (Chomsky, 1995a, p. 53).

This is an inaccurate characterization of visual perception and its investigation. Burge (2010, p. 98–101; see also Burge, 2003, p. 463–465) agrees that visual psychology as a discipline is primarily focused on explaining processes but argues that the methodology (such as perceptual reports) and the characterization of psychological laws in visual psychology presuppose anti-individualism (i.e., kinds are individuated by

[15]*Individualist* (*individualism*, *individual*) is used seemingly interchangeably with *internalist* (*internalism*, *internal*), and *anti-individualist* (*anti-individualism*, *anti-individual*) with *externalist* (*externalism*, external) in the philosophical literature that I am familiar with. An explicit distinction between (analogs to) individualism and anti-individualism seems to be rarely made in the linguistics literature, mostly likely because descriptive concerns are often primary. I use the terms *individualist* (*individualism*, *individual*) and *anti-individualist* (*anti-individualism*, *anti-individual*) in what follows for reasons discussed by Burge (2007b, p. 154).

[16]See especially Ludlow (1999, Appendix P2, 2003) and Stainton (2006).

representational content)[17]. Environment-individual relations help determine the specific natures of visual representations. The psychological kinds indicated by explanations in visual psychology "can be understood only in an anti-individualistic framework" (Burge, 2010, p. 101). The same is true of the meaning-related representations associated with LIs in lexical semantic work, if our focus is on how those representations are ultimately determined.

Anti-individualism about (certain) semantic properties does not reject the view that meaning is "in" the mind/brain (Burge, 2003, p. 455; see also Burge, 2007b, p. 154; Burge, 2010, p. 64). On an anti-individualist view, the relation between linguistic expressions and semantic values does not make explicit reference to objects, properties, or events in the extramental world. Rather, from an anti-individualist perspective, the natures of certain semantic properties "depend on relations that are not reducible to matters that concern the individual alone. But the natures are not themselves relations, and their representational contents are not themselves (in general) relational" (Burge, 2010, p. 154). While some mental states and their content (semantic properties) are constitutively dependent on relations between the individual and the environment, elements of the environment (entities, properties, or events) are not part of (or part of a relation to) the mental state or the state's representational content. Anti-individualism does not assert a direct connection to the extramental world in the mind/brain of the language user.

Some linguists, such as Jackendoff (2007, p. 353), appear to be confused about this aspect of anti-individualism. Jackendoff has long advocated a "cognitive perspective" on linguistic meaning (see Jackendoff, 2012 for a recent expression of this view), arguing that meanings have to be in the heads of speakers rather than out in the world (Jackendoff, 2012, p. 44). Jackendoff explicitly contrasts his view with the view of anti-individualists like (Putnam, 1975). However, like anti-individualist investigations of word meaning, Jackendoff is interested in explaining how the meaning of a word or sentence, something in the head of a language user, can connect with the world (Jackendoff, 2012, p. 49, 50). Anti-individualism provides us with a framework in which we can develop an answer to this sort of foundational semantic question.

To sum up the discussion so far, some foundational lexical semantic questions (such as how semantic features like CAUSE are determined) likely have anti-individualist answers. (The questions themselves are, in fact, probably coherent only in an anti-individualist framework.) Many meaning-related properties of linguistic expressions appear to be non-individualistically individuated: "What a word means, even in an individual's idiolect, can depend on environmental factors, beyond an individual's body, considered as a molecular structure" (Burge, 1989, p. 178). For example, the nature of semantic features such as CAUSE presumably depend at least partly on the perception of patterns (by us, by our conspecifics, by our evolutionarily distant progenitors) in the environment that are independent of the language faculty[14].

Some meaning-related properties of LIs are likely the result of causal interactions with the extracranial, distal environment over centuries by one's progenitors (see Burge, 2010, p. 346 for a similar comment regarding how the perceptual system came to mirror environmental regularities). Others may result from linguistic interactions with one's conspecifics during individual development.

The adjustment of lexical meaning during conversation might give us a window into how some meaning-related lexical properties are determined during individual development. Lexical meanings are underdetermined in that "there is no complete answer to what does and doesn't fall within the range of a predicate like 'red' or 'bald'" (Ludlow, 2014, p. 5). The semantic features encoded in lexical entries consist of "just hints and clues ... that may help us deploy resources to flesh out word meanings" (Ludlow, 2014, p. 80). There is no privileged core meaning. For example, the meanings of the verb *know* and the noun *knowledge* might be quite a bit more constrained in an epistemology course than in a non-academic conversational context (Ludlow, 2014, p. 5). In some fashion, the lexical entry for the verb *know* encodes that the eventuality it denotes includes an agent and the content of a belief, but contains also "argument places for standards of justification and evidence, for subjective certainty of the report, for the reporter's responsibility for having and defending the knowledge, the source of the knowledge, and the mode of presentation of the content of the knowledge report" (Ludlow, 2014, p. 141, 142). The meaning of *know* is adjustable in context along many different dimensions and ultimately a product of collaborative effort between interlocutors. Ludlow argues that there are norms of word meaning litigation (e.g., "modulations should not be too taxonomically disruptive,"[18] Ludlow, 2014, p. 48).

We expect the content of anti-individualist explanations to vary depending on the sort of expression we are investigating. The semantic properties of certain types of expressions, e.g., natural kind terms (such as *tiger*) and proper names, may be less closely associated with direct perceptual interactions with the environment, depending more so on the cognitive resources of other members of the social environment than the speaker's perception of external entities, properties, and events (Putnam, 1975; Burge, 1979, 1989, p. 185; Glanzberg, 2018, p. 201).

Anti-individualist work has presented strong arguments that some semantic properties associated with LIs and complex linguistic expressions are constitutively dependent on certain patterns in the social and physical environment "in the evolution of the species as well as in the experiential history of the individual" (Burge, 1989, p. 179). Other semantic properties might instead have primarily individualist explanations. For example, Glanzberg (2018, p. 215) argues that certain verb meanings (e.g., the verb *kill*) might be well-served by an individualist approach, their extensions fixed

[17] Kennedy and Stanley (2009) make a similar remark about the methodology of natural language semantics, although they do not directly discuss externalism/anti-individualism.

[18] Ludlow (2014, p. 41–51) proposes this particular norm of word meaning litigation in the context of a discussion of the word *planet*. See also Jackendoff (2012, p. 60, 61) on *planet*.

by theories that speakers represent mentally. Individualism might also give us a better handle than anti-individualism on certain intralinguistic phenomena (e.g., semantic relations like synonymy and polysemy; patterns of syntactic distribution which seem to demand semantic explanation like the middle construction; and verb relations such as that between *persuade* and *intend*). There is no reason to think that lexical properties have an uniformly individualist or uniformly anti-individualist explanation. An anti-individualist explanation may be appropriate for some meaning-related properties of LIs but not others[19].

To recap, the previous section discussed what semantic properties are associated with LIs, a descriptive semantic question, whereas this section asked how the semantic properties of LIs are determined, a foundational semantic one. An evolutionary account of LIs within minimalism needs to address both questions. But they must be distinguished. It is implausible that all of the semantic features that populate our accounts of word meaning are individuated solely internally without any reference to the external world. Certain, perhaps many, semantic properties are ultimately typed by relations that individuals (us, our conspecifics, our evolutionarily distant progenitors) have borne to their environment. Anti-individualism provides a framework for thinking through what explanations of the constitutive dependence of certain lexical properties on the extramental world might look like, even if the explanatory goals are currently out of reach, given the evidence available, both in practice and perhaps even in principle.

## 2.3. The Structure of Lexical Entries

The previous two sections discussed the taxonomy of lexical semantic features and their grounding. Ultimately, word meanings must "exhibit the format required by the composition operations that correspond to phrasal syntax" (Pietroski, 2010, quoted in Borg, 2012, p. 174). On the assumption that the meaning of a complex expression is determined by the meaning its parts and the way in which those parts of combined—the assumption that natural language meaning is compositional—word meanings must be composable. I'll call this the *compositionality constraint*[20].

The compositionality constraint will influence our account of the relationship between word meaning and the internal structure of LIs. In the introduction to this section, I characterized the minimalist lexicon as a set of LIs, where each LI is a triple ⟨SEM, SYN, PHON⟩. SEM and SYN are (possibly empty) subsets of the sets of semantic and syntactic features provided by Universal Grammar, while PHON is a string of segments, possibly null, where each segment is a bundle of features (like VOICE). On this view of LIs, it is non-obvious how to relate an instance of SEM (i.e., a set of features presumably resembling something like, for example, {MANNER OF MOTION, CONTACT, . . .}) to a semantic value viable within a compositional semantic system like the ones presented in Heim and Kratzer (1998) and Jacobson (2014).

In this section I consider the internal structure of LIs. Borrowing terminology introduced by Glanzberg (2011, 2014, 2018), I discuss how concepts might be *packaged* into lexical entries as semantic features. As discussed earlier, lexical meaning appears to package concepts from a range of cognitive domains as semantic features of LIs. I'll call the process of packaging concepts into LIs as semantic features *lexicalization*[21]. The main goal of this section is to explore what some of our packaging options are and the consequences of these options for our accounts of the evolution of words. I start with a discussion of the conceptual atoms approach advocated for by Fodor in various publications and then turn to a brief case study of Glanzberg's (2011, 2014, 2018) pointers and packaging approach, an approach to lexical semantics that attempts to address the descriptive and foundational semantic questions explored earlier in this article.

Fodor and Lepore (2002, p. 90; see also Fodor, 1998, 2008; Fodor and Pylyshyn, 2015) advocate for conceptual atomism, the view that the semantic component of lexical entries (typically) lacks internal structure, taking this to be a "sort of null hypothesis." On this view, a lexical entry simply specifies the semantic value (referent) of the corresponding LI rather than specifying, for example, a set of satisfaction conditions, a set of semantic features as in minimalism, or an elucidation of the sort described by Higginbotham (1989a, 1989b) (discussed in section 2.1). For example, according to Fodor and Lepore's view, the semantic component of the lexical entry for *cat* states that *cat* refers to cats (rather than containing, for example, a set of semantic features along the lines of {ANIMAL, . . .} that gives some indication of lexical meaning); the lexical entry for *Rihanna* states that *Rihanna* refers to Rihanna; the lexical entry for *dance* states that it refers to dancing, etc.

Conceptual atomism fairs quite well with respect to the compositionality constraint, as Fodor (2008, p. 16) argues. Reference is the only mind-world semantic property of the language faculty on this approach (there are no meanings, no senses, etc.). There are just two kinds of reference relations in the system: reference to individuals (by singular terms) and reference to properties (by predicates). As Fodor (2008, p. 199) observes,

[19] Fodor (1998) speculates about how interactions between individuals and the environment might result in the acquisition of concepts that can be labeled, proposing what he calls the *locking model of concept possession* (see also Fodor, 2008). Stainton and Viger (2000) present a helpful exegesis of Fodor's model (see also Borg, 2012, p. 195 for brief discussion). Roughly, an individual acquires a concept when a form (a neural structure) within a person's brain becomes "locked" to an extramental entity, property, or event "through brute causal interaction with the environment" (Stainton and Viger, 2000, p. 142). On this view, there are few, if any, innate concepts (cf. Fodor, 1975). Prinz (2002, p. 228–235) critiques Fodor's accounts of concept acquisition. Carey (2009) and Rips (2011) both contain thoroughgoing discussions of concept acquisition.

[20] I think that I'm borrowing the name of this constraint from Davidson by way of Fodor and Lepore.

[21] The term *lexicalization* has a range of more-or-less related uses in the language evolution and historical linguistics literature. It has sometimes been used to refer to the synchronic process of associating concepts/conceptual structure with forms (sounds, gestures, etc.) to create symbols. Boeckx (2011, p. 53) describes lexicalization as a key step in the evolution of syntax: the endowment of concepts with properties (so-called *edge features*) that make them active syntactically, combinable with virtually any other concept. Within the historical linguistics literature (see, for example, Brinton and Traugott, 2005), *lexicalization* has been broadly defined as a diachronic process involving the addition of LIs to the lexicon.

hardcore "internalists" like Chomsky (see, e.g., Chomsky, 2000) and Jackendoff (see, e.g., Jackendoff, 2012) appear to have an even simpler conception of the semantic component of lexical entries. On their view, lexical entries do not specify semantic values at all (i.e., LIs do not encode mind-world relations), although both Chomsky and Jackendoff assume that LIs are related in some fashion to cognitive structures outside of linguistic competence.

There are several limitations to the conceptual atomist view of the semantic component of lexical entries. First, the conceptual atomist view has no way to account for the claim (discussed in section 2.1) that there are semantic determinants of morphosyntactic distribution (see, e.g., Higginbotham, 1989a; Glanzberg, 2011 for references)[22]. Second, the frugal nature of conceptual atomism does not provide us with any resources to group expressions into different semantic categories (such as a category of manner of motion expressions like *crawl*, *run*, *tumble*, ...) through semantic properties (Borg, 2012, p. 194)[23].

To account for the syntactic reflexes of semantic properties and other linguistic phenomena, most approaches to the lexicon (as in minimalism) assume that lexical entries are associated with meaning-related information beyond a simple specification of the LI's semantic value. This is true even of conceptual atomists like Fodor, if you look closely. As discussed in footnote 6 above, Fodor (1998, p. 63) makes a distinction between lexical entries that contain semantic features (i.e., lexical entries that contain bundles of semantic features like SEM) and lexical entries that have meaning-related properties attached to them. Fodor allows for the latter in his atomist view of the lexicon.

Borg (2012, p. 193f.) advocates for a lexicon of the sort that Fodor has in mind, a lexicon comprising lexical entries each of which may have a set of semantic properties attached to them (indicating the semantic class of the LI and any features which affect the LI's syntactic distribution) but possess internally a word-denotation pair (mind-world mapping) alone as their semantic component. For example, the semantic component of the lexical entry for *ready* (as in *Sam is ready*) simply specifies that the referent of *ready* is the property "readiness." Attached to the lexical entry, though, is additional information about how to construct the logical form of sentences that contain *ready* (Borg, 2012, p. 203). Burge (1989, p. 181) makes a related distinction between a lexical item (what Burge calls "the word") and "the explication of its meaning that articulates what the individual would give, under some reflection, as his understanding of the word" (what Burge calls the "entry for the word"). Similarly, Burge distinguishes between "the concept associated with the word and the concept(s) associated with the entry", calling the latter "the conceptual explication" (p. 181).

Glanzberg (2011, 2014, 2018) treats lexical meaning as an interface phenomenon: "semantic competence is only a partial determinant of content" (Glanzberg, 2014, p. 277), at least in the case of lexical vocabulary like nouns and verbs (in contrast to functional vocabulary like quantifying determiners). The semantic component of lexical entries comprises (i) elements of semantic competence and (ii) a pointer to an element in cognition (e.g., a concept) outside of linguistic competence (see Pietroski, 2018 for a somewhat similar view). While lexical entries point to other areas of cognition, they are fully in the faculty of language. Following Glanzberg, I will call this the "pointers and packaging" approach. A key property that distinguishes the pointers and packaging approach from the approaches discussed in the last several paragraphs (e.g., Borg's, 2012 view of the lexicon) is that reference to cognitive structures outside of the language faculty is explicitly encoded within lexical entries through the mechanism of a pointer (rather than, for example, via semantic features attached to lexical entries, as in Fodor's and Borg's characterizations of the lexicon).

Formally, lexical entries split into a structural frame and a pointer. (In what follows, I use italicized capitals to indicate the name of pointers that appear in lexical entries). (4) (from Glanzberg, 2011) gives the semantic component of the lexical entry for the verb *open*. In (4), the structural frame describes the type of event that *open* denotes in terms of a combination of structural elements like CAUSE and BECOME. The pointer "*OPEN*" in (4) indicates the specific, idiosyncratic aspect of the meaning of *open*, pointing to broader conceptual resources outside of linguistic competence[24]. Glanzberg (2011, 2014, 2018) discusses how the pointers and packaging approach fits into a compositional account of semantic competence.

(4) *open*: [[*x* ACT] CAUSE [BECOME *y* ⟨*OPEN*⟩]]]

The structural frame in lexical entries, like that for *open* in (4), plays an important role in addressing some the issues raised in section 2.1. It gives the grammatically relevant components of lexical meaning, assuming that there are semantic determinants of morphosyntactic distribution (as in middles like *the bread cut easily* and resultatives like *Sam pounded the metal flat*). With other work in lexical semantics (see Levin and Hovav, 2005), the pointers and packaging approach assumes that there is a finite set of structural elements like CAUSE and BECOME and that there are constraints on how these structural elements can be combined.

Glanzberg (2011) discusses the nature of structural elements like CAUSE that appear in lexical semantic representations.

[22] Although, as I pointed out earlier, Fodor (1998) and Fodor and Lepore (2002, p. 99–102) dispute the claim that there are semantic properties of this sort. Hence, on their view, there is no need for lexical semantic features (e.g., CAUSE) like those proposed by lexical semanticists. The challenge for this position is to then account for the massive lexical semantics literature that suggests otherwise.

[23] Fodor and Lepore (2002) ultimately settle, however, on a more complex structure for the semantic component of lexical entries. In addition to specifying the referent of the LI, some lexical entries include a composition rule that plays a role in determining the logical form of phrases of which the LI is a constituent (Fodor and Lepore, 2002, p. 113). For example, the lexical entry for *want* contains a composition rule that ensures that the compositional semantics assigns the interpretation 'wants to have NP' (e.g., "wants to have a drink") to phrases of the form *wants NP* (e.g., *wants a drink*).

[24] Glanzberg (2014, p. 281) observes that "there is nothing particularly internalist about this interface picture." Whatever pointers point to elsewhere in cognition must ultimately play a role in providing a semantic value for the corresponding LI. An explanatory account of how this aspect of the content of an LI is determined could be individualist or anti-individualist depending on the target of the pointer.

These elements are part of the language faculty proper. Consequently, the element CAUSE, for example, is not to be identified with the word *cause* or the intuitive concept of causation. There is solid evidence against identifications of this sort. For example, it has long been observed that CAUSE (argued to be a component of the lexical semantic representations of the meanings of verbs like *break* and *open*) is more restricted than the intuitive concept of causation (e.g., Dowty, 1979). Compare (modifying a minimal pair presented in Glanzberg, 2011): *I caused the glass to break, by paying Sam to throw it against the wall* and *#I broke the glass, by paying Sam to throw it against the wall*, suggesting that CAUSE (when a component of the structural frame for a verb like *break*) expresses something akin to direct causation.

Pointers give LIs their distinctive content, pointing to mental representations that live outside of the faculty of language. They are the source of the encyclopedic, worldly information associated with LIs. The pointers and packaging model, as such, is not susceptible to some of the same criticisms that Fodor (1998, 2008; also Fodor and Lepore, 2002) presents against decompositional/definitional approaches to concepts. The extralinguistic concepts that LIs interface with through pointers are linguistically atomic, at least as far as the theoretical characterization of semantic competence is concerned (Glanzberg, 2014, p. 282, 284)[25].

The pointers and packaging approach also provides us with a way to capture Rips's (2011, p. 163–164) distinction between representation about and representation of a category. Mental representation about a category (like towel, padlock, or daisy) gives all the information we have about the category, whereas mental representation of a category is just an unchanging atomic symbol. The pointer "*OPEN*" in the structural frame for *open* in (4) is a mental representation of whatever (complex or simple) outside of language cognition corresponds to the idiosyncratic aspect of the meaning of *open*.

To review, within minimalism, lexical entries are internally complex, containing semantic, phonological, and syntactic information. Lexical meaning itself is multidimensional. On the one hand, LIs typically express idiosyncratic content distinct from that of other LIs. On the other hand, LIs appear to be associated with semantic features that, among other things, influence their morphosyntactic distribution. The pointers and packaging approach is one way to organize these dimensions within lexical entries and address the compositionality constraint discussed at the beginning of this section.

From the standpoint of a minimalist account of the evolution of words, though, a lexicon consisting of internally structured lexical entries presents a challenging puzzle, whether the structure of those entries is a triple ⟨SEM, SYN, PHON⟩ of the sort assumed by much work in minimalism or has the form proposed in the pointers and packaging approach. As discussed in the introduction to this section, many non-human animals appear to have concepts and some of these concepts appear to be similar to those that populate human cognition. But the signals that populate animal communication systems (like predator-specific alarm calls) do not appear to have anything like the internal structure of LIs nor do they express similar content. Accounting for the emergence of internally complex LIs is a significant open problem in our understanding of language evolution.

[25]Wellwood (2019, p. 194) observes a potential limitation of the pointers and packaging approach. If pointers connect LIs to domain-specific concepts outside of the language faculty, then how does the generality that human language affords thought emerge? As Wellwood puts it (p. 194): "If all we supposed was that linguistic meanings link pieces of syntax with concepts that, in many cases, are domain-specific and isolated from other ones, it would be difficult to see how that kind of generality could ever emerge."

## 3. WHERE NOW?

In the introduction I mentioned the *criterion of evolvability*: "any mechanisms and primitives ascribed to UG rather than derived from independent factors must plausibly have emerged in what appears to have been a unique and relatively sudden event on the evolutionary timescale" (Chomsky et al., 2017). This criterion imposes limitations on our account of LIs and the lexicon. Minimalist approaches to LIs (of the sort reviewed here) assume that LIs have a complex internal structure, consisting of three set of features (phonological, semantic, and syntactic). If we focus our attention on the semantic properties associated with LIs, it's quite possible that lexical entries are even more complex than the view that I presented in the introduction indicates. It's not clear how to reconcile this with the criterion of evolvability[26].

In the main body of this article I addressed three questions: what (meaning-related) properties are associated with LIs, assuming a minimalist view of the human language faculty, how are those properties determined, and what is the internal structure of lexical entries? A range of properties appear to be associated with LIs, but not all of those properties are encoded in the lexicon as semantic features. Work on lexical semantics suggests that semantic features should be limited to features that affect the morphosyntactic distribution of the corresponding LIs. Distinguishing between descriptive semantic and foundational semantic questions, and anti-individualist and individualist answers, provides a way of thinking about what questions we might ask about the nature of those features (e.g., CAUSE) within the context of language evolution. The pointers and packaging approach to the lexicon suggests how we might couple semantic features with a mechanism that accounts for the distinctive content of individual LIs and the observation that lexical meaning is an interface phenomenon, while maintaining a relatively simple conception of the lexicon. Giving some thought to how this approach to the lexicon fits into a broader account of language evolution might move us a step closer to understanding what we can and cannot learn about the evolution of our capacity for language.

[26]On the assumption that an account of the evolution of words must satisfy this criterion.

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I have profited from the comments of Noam Chomsky and three reviewers for *Frontiers in Psychology*. Errors and obfuscations remain my own.

## AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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# Human Linguisticality and the Building Blocks of Languages

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This paper discusses the widely held idea that the building blocks of languages (features, categories, and architectures) are part of an innate blueprint for Human Language, and notes that if one allows for convergent cultural evolution of grammatical structures, then much of the motivation for it disappears. I start by observing that human linguisticality (=the biological capacity for language) is uncontroversial, and that confusing terminology ("language faculty," "universal grammar") has often clouded the substantive issues in the past. I argue that like musicality and other biological capacities, linguisticality is best studied in a broadly comparative perspective. Comparing languages like other aspects of culture means that the comparisons are of the Greenbergian type, but many linguists have presupposed that the comparisons should be done as in chemistry, with the presupposition that the innate building blocks are also the material that individual grammars are made of. In actual fact, the structural uniqueness of languages (in lexicon, phonology, and morphosyntax) leads us to prefer a Greenbergian approach to comparison, which is also more in line with the Minimalist idea that there are very few domain-specific elements of the biological capacity for language.

**Keywords: linguisticality, universal grammar, language faculty, convergent evolution, cultural evolution, natural kind entities**

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## INTRODUCTION

This paper makes two interrelated claims and embeds them in ongoing discussions in linguistics and some adjacent areas:

(i) Humans' biological capacity for language (=human linguisticality) is best studied from a broadly comparative perspective – comparing species, capacities, and languages.
(ii) The comparison of languages does not lead to immediate insights about human linguisticality, because languages have a very diverse range of building blocks whose similarities do not appear to be rooted in innate natural kinds.

That biolinguistics (=the study of the biological capacity for language) should adopt a broadly comparative perspective seems such an evident suggestion that it need not be mentioned, but *de facto*, the term "biolinguistics" has come to be associated with the ideas of a single scholar, Chomsky[1], and much work in the Chomskyan tradition does not take a broadly comparative perspective. The vast majority of linguists working in the generative-grammar tradition consider

[1] For example, the "Biolinguistics Manifesto" (Boeckx and Grohmann, 2007) mentions Chomsky's name in the first line, and seven times in the first paragraph (see also Di Sciullo and Aguero-Bautista, 2016, where biolinguistics is likewise closely linked to the Chomskyan approach, as well as Martins and Boeckx, 2016a,b: §2.6). Since Chomsky's ideas are highly contentious and polarizing, many linguists will not want to be associated with the term *biolinguistics*, even though it is in principle neutral and transparent (like *biomusicology*, *bioacoustics*, *biomechanics*, etc.).

only humans, only the capacity for language, and in addition, like most other linguists, they tend to focus on a single language.

Still, linguists who work on a single language tend to emphasize the broad implications of their work. In a recent introductory textbook on syntax, for example, the authors write that linguists are motivated by "the desire to understand the human brain." (Koeneman and Zeijlstra, 2017: 3), even though their textbook talks almost exclusively about English syntax. Thus, here I emphasize the diversity of languages, and I note that their comparison is not at all straightforward. We cannot simply use the building blocks as established on the basis of Latin, English, or Chinese, and carry them over to all other languages. And even if we compare many different languages, it is not clear if our results contribute to "understanding the human brain" or other aspects of human biology.

This point is often underappreciated, even by many linguists who work on diverse languages. I conclude that biolinguistics must become much broader if it wants to go beyond speculation and gain lasting insights into the biological foundations of human language.

In the next section, I explain why I use the new term "linguisticality" for the human capacity for language, and how it relates to other widely used terms ("faculty of language," "universal grammar"). Then I elaborate on the need for a broadly comparative perspective, before coming to the central point, the diversity of the structural building blocks of languages.

## HUMAN LINGUISTICALITY, THE "LANGUAGE FACULTY" AND "UNIVERSAL GRAMMAR"

Linguisticality is the set of capacities that allows humans to learn and use languages in all their diverse forms (spoken, signed, written, vernacular, whispered, sacred, in song lyrics, in proverbs, in language games, and so on). Since linguisticality is a species-specific capacity and is invariant across the entire human population, it is appropriately studied from a biological perspective (in what might be called biolinguistic inquiry; but see n. 1).

The term *linguisticality*, introduced in this paper, was formed on the analogy of the term *musicality*[2], which is used by musicologists to refer to the human capacity for music. For example, Honing (2018) says (see also Trehub, 2003):

> "Over the years, it has become clear that all humans share a predisposition for music, just like we have for language. all humans, not just highly trained individuals, share a predisposition for music in the form of musicality – defined as a spontaneously developing set of traits based on and constrained by our cognitive abilities and their underlying biology."

It may seem strange to propose a completely new term, linguisticality, for such a basic phenomenon, after hundreds of years of language study. And of course, many scholars have talked about linguisticality, but there is no other single term that could be used to make it clear exactly what is meant. Some authors talk about the "capacity for language" (as I did in (i) above), or the "language capacity" (e.g., Jackendoff, 1999), and these are certainly good alternative terms.

But many others simply use "language," and this word is too vague. "Language" can refer to particular languages (sets of conventions used by particular speech communities), or to the use of a language in speech, or to the entire domain of phenomena related to language use and language systems. As an example of this vagueness, consider the expression "language evolution": This can refer to the (biological) evolution of linguisticality, or to the (cultural) evolution (or diachronic change) of particular language systems. To be on the safe side, Jackendoff (1999) talks about "the evolution of the language capacity." It would be clearer to distinguish between (biological) "evolution of linguisticality" and (cultural-diachronic) "evolution of languages"[3].

The human capacity for language is in many ways like an instinct, and Pinker (1994) used "language instinct" as a book title. But much more common is another term: "language faculty." This term seems to go back to Saussure's (1916) *faculté du langage*, but nowadays, it is often used in a much narrower sense. While Rizzi (2004) continues the Saussurean tradition and uses it in the same sense as linguisticality[4], many other authors use "language faculty" (or "faculty of language") for a domain-specific cognitive module (sometimes called "the language organ," Anderson and Lightfoot, 2002)[5]. For example, Chomsky et al. (2019) say at the beginning of their paper about the language faculty:

> "Generative Grammar (GG) is the study of the linguistic capacity as a component of human cognition."

If the language faculty is what generative grammarians study, then it must be the hypothesized domain-specific cognitive module, because generative grammarians do not (in practice) study domain-general aspects of human cognition and human

[2]The analogy is *music/musical/musicality = language/linguistic/linguisticality*. To be sure, the term *musical* not only means "music-related" (just as *linguistic* means "language-related"), but also "capable of making/enjoying music," whereas *linguistic* does not have this sense (presumably because every human is "linguistic"; though infants are often called *prelinguistic*). The term *linguisticality* is thus not completely transparent. (It should be noted here that "linguistic" is also sometimes used as an adjective for *linguistics*, the discipline of language study. Linguisticality should of course be understood in the first sense. Thus, in a language like German, which distinguishes between *sprachlich* "language-related" and *linguistisch* "linguistics-related," the counterpart of *linguisticality* is *Sprachlichkeit*.)

[3]Often, such vague terminology does not do any harm because the context makes it clear what is intended, but in this particular case, there is a serious problem – so much so that it is unclear what is in the scope of the *Journal of Language Evolution* (biological evolution, or cultural evolution, or both?). In response to a critical blogpost of mine (https://dlc.hypotheses.org/894), the editors changed the wording of the Aims and Scope statement, but it is still not very clear.

[4]"[The fundamental object of inquiry is] "the language faculty," the "instinctive tendency" for language, according to the terminologies used by Ferdinand de Saussure and Charles Darwin, respectively: a cognitive capacity rooted in the biological endowment of our species which allows us to acquire the natural language(s) we are exposed to in childhood and use it for communication, social interaction, and the expression of thought" (Rizzi, 2004: 323).

[5]Compare also the following quotation: "The faculty of language can reasonably be regarded as a "language organ" in the sense in which scientists speak of the visual system, or immune system, or circulatory system, as organs of the body" (Chomsky, 2000: 4).

auditory and articulatory abilities, which are also part of human linguisticality. This narrow understanding of the term "language faculty" was also used in 1978 in the famous "GLOW Manifesto" (by Jan Koster, Henk van Riemsdijk, and Jean-Roger Vergnaud):

> "It appears quite likely that the system of mechanisms and principles put to work in the acquisition of the knowledge of language will turn out to be a highly specific "language faculty"."[6]

And non-Chomskyan authors who find the evidence for a domain-specific module insufficient sometimes even say that they reject the language faculty, e.g.,

> "the language faculty is, quite literally, empty: natural language emerges from general cognitive constraints, and. there is no innately specified special-purpose cognitive machinery devoted to language" (Christiansen and Chater, 2015: 1–2).

Christiansen and Chater do not, of course, reject the existence of human linguisticality – they would merely say that the human capacity for language consists of multiple different subcapacities that are not specialized for language, at least not for morphosyntax (they do accept that there may be a specialized capacity for speech processing; Lieberman, 1984).

In addition to this ambiguity of the term "language faculty" [referring to (i) linguisticality or (ii) to a hypothesized domain-specific cognitive module], additional confusion was created by Hauser et al. (2002), who introduced a distinction between "the faculty of language in the broad sense (FLB)" and "the faculty of language in the narrow sense (FLN)." The first, FLB, is the same as linguisticality[7], but the second is much less clear ("FLN is the abstract linguistic computational system alone, independent of the other systems with which it interacts and interfaces"). The authors emphasize the special importance of recursion and suggest that "FLN only includes recursion," which would mean that it is not domain-specific (see the discussion in Scholz et al., 2011: §2.3). Thus, FLN cannot be the same as the hypothesized domain-specific cognitive module (or language organ).

Finally, the term "universal grammar" (often abbreviated as UG)[8] has often been used in this context by Chomskyans, but this is not an unambiguous term either. Most commonly, linguists use it for the set of building blocks (features, categories, and architectures) that they hypothesize to be innate:

> "Universal grammar consists of a set of atomic grammatical categories and relations that are the building blocks of the particular grammars of all human languages, over which syntactic structures and constraints on those structures are defined. A universal grammar would suggest that all languages possess the same set of categories and relations." (Barsky, 2016)

Chomskyan linguists rarely commit themselves to specifying exactly which categories they assume to be innate (see section "The Structural Uniqueness of the Building Blocks")[9], but the entire enterprise is built on these assumptions, because otherwise there would be no justification for using different criteria for different languages (cf. Croft, 2009). And at least for segmental features, there have been some very concrete proposals for UG features since the 1950s (the distinctive features of phonology, first proposed by Jakobson, Halle, and Chomsky). Moreover, there are many architectural proposals for the language system (e.g., the earlier distinction between deep structure and surface structure, or ideas about the ways in which phonology, syntax, and the lexicon interact), which are widely thought to be due to innate structures.

Since there is no doubt about the biological basis of human linguisticality, it is perfectly possible that not only the instinct to communicate, to imitate and to extract patterns from observed speech signals is innate, but that also a substantial number of specific structural building blocks (features, categories, and architectures) are in place before children start hearing their caretakers speak. The capacity for language would be like the capacity for taste, where culture-specific taste categories (which enable culture-specific recipes and cuisines to exist and to be transmitted) coexist with (and have an ultimate basis in) five innate basic taste categories (sweet, sour, salty, bitter, umami).

But in addition to this first ("innate categories") sense of "universal grammar," there is also a second sense, where UG is roughly synonymous with "domain-specific aspects of linguisticality":

> "No known 'general learning mechanism' can acquire a natural language solely on the basis of positive or negative evidence, and the prospects for finding any such domain-independent device seem rather dim. The difficulty of this problem leads to the hypothesis that whatever system is responsible must be biased or constrained in certain ways. Such constraints have historically been termed 'innate dispositions,' with those underlying language referred to as 'universal grammar.' Although these particular terms have been forcibly rejected by many researchers, and the nature of the particular constraints on human (or animal) learning mechanisms is currently unresolved, the existence of some such constraints cannot be seriously doubted." (Hauser et al., 2002)

This formulation is much more careful and vague than the earlier quote from Barsky (2016). Hauser et al. (2002) apparently do not want to commit themselves to more specific claims here, but they still use the term "universal grammar." In the above passage, they define UG as the domain-specific capacity to acquire a language, so if one doubts the existence of domain-specific components of linguisticality, one can say that there is a "UG hypothesis" (e.g., Dąbrowska, 2015), and that one regards this hypothesis as "dead" (e.g., Tomasello, 2009). But there is also a third sense of UG, where it is the same as the "(broad)

[6] https://glowlinguistics.org/about/history/manifesto/

[7] "We take as uncontroversial the existence of some biological capacity of humans that allows us (and not, for example, chimpanzees) to readily master any human language without explicit instruction" (Hauser et al., 2002: 1571).

[8] Sometimes the upper-case spelling "Universal Grammar" is used, maybe to match the abbreviation (UG), or maybe to make it clear that this is an opaque term that is not meant to refer to a "grammar" that is "universal."

[9] With some exasperation, but not without justification, Tomasello observes: "Ask yourself: what exactly is in universal grammar? Oh, you don't know – but you are sure that the experts (generative linguists) do. Wrong; they don't. And not only that, they have no method for finding out." (Tomasello, 2009; see also text footnote 14 below on the last point).

language faculty"[10], and thus the same as linguisticality, e.g., in this quotation:

> "The term Universal Grammar (UG) is simply a label for this striking difference in cognitive capacity between 'us and them' [=humans and non-human animals]. As such, UG is the research topic of GG: what is it, and how did it evolve in us?" (Chomsky et al., 2019).

Since there is no doubt about the difference in cognitive capacity between humans and non-humans, UG in this third sense is not a hypothesis[11].

Thus, we have seen that the terms "language faculty" and "universal grammar" have been used in multiple and confusing senses in the literature. It is therefore best to use a new term, *linguisticality*, for the biological capacity for language, analogous to the term *musicality* for the biological capacity for music[12]. The term should not be taken as implying any further claims about the nature of this biological capacity. This should be taken as an empirical question.

## THE COMPARATIVE STUDY OF LINGUISTICALITY: SPECIES, CAPACITIES, LANGUAGES

In order to understand any biological behavioral trait or capacity (such as birdsong, or echolocation in bats, or web-building in spiders, or territoriality), it is important to study similarities across different species. This is a fundamental principle in all areas of behavioral biology, and it should of course also be adopted in biolinguistics. Concepts specific to human languages (such as *relative clause* or *determiner*) are unlikely to be useful for this kind of comparison. Some linguists have taken an interest in communicative or vocal behaviors of other animals, but they have more often emphasized the uniqueness of human languages (e.g., Anderson, 2004), and have not often looked broadly across species for similarities in order to understand how the various components of linguisticality might have arisen. What Fitch (2015) says about musicality applies in exactly the same way to the capacity for language:

> "[The comparative principle] urges a biologically comparative approach, involving the study of behavioral capacities resembling or related to components of human musicality in a wide range of non-human animal species. This principle is of course a question familiar to most biologists, but remains contentious in musicology or psychology. 'Broad' in this context means that we should not limit our biological investigations to close relatives of humans (e.g., non-human primates) but should rather investigate any species exhibiting traits relevant to human musicality." (Fitch, 2015: §2c)

For understandable reasons, many researchers have focused on comparing linguisticality in humans with the capacities of closely related species (especially chimpanzees and other primates, but also dogs), but as Fitch (2017) notes, "our understanding of cognitive evolution would be seriously incomplete if we focused exclusively on comparisons of humans with other primates (a narrow comparative approach). Fortunately, the genomic revolution has led to a widespread recognition of the fundamental conservatism of gene function in very disparate species. and there is a rising awareness that distant relatives like birds may have as much, or more, to tell us about the biology and evolution of human traits as comparisons with other primates." I am not competent in this area, but it seems to me that Fitch is right that a biologically comparative approach is required for deeper understanding of linguisticality, just as such an approach is needed for any other biological trait of any species.

Second, we should also compare different capacities of humans if we want to understand each of them in a deeper way. Most linguists who claim to be interested in language as a cognitive capacity do not consider related capacities such as musicality, numerical cognition (e.g., Dehaene, 1997), visual perception. But just as we are unlikely to understand the behavioral capacities of a single species, we are unlikely to understand the biological bases of a single capacity in isolation. In view of the great specialization of the research fields, there are of course many practical impediments for such comparative research, but we should not delude ourselves and think that deeper insights will be possible without serious comparison across a range of behaviors. It is natural that most linguists work in those areas where they feel most comfortable, but the rhetoric of some linguists suggests that they expect (or have already reached) deep insights without any such comparison.

Third, and most importantly from my own perspective, we need to compare different languages in a serious way. I will elaborate on this in the next three sections, but here I will make two general points. First, it is of course true that Western linguists have considered different languages at least since the 17th century, when French and other European languages came into their view in addition to Latin. But this comparison became truly systematic and empirically serious only in the 19th century, and in that period, the comparison was historical. Many of the most influential philosophers and linguists of the 20th century that considered human language in general terms (e.g., Chomsky, 1965; Grice, 1975; Lyons, 1977; Langacker, 1987;

[10] Hornstein (2019) basically equates them and consistently uses the term "FL/UG". He says: "If we call this meta-capacity [to acquire a grammar] the *Faculty of Language* (FL), then humans necessarily have an FL and necessarily have UG, as the latter is just a description of FL's properties." (Hornstein, 2019: 189).

[11] The second or third sense of the term UG is also used by Pinker (2007): "This idea [=universal grammar] sounds more controversial than it is (or at least more controversial than it should be) because the logic of induction mandates that children make *some* assumptions about how language works in order for them to succeed at learning a language at all. The only real controversy is what these assumptions consist of: a blueprint for a specific kind of rule system, a set of abstract principles, or a mechanism for finding simple patterns (which might also be used in learning things other than language)." – As Pinker notes, the first assumption, that what is innate is "a blueprint" (=a set of innate categories and architectures), is indeed controversial, but this is what most generative linguists who study languages have been assuming. And it is this "UG of innate categories," or "UG of natural kinds," that I will discuss further below.

[12] Fitch (2015: §1) says about musicality and biomusicology: "Human MUSICALITY refers to the set of capacities and proclivities that allows our species to generate and enjoy music in all of its diverse forms. A core tenet of bio-musicology is that musicality is deeply rooted in human biology, in a form that is typical of our species and broadly shared by members of all human cultures." The same could be said analogously about linguisticality and biolinguistics.

Jackendoff, 2002; Goldberg, 2006) did not base their claims on a broadly comparative set of data. And second, within the Chomskyan community, a strongly aprioristic approach has always been dominant, even though since the 1990s, more and more linguists have tried to apply the mainstream generative grammar (MGG) formalisms to languages from outside Europe. The general direction of research has always been to show that languages other than English are really much like English after all (they have DPs/determiner phrases, configurational clause structure, standard word-class distinctions, a movement-based treatment of alternative orders, and so on). This is understandable, since all the textbooks are based on English, and the textbook assumptions are the only assumptions shared by all generative linguists. Thus, the desideratum of a biolinguistics that would be based on a broadly comparative approach without privileging any one language (like a biomusicology that does not, for example, privilege Western art music; Fitch, 2015; Honing et al., 2015) still needs to be fulfilled.

## HOW P-LINGUISTIC ANALYSES MAY ILLUMINATE LINGUISTICALITY: THE NATURAL-KINDS PROGRAM

Instead of comparing languages in a systematic way, what the great majority of linguists (even those who emphasize their interest in larger questions) have been doing over the last few decades is engage in the study of particular languages. But how can analyses of particular languages ("p-linguistic analyses") lead to insights into general questions about Human Language?

In Haspelmath (2020b), I observe that p-linguistics is not necessarily relevant to general linguistics (or "g-linguistics," the study of Human Language), because the properties of individual languages are historically accidental. But there are two ways in which the study of a single language such as Mohawk (Baker, 1996) or French (Kayne, 1975) could contribute to our understanding of linguisticality: (i) We can study aspects of these languages which we know are not conventional, or (ii) we can study the conventional grammatical rules and hypothesize that they are based on innate building blocks (features, categories, and architectures). The first type would include psycholinguistic research (where speaker behavior is studied independently of speakers' social knowledge) and stimulus poverty considerations.

Here I will focus on the second type of study: P-linguistic analyses that are based on the idea that all languages take their building blocks from a common innate blueprint or "framework" (see Haspelmath, 2010b for some discussion of this term). This approach has been very influential, and has often been presented as the only possibility for linguistics, even though it has always been clear that languages can also be studied as parochial systems of social conventions (because this is what we do when we take a language class). Let us look at a concrete example of a p-linguistic analysis.

Bloomfield (1933) observed that it is useful for English grammar to posit a special Determiner category that is unknown from Latin (and 19th century English grammar). As an approximation, we can say that English nominals consist of four slots, as in (1a). English Determiners include the forms in (1b).

(1) (a) Predeterminer – Determiner – Adjective – Noun
(b) *the, a(n), my, your, their, this, that*

If we additionally say that the first three slots may be empty and that the two Predeterminers are *all* and *both*, we immediately explain why we can have all of (2a–e), but not, for example, (3a–c).

| | | | | |
|---|---|---|---|---|
| (2) (a) | *all* | *the* | *new* | *houses* |
| (b) | *both* | *my* | *little* | *children* |
| (c) | | *that* | *expensive* | *dress* |
| (d) | | *their* | *old* | *article* |
| (e) | | | | *apples* |

(3) (a) **the my children*
(b) **old the article*
(c) **that their expensive house*

P-linguistic analyses consist in setting up categories of this kind and in specifying further conditions on the forms that can occur in the categorial slots (e.g., the English Determiner slot can be empty only if the noun is plural). So how could such an analysis illuminate not only the structure of English, but the biological capacity for language?

Bloomfield (1933) intended the Determiner category as a language-particular category for English, but it could of course be that it is an innate category, and that further categories such as those in (4) are likewise part of an innate blueprint. This is in fact what most syntacticians in the generative-grammar tradition claim, whether explicitly or (more commonly) implicitly.

(4) verb, noun, auxiliary, verb phrase, adposition, complementizer, case-marker, accusative, dative, ergative, agreement-marker, finite verb, reflexive, pronoun, coordinator, relative clause, singular, plural, first person, second, person, tense, mood, question word, question particle.

Clearly, the study of particular languages requires features and categories of this kind, and it also requires larger constructions (such as passive or causative constructions, or question-word constructions) and relations between constructions (of the kind that have been described by alternations or transformations). Again, one may hypothesize that the kinds of rules that one posits to express these regularities are part of human linguisticality from the very beginning (that they "belong to the language faculty," as linguists often say).

As noted earlier, the idea that the building blocks of languages are innate is analogous to the finding that there are basic tastes that are genetically determined and do not vary across human populations, and one could also point to the idea that there are half a dozen basic emotions that are invariant and not subject to cross-cultural variation (cf. Barrett, 2006). The building blocks of languages would thus be natural kinds, like the building blocks of matter – the chemical elements.

Chemical elements are often said to be the best example of natural kinds, but biological species and their parts are also natural kinds in that they are given in advance by nature and are not identified by definitions. In order to identify gold (chemical symbol *Au*) or a red fox (*Vulpes vulpes*), we do not make use of definitions, but of a wide variety of symptoms (see Haspelmath, 2018 for further discussion of natural kinds in different disciplines). That the building blocks of languages are analogous to chemical elements has been argued extensively by Baker (2001). When serious chemical inquiry started in the 17th century, it was not clear whether all parts of the world (let alone the celestial bodies) consist of the same kinds of stuff. It was only through painstaking study of many particular substances from different parts of the earth (and also from meteorites, which were known to originate from outer space) that chemists eventually came to recognize that there are a few dozen elements of which all other substances are composed.

Thus, it is possible in principle that the study of the building blocks of particular languages gives us insight into the innate building blocks because the language-particular building blocks are actually drawn from the universal set. Determiner would not only be a category of English, but an element of the innate blueprint for Human Language (in other words, part of UG in the first sense, as in the Barsky quote in section "Human Linguisticality, the 'Language Faculty' and 'Universal Grammar'"). This is what I call the natural-kinds program for finding the innate building blocks, making use of p-linguistic analyses.

## THE STRUCTURAL UNIQUENESS OF THE BUILDING BLOCKS

The difficulty with the natural-kinds program is that different languages do not have the same building blocks. They show many similarities, and for most practical purposes, it is possible to translate from one language into another language. But there are also many differences which cannot be reduced to a set of elementary building blocks, at least at the present state of our knowledge.

For example, different languages carve up the same conceptual space in different ways, mapping to different word shapes. Where English has just a single word *hair*, French distiguishes between *cheveu* "head heair" and *poil* "beard or body or animal hair," and Latin made a still different subdivision by distinguishing between *capillus* "heard or beard hair" and *pilus* "body or animal hair" (Koch, 2001: 1146). And where Russian distinguishes between *les* "forest or woods" and *derevo* "wood or tree," French has *arbre* for "tree" and *bois* for "wood or woods or forest" (this example goes back to Hjelmslev's discussion in the 1930s; cf. Haspelmath, 2003: 237). Ideally, this diversity of lexical semantics would be reduced to a small number of building blocks which combine to yield the diversity that we actually observe. And there is a proposal by Wierzbicka (e.g., Wierzbicka, 1996), to explain all word meanings on the basis of about 100 elementary (and presumably innate) semantic building blocks ("semantic primes," or natural kinds). However, this research program has not been adopted by the discipline because Wierzbicka's methodology for semantic decomposition does not seem rigorous. It seems that most linguists regard the goal as overambitious.

The situation is somewhat different in the case of phonological segments, where several proposals have been made for lists of innate building blocks that can be applied to all languages: The "distinctive features" for segments (first proposed by Jakobson et al., 1951 and made famous by Chomsky and Halle, 1968). However, while there are a number of authoritative proposals that are taught to students in textbooks (and can be looked up in encyclopedic articles)[13], these still have the status of widely adopted proposals and do not have the status of generally accepted discoveries. Authors such as Blevins (2004) and Mielke (2008) have given good arguments for a different understanding of cross-linguistic similarities in phonology, where each language is analyzed in its own parochial terms and cross-linguistic similarities derive from diachronic ("evolutionary") or adaptive tendencies. And authors like Lass (1984) and Simpson (1999) have pointed out that comparing phoneme inventories across hundreds of languages (as is done by Maddieson, 1984 and others) is not possible, because a phoneme system is determined by language-particular generalizations. Even if the distinctive features were universal, the organization of phoneme inventories is unique in every language. It was noted by Trubetzkoy (1939), in the founding document of modern phonology, that the French /t/ and the Greek /t/ are not the same element because they occur in different contrasts in their respective systems – they are structurally unique elements that we happen to use the same notation for. Phonological research over the last 80 years has not led to any different conclusions. Even though there are many obvious similarities, each language has its own system (and its own building blocks), and we do not know how to reduce these systems to a set of innate natural kinds.

In the case of syntactic building blocks, the situation is still different from lexical semantics and phonology, but not better, despite Baker's (2001) suggestion that comparative syntactic work has advanced as much as comparative chemical work in the mid 19th century, and that our Mendeleev could just be around the corner, providing syntacticians with a "periodic table of innate syntactic elements" to be taught in syntax classes and to be used in linguistic analysis. But in practice, this is not the case. The fate of Bloomfield's "determiner" concept is symptomatic in this regard. In the late 1980s, it was proposed that the "Determiner" plays a more important role in English syntax than was previously thought, and as soon as it got more prominent in English syntax papers, the concept was transferred to other languages where it cannot be motivated in the same way (on the assumption that it is not a unique building block of English, but must reflect the innate blueprint). For example, in Modern Greek, the definite article and the demonstrative co-occur and thus cannot be in the same slot

[13] e.g., https://en.wikipedia.org/wiki/Distinctive_feature

(e.g., *aftó to spíti* [that the house] "that house"). Different criteria were used in different languages for a determiner, and it was simply assumed that all languages have it, even when it is not overt most of the time. The motivation for assuming such an innate category came from English, not from comparative studies[14].

The general situation in syntax is different from lexical semantics in that many syntacticians assume that there is a fixed list of innate building blocks (whereas few lexical semanticists assume this), but unlike phonologists, syntacticians have not come up with an authoritative proposal. The different "frameworks" that arose in the 1980s have proposed very different sets of basic building blocks (e.g., Relational Grammar, Blake, 1990; Lexical-Functional Grammar, Bresnan, 2001; Mainstream Generative Grammar; Adger, 2003), and within the numerically dominant MGG school, there are many different views which are often mutually incompatible. Authors like Cinque (1999) have argued for a "cartographic" approach in which many dozens of innate categories are proposed, but other authors, inspired by philosophical "Minimalism," have argued that it is quite impossible for so many natural-kind categories to be innate because they could not have evolved (this has been called "Darwin's problem", e.g., Bolhuis et al., 2014: 5). And finally, actually practicing language describers have not found any use for any of these proposals. Unlike the proposals of phonological theorists, which have sometimes been made use of in comprehensive grammatical descriptions, the "framework-based" proposals play no role in the training for linguistic fieldwork (cf. Payne, 1997; Chelliah and De Reuse, 2011).

Language describers basically still follow Boas's (1911) exhortation to describe each language in its own terms (just as anthropologists describe each culture as a unique set of practices), rather than imposing some preconceived scheme on them, even though they have realized that comparative work can help them because of the many similarities of languages[15].

Now one may of course object to this negative assessment by observing that our current lack of a complete theory of innate building blocks does not mean that such a theory is impossible. This is true, but there seems to be little awareness among linguists who are pursuing this program that a natural-kinds theory is not necessary, and that much of the current research is based on the unquestioned presupposition that there is no alternative to it. The next section will sketch such an alternative: The idea that the cross-linguistic convergence of linguistic features (leading to striking similarities between languages) may be due to convergent cultural evolution, rather than to innate natural kinds.

[14]Thirty years after the original proposal, many authors still work with a universal determiner category, though many others have raised objections. As a recent workshop on the topic NP vs. DP (at the Annual Meeting of the DGfS, Bremen, 2019) showed, there is no agreement on methodological standards for determining whether such a universal building block exists.

[15]For example, Epps (2011: 648) says that fieldworkers should "produce descriptions in formats that will enable and facilitate comparison across languages, but also remain true to the languages themselves, without forcing them into ill-fitting predetermined categories (Gil, 2001; Haspelmath, 2007, 2010a)."

## A BIOLOGICAL BLUEPRINT VS. CONVERGENT CULTURAL EVOLUTION

In various domains of study, similarities across different phenomena may have quite different causes, and it may be challenging to identify them. For example, biologists are not sure whether the similarities between species in different taxa (e.g., wings in birds and bats) can be exclusively explained by convergent biological evolution. Alternatively, one might think that many of the similarities are due to constraints on basic structures that cannot be overridden by biological adaptation. These do not seem to be currently well-understood, but at least one biologist, Stephen Jay Gould (1941–2002) became famous for suggesting that the power of convergent evolution has been overestimated (Losos, 2017 provides some very accessible recent discussion).

Similarly, the explanation for the similarities between languages may not lie exclusively in convergent cultural evolution. There may be specific biological constraints on possible language systems, just as there are (apparently) specific biological constraints on taste categories and emotion categories. These are not currently well-understood by linguists (as noted earlier), but they may well exist, just as there may be "constraints on basic structures" in biology.

However, it should be self-evident that there are also many similarities between languages that are sufficiently explained by convergent cultural evolution. Just as nobody doubts that the cross-cultural existence of similar kinds of houses, tools, weapons, musical instruments and governance structures (e.g., chiefdoms) is not due to a genetic blueprint for culture but to convergent cultural evolution, there is also no real doubt that many similarities in the words of languages are due to cultural similarities and need no biological explanation. For example, many languages in the 21st century have short words for mobile phones, and these can be created in different ways (by abbreviating longer terms, e.g., Polish *komórka* from *telefon komórkowy*, by using a brand name, e.g., *Natel* in earlier Swiss German, or even letter abbreviations like *HP* in Indonesian, for *hand phone*). Nobody would doubt the claim that this is an adaptive feature of these languages that is not due to anything in our biology.

It is an obvious feature of human linguisticality that human groups form linguistic conventions that are subject to change. The change is not fast, and speakers of the same community usually find it easy to understand each other even across three or four generations. But over the centuries, it accumulates, and when cultural change is fast (as with mobile phones and many other terms for modern technology), languages may change fast to adapt to the speakers' needs. Thus, languages are subject to cultural evolution (Croft, 2000a; Mesoudi, 2011), and when there are selective pressures, this change may be adaptive. Many general aspects of languages are apparently due to the adaptation of language structures to the needs of the speakers. Not only the length of words can be explained as an adaptation to their predictability and frequency (as in the mobile phone example; cf. Zipf, 1935; Kanwal et al., 2017), but also the length and presence of grammatical markers (see Haspelmath, 2020a on asymmetric coding in grammar). In phonological systems, not only vowel dispersion, but also the structure of consonant inventories is clearly adaptive (e.g., Flemming, 2017). And in morphosyntax, not only asymmetric coding tendencies, but also many word and clause ordering tendencies can be explained on the basis of general processing preferences that are not specific to linguisticality (Hawkins, 2014). Similarities across languages in terms of word class categories (Croft, 2000b) and reflexive constructions (Haspelmath, 2008) have likewise been explained in functional-adaptive terms. Basically, all of the categories listed in (4) above may well be similar across languages because they serve universal needs of speakers.

Thus, linguists who compare languages and want to explain patterns that are general across languages and cannot be due to historical accidents need to consider two possible sources of these similarities:

(i) convergent cultural evolution of languages to the same needs of speakers,
(ii) constraints on biologically possible language systems: innate building blocks (natural kinds) that provide a rigid blueprint for languages.

The two answers might even be correct simultaneously, but there is of course also a question of instrinsic likelihood: How likely is it that a grammatical feature is part of an innate blueprint, which would have had to evolve biologically within a million years or less ("Darwin's problem")? By contrast, how likely it is that an adaptive feature of a language system would have evolved culturally over a few generations, given that we observe such changes wherever we look in the historical record?

## CONCLUSION: THE BUILDING BLOCKS OF LANGUAGES UNDER A MIMIMALIST LENS

If we take a comparative approach to human linguisticality, we observe at the species level that linguisticality is unique to humans. But at the level of different human communities, we observe that each language is unique, just as other aspects of human cultures are unique to each culture. Languages exhibit many similarities, but just as biological similarities need not be due to genetic identity, linguistic universals need not be due to an innate blueprint. Analogously to biological convergent evolution, which can produce similar outcomes in unrelated taxa (eyes in insects and vertebrates), the similarities between languages may be due to convergent cultural evolution. This means that the description and comparison of languages does not lead to immediate insights into human linguisticality (see (ii) in §6).

As noted, an alternative possibility is that some of the linguistic universals are due to a biological blueprint [a "universal toolkit," as Jackendoff (2002: 75) calls it], and sometimes a biological and a cultural-evolution explanation may be simultaneously appropriate. Linguists have found it very difficult to decide between these two possibilities, but a "minimalist lens" would seem to suggest that as little as possible should be attributed to biological constraints (i.e., to natural-kind categories). There are some evident biological constraints in other parts of cognition, so it cannot be ruled out that categories like "noun" and "verb," or "consonant" and "vowel," or even "deep structure" and "surface structure," are innate building blocks of our cognition in the same manner as the five basic tastes[16].

But general principles of explanatory economy (cf. the "cost scale" of explanatory factors in Haspelmath, 2019: 16) would suggest that one should posit innate building blocks of languages only if convergent-evolution explanations do not exist or are very unlikely. As far as I can see, the evidence from comparative linguistics does not currently provide strong evidence for innate building blocks of grammars[17]. While my perspective is shaped by the "functionalist" tradition of comparative linguistics (Greenberg, 1963; Croft, 2003; Givón, 2010), this provides an interesting convergence with some Chomskyan Minimalists such as Hornstein (2018), who recognize that there may be far fewer innate building blocks that than were often assumed in the past[18].

Nevertheless, we need to pursue all avenues in order to come to a better understanding of human languages and of human linguisticality. I do not dismiss the natural-kinds program, and linguists who pursue the natural-kinds program cannot dismiss the successes of the convergent-evolution approach[19].

## AUTHOR CONTRIBUTIONS

MH conceived and wrote the manuscript.

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[16]Recall from section "Human Linguisticality, the 'Language Faculty' and 'Universal Grammar'" that the term "universal grammar" has not only been used in the concrete sense of specific innate building blocks (which can be investigated by a natural-kinds program as currently carried out by many syntacticians), but also in the sense of "whatever is domain-specific to human linguisticality." This is not something that the comparative study of languages can contribute to, but it seems quite likely that other considerations lead one to assume such domain-specific capacities (e.g., in speech perception and word learning, as noted by Pinker and Jackendoff, 2005: §3).

[17]This would also explain why the natural-kinds program (section "How P-Linguistic Analyses May Illuminate Linguisticality: The Natural-Kinds Program") has not been very successful so far (as noted in section "The Structural Uniqueness of the Building Blocks").

[18]However, Hornstein makes a distinction between substantive and structural universals (following Chomsky, 1965), and he is still quite optimistic about the latter being innate ["the Subjacency Principle, Principles of Binding, Cross Over effects, X' theory with its heads, complements and specifiers; these are all structural notions that describe (and delimit) how Gs function"]. But I do not think that the phenomena described by these terms are any different from the asymmetric coding, word-class and word order universals that have been successfully explained in functional-adaptive terms by Croft, Hawkins, and Haspelmath.

[19]Pinker and Jackendoff (2005) say that it "seems likely" that constituent structure, word order, agreement and case are specific to language and they simply assume that they are biological. For some reason, they do not even consider the possibility that the corresponding phenomena in languages are due to convergent cultural evolution (even though short markers of semantic roles, as provided by case flags and agreement markers, are just as useful for all speakers as short word for mobile phones; see Lehmann, 1982 for a functional account of agreement phenomena).

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# Lessons From Neuro-(a)-Typical Brains: Universal Multilingualism, Code-Mixing, Recombination, and Executive Functions

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In the literature, the term code-mixing/switching refers to instances of language mixing in which speakers/signers combine properties of two or more languages in their utterances. Such a linguistic behavior is typically discussed in the context of multilinguals, and experts commonly focus on the form of language mixing/switching and its cross-linguistic commonalities. Not much is known, however, about how the knowledge of code-mixing comes about. How come any speaker/signer having access to more than one externalization channel (spoken or signed) code-mixes spontaneously? Likewise, why do both neurotypical speakers/signers and certain neuro-atypical speakers/signers produce structurally similar mixing types? This paper offers some answers to these questions arguing that the cognitive process underlying code-mixing is a basic property of the human learning device: *recombination*, a fully automated cognitive process. Recombination is innate: it allows learners to select relevant linguistic features from heterogeneous inputs, and recombine them into new syntactic objects as part of their mental grammars whose extensions, arguably individual idiolects, represents what Aboh (2015b, 2019a,b) characterizes as hybrid grammars.

**Keywords: code-mixing, universal multilingualism, executive functions, hybrid grammars, recombination, syntax**

## INTRODUCTION

Over the past decades, there has been an increasing interest in multilingualism and its implications for the study of language, language use, and cognition. Nevertheless, it is not exaggerated to say that most formal approaches to language, language acquisition, and language change still regard multilingualism as exceptional, and thus rely on idealizations of monolingualism embedding a specific target uniform to every Speaker/Signer-learner (henceforth S-learner) of a community. Such frameworks are not conceived to model the linguistic knowledge of S-learners in highly multilingual communities, which nevertheless are very common. To wit, let us consider the background of this author, who grew up in a town in the South of Benin (West Africa) called *Xɔ̀gbónù* in Gungbe (Kwa), the native tongue of his father, *Àjàcɛ́* in Yoruba (Benue-Congo)[1],

[1] Interestingly, *Àjàcɛ́* is an approximation by Yoruba or (Nago) speakers of the expression *àjá cè* which itself is a Gbe expression meaning *my Adja* (i.e., the original location of the Gbe people). These expressions are indicative of the interaction between the founding populations, and how speakers of different languages approximate the languages of their neighbors.

of which he has some basic knowledge, and Porto-Novo in French (Romance)[2], which he speaks natively, albeit the *Béninois* variety. These three names are indicative of the major communities of speakers or languages in contact in this city of about 300,000 inhabitants. Though this author spent his adolescent and pre-adult years in *Xɔ̀gbónù*, he was not born there but in Parakou, a city in the Northern part of the country. There, the major communities and languages in contact are Baatonu (Gur); Dendi (Songhai), and Waama (Gur). He does not speak any of these languages, though some of his siblings who were already attending school then do. At the age of six, his parents relocated in Agbomey, in the central part of the country. Here the major language is Fongbe (Kwa), which he speaks as L2. His family later relocated in *Xɔ̀gbónù* when he was 11 years old. Finally, he has always been exposed to his mother's native language Gengbe (Kwa), which he speaks only as heritage language. Then in secondary school, he learned English (age 12), and subsequently Spanish (age 16) which were obligatory in the curriculum and represented the so-called first and second "modern languages." Working now in the Netherlands, he is exposed to Dutch of which he took lessons and has a passive knowledge.

This description shows that the linguistic knowledge of S-learners is in constant flux and so are the community networks generating the inputs S-learners are exposed to throughout life. This holds of speech communities in Benin, in Sub-Saharan Africa, and presumably in an ever-increasing number of urban zones in our globalizing world. Multilingualism is therefore becoming the standard, while pure monolingualism appears very exceptional.

Benin, the home country of this author, extends over 112,000 km$^2$, with a population of about 10 million inhabitants who speak about sixty languages (excluding European languages). Given such a learning ecology, which we can take to be the norm for most S-learners in the world (and even more so in the Global South), several questions arise: Which language does such a multilingual S-learner speak natively? How can one define a native S-learner formally in such an ecology? How do the languages the S-learner knows interact during comprehension and production? What role do these languages play in subsequent learning experiences? What do the mental grammars of such an S-learner look like?

These questions have already been raised in the literature, but in a monolingual framework. An implicit traditional assumption is that linguistic theory describes the knowledge of an ideal S-learner who lives in "a completely homogeneous speech-community" and "knows her language perfectly" (cf. Chomsky, 1965, p. 5). Despite allowing a tremendous progress in formal linguistics and cognitive approaches to language, this methodology is not ecologically valid because it idealizes the exceptional case, rather than the default. The notion of a "perfect" S-learner becomes obsolete when one considers multilingual communities, population movements, and migration which all contribute to creating mosaic speaker/signer's profiles.

[2]Like *Àjàcɛ́*, Porto-Novo is the French rendering of Puerto Nuevo, the name given to the town by the Portuguese, prior to colonization by the French.

In this paper, I argue for a different perspective: universal multilingualism, every S-learner is formally multilingual because s/he entertains several mental grammars ranging from registers, dialects of the same language, to typologically and genetically different languages. S-learners live in heterogeneous communities involving individuals with different experiences. It is therefore unlikely that S-learners harbor monolithic mental grammars that are opaque to each other. As has been shown by the rich literature on cross-linguistic influence, the languages of multilinguals affect each other, and a prevalent practice in multilingual communities is code-mixing: a behavior which does not match with the ideal of a "perfect" S-learner assumed in traditional approaches.

In Sub-Saharan Africa, for instance, most speakers alternate between different languages daily or mix different languages in their utterances. Sentence (1), constructed by this author, illustrates code-mixing. In the remaining of this article, I refer to this speaker, whose background is described in the preceding paragraphs, as "polyglot A."

(1) *Polyglot A*

Dáwè lɔ̀ ɖɔ̀ ná mì **ɖɔ̀**$_{\text{[Gungbe]}}$/
man DET tell TO 1SG that

*la vie est un combat*$_{\text{[French]}}$/
DET life is DET struggle

**vɔ̀à** *kɔ̀nbá* éwàn mú nyin àvù bé nyàn ò$_{\text{[Gengbe]}}$/
but struggle DEM NEG COP fight POSS matter NEG

you've got **to**$_{\text{[English]}}$/
2SG have MOD to

leren, werken en plannen$_{\text{[Dutch]}}$/.
learn work and plan

'The man told me that life is a struggle, but that struggle is not a matter of physical fight, you've got to learn, work, and plan.'

In this example, polyglot A combines pieces of structures from five different languages separated by the symbol "/." These languages include Gungbe/French/Gengbe/English/Dutch in this order. Interestingly, the Gengbe stretch (i.e., the third sequence) contains a French loan word *kɔ̀nbá* "combat." Examples like these are characterized as code-mixing/switching in the literature and are typically assumed to require some cognitive capacity of the speaker. This polyglot, who is not an expert in all the five languages involved, could be thought of as being capable of deploying appropriate cognitive processes to select the switching point as well as the target grammatical categories in the relevant languages. Such a capacity, obviously, involves the ability to inhibit competing languages, for instance, the selection of French in the second segment rather than Dutch, or the selection of the Gengbe conjunction *vɔ̀à* rather than its competing equivalents in the other languages that this polyglot speaks (i.e., *but*$_{\text{[English]}}$, *mais*$_{\text{[French]}}$, *maar*$_{\text{[Dutch]}}$, *àmɔ̀n*$_{\text{[Gungbe]}}$). Typically, polyglot A will use an utterance like (1) in a context in which the interlocutor also knows the five languages involved sufficiently to understand the utterance. Accordingly, polyglot A can also refrain from code-mixing (e.g., in a discourse context in which only one of the languages he speaks is allowed).

In contrast to (1) which might be thought of involving some "control" or language planning from its speaker, and could be representative of a neuro-typical cognitive phenotype, Fabbro (1999, p. 153–155) reports example (2) uttered by an aphasic polyglot, named E.G., a 55 years old and right-handed male. He spoke Slovene as mother tongue, Italian as L2, Friulian as L3, and English as L4. After a stroke, he exhibited Wernicke's aphasia in all the languages he spoke, with "a severe mixing phenomenon in Italian, Friulian, and English" (Fabbro, 1999, p. 154). E.G. exhibited *pathological code-mixing*: In this example, E.G. combines English and Italian, regardless of the speech context. Aphasic patients showing pathological code-mixing cannot refrain from code-mixing. Throughout this paper, I present the data as reported in the sources.

(2) Context: What was your job in Canada?

*Polyglot B*: In Canada? *Co facevo la via*? I was working **with** *ce faccio coi . . .del . . .fare*, *I signori la che I faceva*. [. . .] *Allora le case*, *tante case e dopo di note lavoravo* **for** *i martesi* **for** *i canadesi*.
'In Canada? What I did there? I was working with, I do with do. . . men there who did . . .then houses many houses, and during the night I worked for Martanians, for Canadians.' (Fabbro, 1999, p. 154)

Despite the different conditions of their speakers, the examples in (1) and (2) show striking similarities with regard to their switching patterns: The switch occurs at clause boundaries, as indicated by the alternating languages in (1) or the sequence "In Canada? *Co facevo la via*?" in (2). In addition, the elements in boldface in these examples indicate that switching also occurs at the junction of grammatical elements such as coordinating and subordinating conjunctions as well as adpositions. It therefore seems that the cognitive process underlying the selection of the relevant categorial units of mixing is intact in both polyglots A and B. Observations like these, as well as comprehension data led Perecman (1989, p. 233) to conclude that "*the aphasic polyglot has an intact language system but imperfect control of the system* [. . .] *the damaged brain processes language according to the same general principles as the non-damaged brain*" (see also Perecman, 1984 and references therein). One explanation suggested by Abutalebi et al. (2000, p. 54) is that what appear to be impaired in some aphasic patients showing pathological code-mixing are the inhibitory mechanisms responsible for deactivating lexical selection from the competing languages that the speaker has acquired.

If polyglots A and B only differ in their capacity to deploy the inhibitory mechanisms responsible for deactivating lexical selection, then the similar switch patterns in (1) and (2) which ultimately relate to structural properties call for a principled answer. What properties of the human language capacity explain these structural parallels? Why do speakers/signers (regardless of their cognitive phenotype) sometimes produce structurally similar mixing patterns even though they may be operating on typologically and genetically distinct languages (cf. 1–2)? What do such apparent structural commonalities tell us about the knowledge of code-mixing: the fact that any speaker/signer having access to more than one externalization channel code-mixes spontaneously, even if this linguistic behavior is not favored in her speech/signing community, and she has never been exposed to mixed inputs?

Current studies on code-mixing cannot answer these questions because they generally focus on the form of code-mixing, its social functions, and its cross-linguistic commonalities (e.g., Poplack, 1980, 2015; Myers-Scotton, 1998, Myers-Scotton, 2006; Muysken, 2000; MacSwan, 2005a,b; Kecskes and Albertazzi, 2007; Bulluck and Toribio, 2009). In addition, studies comparing properties of code-mixing between neuro-typical and neuro-atypical populations are sparse. Yet, answering these questions is essential to our understanding of the human language capacity, and how it is put to use in a multilingual context. Furthermore, understanding the fundamental similarities or differences between neuro-typical and neuro-atypical populations is important to establish which core aspect of the language capacity is resilient and presumably uniform to the species, and which aspect is less so.

In this paper, I take up this challenge and provide the first steps to answering these questions. I argue that the fact that the cognitive process underlying code-mixing in (1) is so entrenched in S-learners, appears to be very resilient, and prevails in absence of relevant language selection mechanisms (e.g., in some aphasic patients as indicated by example 2), suggests that it is a basic property of the human learning device: the language faculty. I show that this process, *recombination*, is present in all S-learners (monolinguals and bilinguals alike). During language acquisition, recombination allows S-learners to select relevant linguistic features from the heterogeneous inputs they are exposed to, and recombine them into pieces of mental grammars whose extensions represent individual idiolects, which Aboh (2015b) characterizes as hybrid grammars. In supposedly "monolingual" settings, hybrid outcomes of recombination are less noticeable because S-learners develop closely related variants. Yet, studies on the Flemish regiolect, the so-called *tussentaal* (De Caluwe, 2007; Ghyselen, 2016), as well as so-called ethnolects in various (urban) communities show that such mixes become apparent once the variants combined are more contrastive or involve typologically and genetically different languages (cf. the *International Journal of Bilingualism*, vol. 12, Issue 1–2, March 2008). I argue that recombination in traditionally assumed monoglots operates on closely related variants (e.g., registers or dialects of the same language), while, in polyglots, it involves more contrastive variants (i.e., typologically and/or genetically different languages). Based on these variants, S-learners develop an array of grammars that are combined during communication. This would mean that S-learners always operate in formally multilingual settings, that is, contexts in which different pieces of grammars (whether from dialects or registers of the same language or different languages) compete.

Section Universal Multilingualism and Code-Mixing discusses universal structural properties of code-mixing across neural-typical and neuro-atypical speakers/signers. These examples indicate that code-mixing emerges spontaneously as a result of *recombination*, an innate capacity.

Building on this, section Recombination: An Innate Capacity discusses the role of executive functions in language processing/production, and proposes a view of the Human Language Capacity in which recombination is fully automated, while selection of vocabulary items for spell-out purposes is mediated through executive functions. This would mean that surface manifestations commonly referred to as code-mixing, code-switching, code-blending, etc. only become apparent when some (aspects) of the competing languages of the polyglot are not inhibited so that several lexica are used to spell out a unique structure[3].

Section Implications for the Study of Language further discusses the consequences of this framework for the study of language, including the common notion of "grammaticality judgment" which is redefined accordingly. The last section concludes the paper.

At this point, a disclaimer is in order. This paper is programmatic in nature: it raises fundamental questions about how to characterize the human mind through the lenses of universal multilingualism, the consequences that this view has for a linguistic theory based on linguistic hybridism, and how the assumptions made here relate to different subfields of linguistics. Accordingly, the discussion leaves out some technical syntactic details which I postpone for future work.

## UNIVERSAL MULTILINGUALISM AND CODE-MIXING

This paper discusses aspects of code-mixing, also referred to in the literature as intra-sentential code-mixing. Adapting Muysken's (2000, p. 1) definition, I use the term code-mixing to mean *all cases in which aspects of lexical items and/or grammatical items of different languages/varieties are combined into a single linguistic expression*[4]. In terms of this definition, and as already mentioned in section Introduction, examples (1) and (2) indicate that the neuro-typical and the neuro-atypical speakers behave similarly: their utterances involve comparable switching points:

(i) +/− Finite complementizers (including prepositions),
(ii) Clause boundaries,
(iii) Prepositions (introducing adjuncts or new arguments).

Recall, however, from the introduction that polyglot A presumably falls within the spectrum of neurotypicality, and as such can control for the languages used in code-mixing or refrain from code-mixing in appropriate context. Polyglot B, on the other hand, exhibits *pathological code-mixing*: a condition in which some patients' utterances involve "frequent and uncontrolled switching to another language" (Fabbro, 1999, p. 142). As the data from E.G. – the speaker of example (2) – show, such patients cannot inhibit the competing languages they speak.

The literature on aphasic polyglots showing pathological code-mixing includes very many reports indicating that such patients produce mixing patterns that fall well within the general typology of code-mixing (cf. Perecman, 1984, 1989). Following Muysken's (2000) typology, example (2) instantiates *alternation* between Italian and English. Example (3) reported in Chengappa et al. (2004, p. 71) instantiates *insertion*: a lexical element or a constituent from one language is integrated in another language. All participants in Chengappa et al. (2004) study suffered from Broca's aphasia in both Malayalam and English. Example (3a) represents a Malayalam context, while (3b) illustrates an English context.

(3) a. Malayalam context
*nan samsaritʃa ailə̆ entə̆ teacher a:nə̆*
The person with whom I spoke is my teacher.
b. English context
*The branch odinu man and birds ta:rə̆ vi:nu*
The branch broke and the man and the birds fell down.

This study further reports that some patients can engage in what Muysken (1981b) defined as *relexifiation*: a cognitive process by which speakers spell out the grammar of one language drawing on lexical items from a different language (cf. Mous, 2003). Such examples are given in (4), which the authors argue are built on the Malayalam equivalents suggested below each sentence.

(4) a. *One who eating salt, he will drink water*.
Malayalam equivalent: *uppu tinnunnaven vellam kudikkum*
b. *I was going the house that is in this way*.
Malayalam equivalent: *na:n po:ja vidə̆ e: varijila:nə̆*

The examples in (5) show that the patients in this study also produced word-internal mixing, as clearly indicated by the Malayalam affixes combined with the English words.

(5) a. *na: n eight ninth tenth class-**il** patippikkunnu*
I am teaching in eight ninth and tenth classes
b. *Father mother ellam sixth-**il** patikumbol maritʃu po:ji*
Both father and mother passed away while (I) was studying in sixth.
c. *antintə̆ se: ʃam hospital-**ilek**ə̆ kondu po:ji*
After that (I) was taken to the hospital

Such word internal mixing has already been reported in the literature, and appears to be very systematic with regard to the selection of affixes and roots combined. The process does not seem random: the affixes generally match the category of the root they attach to, nominal affixes attach to nominal roots, verbal affixes combine with verbal roots, etc. For instance, E. G., who uttered example (2) discussed above, also produced words in which an Italian affix *−a* was attached to an English noun root, as illustrated by *carra* in (6a) (cf. Fabbro, 1999, p. 155). Examples (6b) and (6c), also discussed by Fabbro (1999, p. 155,

[3]This seems compatible with how S-learners feel about code-switching/mixing. When asked about this mode, speakers report finding it "easy" or indicate that they adopt it out of "laziness," "exhaustion," or "excitement" (cf. Dorleijn, 2017 and references cited therein). Accordingly, code-switching/mixing happens when S-learners do not want to or cannot control for language selection entirely.

[4]I follow the Minimalist convention in which "lexical item" refers to both content and functional items.

156), involve productions of German-English bilinguals which instantiate combination of a verbal affix from one language with a verbal root from another language. Finally, example (6d) taken from Perecman (1984, p. 51) is produced by a patient, named H.B., who was asked to interpret the phrase *a swelled head*[5]. While the translation he produced did not match the English equivalent (e.g., *head* is translated as *haus* "house") his Germanicized English root *ʃvɛldɛs* is combined with a Germanic past participle affix *ge*— to form ***gɛ***-*ʃvɛldɛs*.

(6) a. *Per andare all' ospedale ho preso la* ***car***-***ra***
To go to the hospital, I took the *carra*
b. gelt-**ing** (German/English);
c. Com-**en** (English/German)
d. [gɛʃvɛldɛs] Haus

The examples presented here have all in common that they represent morpho-syntactically well-formed outputs of the types commonly observed in situations of language contact or "language creation" within neurotypical populations in which word categories of one language are combined with relevant grammatical elements of another language, as instances of what Aboh (2015b) refers to as hybrid constructs (see also Mufwene, 2001, 2008; Aboh and DeGraff, 2014, 2016, and references therein). Indeed, the examples of word-level mixing presented here do not represent "illicit" syntactic units involving, for instance, a combination of a nominal plural affix with a future auxiliary, or a gender morpheme with an aspect marker, etc. The patients who produced the forms discussed here show uncontrolled language mixing, and one could think that this would also affect lexical selection across their languages, such that any grammatical element or morpheme in one language can randomly combine with any other element in another language. This is, however, not the case in the data discussed here. These speakers produce perfectly "licit" syntactic objects which, in favorable circumstances, can be conventionalized into a community language. It therefore seems that the cognitive process responsible for the selection of relevant grammatical categories is intact in these patients.

Indeed, nothing distinguishes formally between the examples in (3)–(6) and classical cases of code-mixing in neurotypical populations discussed in the literature (cf. Muysken, 2000 and references therein)[6]. This is clear from the following Media Lengua example discussed in Muysken (1981b).

(7)

| | | | |
|---|---|---|---|
| Qechua | yalli-*da* tamia-*pi-ga*, mana ri-*sha-chu* | | |
| Media Lengua | **dimas**-*ta* | **llubi**-*pi-ga*, | no |
| | too-much | rain-SUB-TO, | not |
| | **i**-*sha-chu* | | |
| | go-1FUT-NEG | | |
| Spanish | si **llueve demas**, no voy a **ir** | | |
| | 'If it rains too much, I won't go.' | | |

In this example, the content lexical elements in boldface are taken from Spanish, while the grammatical items in italic are selected from Qechua. Similar examples involving various languages abound in the literature, and nothing distinguishes them formally from those in (6), though the latter are produced by neuro-atypical speakers. We can therefore conclude from these facts that the cognitive capacity underlying code-mixing is sensitive to categorial distinction involving grammatical features, and appears to generate well-formed syntactic objects only. Accordingly, I assume this extremely resilient cognitive capacity to be innate and therefore uniform for all S-learners.

This assumption is further supported by bimodals, that is, individuals who acquire a spoken and signed language natively (e.g., hearing children of deaf adults, cf. Bishop and Hicks, 2005, 2008, and references therein). Data from these bimodals represent strong evidence that code-mixing emerges spontaneously since the inputs these S-learners are exposed to are unimodal (either spoken or signed). The example in (8), reported in Donati and Branchini (2013) and Branchini and Donati (2016), illustrates bimodal code-mixing in Italian and Italian Sign Language (LIS). In this example, the first line represents Italian, while the third line includes constituents in LIS. The second line shows the gloss and the columns group together constituents which are spoken and signed simultaneously.

(8)

| | | | |
|---|---|---|---|
| **It:** | Parla | con | Biancaneve. |
| | talk. PRS.3SG | with | Snow white |
| **LIS** | TALK | **HUNTER** | |
| | 'The hunter talks to Snow white.' | | |

Similar examples are reported in İşsever et al. (2018) for Turkish and Turkish Sign Language, and Emmorey et al. (2005) for English and American Sign Language. These facts show that while code-mixing is sensitive to structural properties, its spellout need not be sequential, as one could believe looking at spoken languages only (cf. Donati and Branchini, 2013).

Like with polyglots in spoken languages, bimodals too can exhibit pathological code-mixing between the two modalities. Fabbro (1999, p. 152) reports the case of a patient who prior to insult could accompany his signs with individual words in other languages he had learned (e.g., Czech). After insult, however, this patient lost this capacity and produced combinations of signs and unrelated spoken words.

## Interim Conclusion

We can conclude from this discussion that the cognitive process underlying code-mixing is extremely resilient, and appears present in all humans who possess language. The discussion further shows that code-mixing is rule-governed regardless the "neuro-phenotype" of the S-learner (cf. Perecman, 1984, 1989). This would suggest that even though the capacity to code-mix is present in all S-learners, mono-lingual/modal and multi-lingual/modal alike, it may go unnoticed when speakers/signers operate on closely related vocabulary items.

[5]H.B., was an 80 years old male patient, born in Cameroon. His parents were German, and he spoke German natively, then French as L2, and English as L3, when he settled in the US at the age of 18. English was his most active language.

[6]It is very well possible that neuro-atypical speakers showing pathological code-mixing produce some other patterns that are structurally different or absent in neuro-typical populations, or that neuro-typical speakers produce patterns that are never found in neuro-atypical speakers. I'm not, however, aware of any study that discusses such structural dissimilarities systematically.

These conclusions raise two puzzles:

(1) Speakers/signers code-mix spontaneously: Where does this capacity come from?
(2) Limits of syntactic computation: Structural similarities between mixed outputs of neuro-typical and neuro-atypical speakers/signers strongly suggest that the human mind does not produce formally illicit (or ungrammatical) outputs, that is, structures outside the range of Universal Grammar. If so, how can we further understand the notion of "ungrammaticality"?

According to Chomsky (1995, p. 14), the human language capacity can be conceived of as a continuum involving an initial state, which is innate and "uniform for the species" and a final state that results from the experience of the S-learner. Universal Grammar (UG) represents the theory of the initial state. In terms of Chomsky (2005, p. 4):

> *UG must provide, first, a structured inventory of possible lexical items that are related to or perhaps identical with the concepts that are the elements of the "cognoscitive powers," sometimes now regarded as a "language of thought" [...]; and second, means to construct from these lexical items the infinite variety of internal structures that enter into thought, interpretation, planning, and other human mental acts, and that are sometimes put to use in action.*

In the context of this definition, the data of code-mixing from neuro-typical and neuro-atypical speaker's profiles discussed in this paper suggest that the notion of *ungrammaticality* formally involves two aspects: one that relates to non-converging outputs (i.e., illicit outputs filtered out by UG) due to constraints on the computational system, and one that relates to conventionalized forms in the lexicon (i.e., illicit outputs within a speech community). The latter relates to acceptability judgments offered by S-learners of a specific variety.

## RECOMBINATION: AN INNATE CAPACITY

In addressing the facts presented in section Universal Multilingualism and Code-Mixing and the puzzles they raise, I make three working hypotheses, which I now discuss in turn:

*Working hypothesis 1*: The cognitive process underlying code-mixing is what drives acquisition. This hypothesis is based on the fact discussed in section Universal Multilingualism and Code-Mixing that S-learners demonstrate the capacity to code-mix spontaneously, even if they live in a community in which such linguistic behavior is not favored, and could not be said to be part of their learning experience (e.g., bimodals). Code-mixing therefore appears to be contingent upon acquisition of language. The discussion has also shown that not only is the capacity of code-mixing present in all S-learners regardless of their cognitive phenotype, but the outputs within and across populations share striking structural similarities. Put together, these facts indicate that S-learners have an instinct for code-mixing: an innate capacity. S-learners are born endowed with the capacity to code-mix.

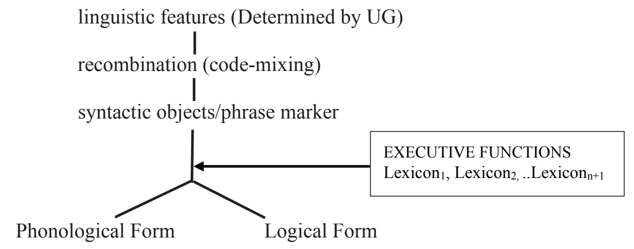



**FIGURE 1 |** A tentative model of grammar.

*Working hypothesis 2*: Vocabulary selection (as understood in formal syntax) is mediated through the executive functions. In accounting for pathological code-mixing, Abutalebi et al. (2000, p. 54) conclude that this condition is not due to language processing or code-mixing *per se* but to a dysfunction in the executive function system, "*the control mechanism subserving lexical selection across languages*" (see also Perecman, 1984; Fabbro, 1999; Paradis, 2004; Abutalebi and Green, 2008; Green and Abutalebi, 2008). This conclusion is compatible with the view developed here that the capacity of code-mixing must be dissociated from executive functions responsible for lexical selection. *Executive functions* is a cover term for various cognitive processes involving attention control, behavioral inhibition and working memory, all necessary for the deliberate control of goal orientated actions (cf. Gooch et al., 2016). Several studies report an interaction between executive functions and vocabulary learning, and hence language acquisition (e.g., Kalia et al., 2017).

*Working hypothesis 3*: If code-mixing is innate and drives acquisition but is subject to the executive functions for vocabulary insertion, then the cognitive process which produces code-mixing, that is, recombination, must precede vocabulary selection. Executive functions are necessary for the selection/learning of a specific lexicon or vocabulary, but they must be deployed after syntactic computation.

Together, these three working hypotheses lead to the tentative model of grammar, based on the generative traditional "Y-model," as represented in **Figure 1**.

This model is compatible with the view that some surface phenomena (e.g., affix reordering) are post-syntactic (as commonly assumed in Distributed Morphology, cf. Halle and Marantz, 1993, 1994, and much subsequent work). Under this view, such surface phenomena happen when executive functions are deployed, that is, after the phrase marker has been built. This view seems supported by instances of pathological code-mixing at the phonological level (e.g., the pronunciation of a vocabulary of one language with the intonation of another), reported in Perecman (1984, 1989)[7]. Though the issue is not uncontroversial (see for example, Tsiplakou et al., 2016; Leivada et al., 2017;

[7] It is not clear in the literature I've consulted whether such mixing occurs at the morphemic level (e.g., a root and its affix being pronounced by the intonation of two different languages).

Alexiadou and Lohndal, 2018), MacSwan (2005a, p. 5) claims that code-mixing at the phonological level is ruled out under his *PF Disjunction Theorem* (see also MacSwan, 2005b for discussion). Space limitation prevents me from exposing his arguments here, but the relevant point is that the tentative model in **Figure 1** is compatible with the observations in the literature: the apparent absence of code-mixing at PF in neuro-typical populations, but not in neuro-atypical ones. In this model, executive functions intervene after recombination, but before PF, hence there may be no code-mixing once lexical items are selected with their related PF-ordered rules. MacSwan's (2005a,b) PF filter bans word-internal mixing which does occur, as already discussed in the literature, and as the data surveyed here (e.g., examples 3, 6) further attest to. In an approach to mixing based on Distributed Morphology, Alexiadou and Lohndal (2018) argue that bilinguals have access to a default mechanism that allows the integration of roots from one language to the morphology of another (e.g., German roots to Greek morphology)[8]. According to these authors, "the bilingual speaker in view of the fact that she has more [vocabulary items] at her disposal will pick an overt realization, if a default such realization is available. The default realization is the one that is compatible with the largest number of roots, i.e., the roots of both languages." (p. 11). They further conclude: "if speakers can pick among different types of n/v to combine with roots, they pick those that will fit the general phonology/properties of the phase head. Put differently, the phonology within a phase head needs to be uniform." (p. 12). Rather than a general ban on word-level mixing, this phase-level PF-filter offers a more parsimonious analysis of word-internal mixing and appears compatible with the framework developed here based on recombination and hybrid grammars.

The discussion in this section also indicates that recombination (the capacity to combine morphemes into larger well-formed lexical items) remains intact even when the executive functions are obliterated. Accordingly, this resilient cognitive capacity which allows S-learners to select relevant linguistic features from the inputs and recombine them in new linguistic objects can be assumed to be innate, and forms part of the human "instinct for language[9]."

In this approach, recombination is an innate, fully automated, cognitive capacity. It is an instance of general MERGE (as defined in Chomsky, 1995) applied to linguistic features relating to different components of the grammar (phonology, morphology, syntax, semantics). I have already mentioned that both monoglots and polyglots exhibit recombination, but differ with regard to the variants that the process operates on (Aboh, 2015b). Recombination in the "monoglot's mind" is restricted to closely related variants (i.e., of the same language or dialect), while recombination in the "polyglot's mind" may operate on distant variants (i.e., from different typological and/or genetic languages). That recombination is contingent on acquisition is also supported by the fact that the process generates licit syntactic objects even in the absence of a "coherent" lexicon. Recall, for instance, the examples of word-level mixing shown in (6), and repeated in (9) for convenience[10].

(9) a. Per andare all' ospedale ho preso la car-ra
To go to the hospital, I took the *carra*
b. gelt-ing (German/English)
c. com-en (English/German)
d. [gɛʃvɛldɛs] Haus

Though much study is needed to fully understand the interaction between recombination, the derivation of clause structure, and the interfaces with PF and LF, the model proposed here suggests that the language faculty is a much more dynamic and flexible system than commonly assumed. This view is in line with recent advances in neurosciences indicating that language processing relates to a diffused combinatory network in the brain (e.g., Vigliocco, 2000; Kaan and Swaab, 2002; Friederici, 2011).

While I hope to return to these questions in future collaborative work, an urgent question now arises: How does a model advocating universal multilingualism relate to acquisition by monoglots (or acquisition *tout court*)? Answering this question has some implications for the study of language, language acquisition and change, which I will elaborate on further in the following sections.

## IMPLICATIONS FOR THE STUDY OF LANGUAGE

The discussion in previous sections shows that speech communities are heterogeneous in terms of their linguistic practices (i.e., not all members of a community develop exactly the same competence in all registers/dialects/languages in the community). In this regard, the remarkable versatility of S-learners in language use suggests that Roeper's (1999) notion of formal bilingualism, should be understood as *formal multilingualism*, the null hypothesis in any learning setting.

### Variation Within and Across Individuals

Every S-learner is exposed to a range of variants, that are arguably expressions of different language types (or different grammars). This appears obvious in a context like Benin, as depicted in the introduction, but it can also be shown for speech communities which are not typically assumed to be multilingual. It is, for instance, common practice to focus on Standard French in studying acquisition of French. Yet, a probe into individuals shows that while speakers may all converge in producing the following three grammatical options to express direct yes-no questions, these constructions do not have the same distribution nor do they have the same status (cf. Arrighi, 2007; Dagnac, 2013).

(10) a. Súrù est-elle venue?
Suru is-3SG come

[8] In terms of this paper, this capacity is subsumed by recombination.

[9] I thank a reviewer of *Frontiers* for her/his comments on this formulation.

[10] Outputs of recombination in apparent "monolinguals" can also be illustrated by speech errors (cf. Pfau, 2009 and references therein).

b. Est-ce-que Súrù est venue?
is-DEM-that Suru is come

c. Súrù est venue?
Suru is come
'Has Suru come/arrived?'

Though these three strategies have the same meaning "has Suru come/arrived?", each has a very different status: (10a) appears in texts mostly and represents a high register. (10c) is the most common strategy typically used in spoken French because it makes use of intonation only, and (10b) has an intermediary status appearing both in formal and informal contexts. Yet, these three strategies which are typically analyzed in terms of register, relate to yes-no question formation strategies found in typologically different languages. (10a) can be said to be typical of Romance, with clitic inversion. (10b), analyzed as involving a question marker *est-ce-que*, is comparable to languages involving a sentence-initial question particle added to a simple declarative clause. (10c), with final rising contour added to a declarative clause, is comparable to languages in which a sentence-final question particle (sometimes a tone, such as in Gungbe) is added to a simple declarative clause (see Dryer's, 2013, description in WALS for some typological distribution). These three strategies relate to three pieces of grammars found cross-linguistically. Accordingly, contemporary French speakers internalize three typologically different pieces of grammars in their expressions of yes-no questions.

The traditional generative approach to such systematic variation, would be to assume that these three separate registers are somehow part of a holistic mental grammar (in which competing variants are sometimes filtered out, see Roeper, 1999, for a critique). Yet, the impressive range of variation within and across individuals, the magnitude of the variants an individual can harbor as well as the flexibility with which S-learners adapt to, and adopt new variants used by their interlocutors suggest that such a view cannot be correct. If it were, there would be much less variation within and across S-learners and languages than there actually are. The dynamicity of human linguistic capacity suggests otherwise, and so do sociolinguistic studies, since Labov's seminal work in the 60s, which show how systematic S-learners are in combining and using variants they are exposed to, while creating new ones (see for instance, Doğruöz and Backus, 2009, Backus, 2010; Ghyselen, 2016; Ghyselen and De Vogelaer, 2018, for some recent references). Likewise, work on diachronic changes (e.g., Kroch, 1989, 2001, Lightfoot, 2006, and much related work), indicates that S-learners may entertain different competing grammars, even in the same language.

While I maintain that linguistic features compete in the mind of the S-learner (cf. Aboh, 2009), I further propose that what S-learners internalize is a rainbow of pieces of grammars (such as in 10) that are put together in communication. The central point here is that learning feeds on heterogeneous inputs that are in a state of flux, and the outputs of recombination are hybrid mental grammars (Aboh, 2015b, 2019a). The proposed view in terms of recombination as a fully automated cognitive process, independent of lexical insertion, leads me to conclude that acquisition of a language (i.e., a conventionalized system used in a speech community) boils down to deploying the executive functions to map the outputs of recombination on specific lexica.

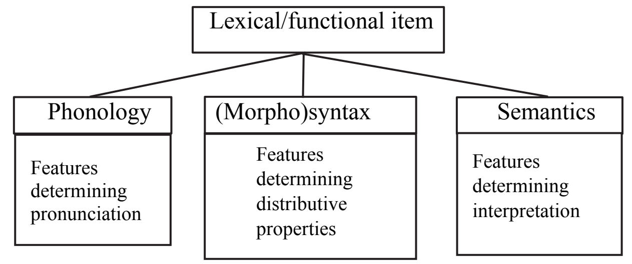



**FIGURE 2 |** Lexical/functional item.

In this regard, I (Aboh, 2015b, 2017, 2019a) explain the role of recombination of linguistic features in the emergence of bundles of features that are mapped onto specific lexical items, in contact situations that led to the emergence of creole languages[11]. The demonstration is based on the Minimalist assumption that a lexical item embeds three components minimally: phonology, morphosyntax, and semantics (cf. **Figure 2**).

I argue in these studies that features pertaining to these three components can be recombined individually during acquisition, based on the learner's hypotheses over the inputs she is exposed to. Recombination is responsible for variation within and across individuals because S-learners develop different versions of the bundles of features mapped onto specific lexical items (cf. Alexiadou and Lohndal, 2018). In principle, every acquired lexical item relates to seven potential competing variants. Consider **Figure 3** (taken from Aboh, 2017, 2019a,b) in which the digit 0 represents the target language, while 1 represents a point of change.

This figure shows potential variation in the inputs due to S-learner's approximations. Aside perfect replication (i.e., the box with three digits "0" at the bottom), which no one, or maybe only a few experts achieve, learning may generate seven other competing variants. The figure also indicates that variants created by S-learners approximate the target to various degrees. A variant which exhibits semantic change only (e.g., the second box from the bottom) is closer to the target than one that involves a phonological, a morphosyntactic, and a semantic change (e.g., the upmost box). Though these variants arguably form a continuum, they can be described in terms of two classes. The first class, referred to as "close variants" in **Figure 3**, involves variants which have modification in one component only, and are arguably close enough to the target to go unnoticed within the community or to be tolerated as possible variants. For example, a lexical item characterized as (Ph1, Sy0, Se0) can be labeled as a "different accent" by speakers of a community (e.g., speakers from Newcastle are generally considered native speakers of English

[11]In order to keep the discussion manageable, I leave aside potential cases of recombination in which lexical components co-vary (e.g., phonology vs. morphosyntax or morphosyntax vs. semantics). I hope to return to these cases in future work.

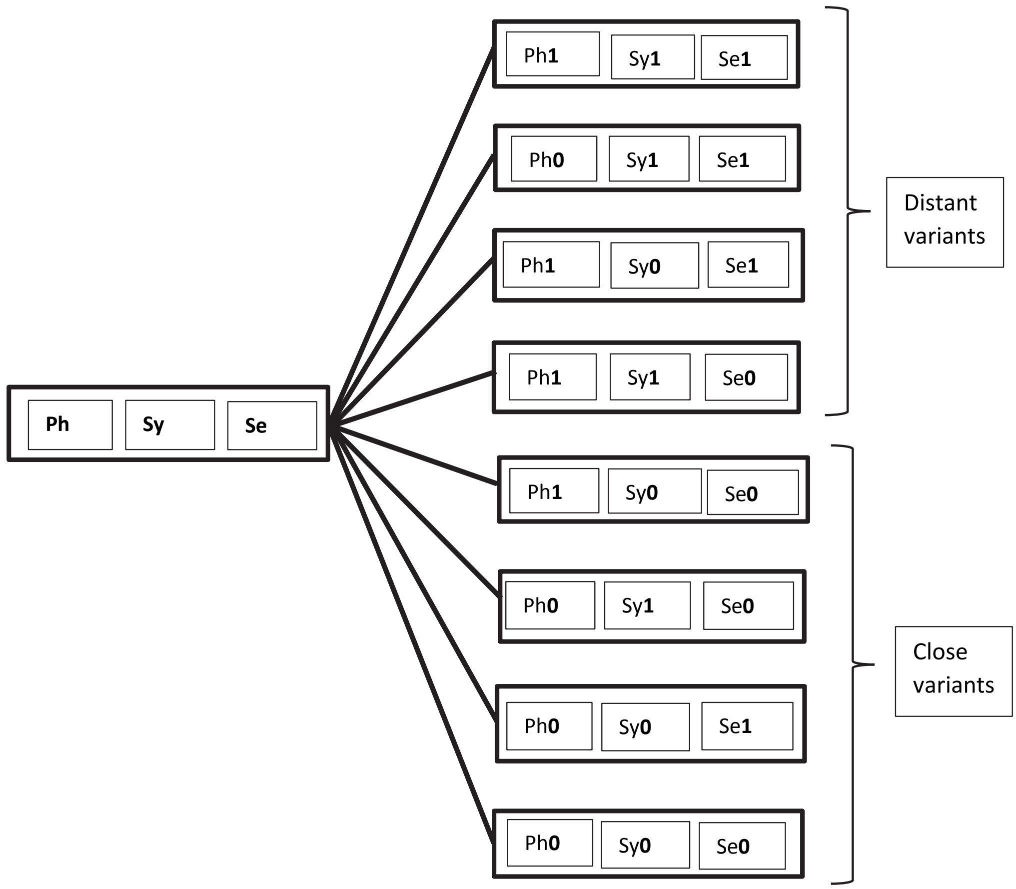



**FIGURE 3 |** Possible combinations in learning a lexical item.

even though they do not sound like speakers from London, and *vice versa*).

The second class includes outputs that I refer to as "distant variants." Similarly to instances of recombination observed in pathological code-mixing (cf. 9), these variants are licit grammatical options. However, they may be farfetched from speech conventions in a community, and speakers/signers may consider them to be marginal, degraded, or even unacceptable. Nothing, however, prevents such variants from competing with "close variants" and spreading within a community if circumstances permit. This is how we can account for the variation between Standard American English adverb *rather* as in (11a) versus instances of verbal *rather* (11b-c), which Wood (2013) shows is part of the grammar of some speakers of colloquial American English.

(11) a. I would rather buy a new car.
b. I wouldn't tell him, but I would have *rathered* slept in a bed because, in all honesty, his lap was not very comfortable.
c. But all in all, a strip club is where I would have *rathered* him gone! (Wood, 2013, p. 1)

The same could be said of modal combinations, which are generally assumed to be ungrammatical in Standard American English, but which have been shown since the 60s to occur in many varieties of Southern American English, as illustrated by (13) taken from Mishoe and Montgomery (1994, p. 9–10)[12].

(12) a. It's a long way and he MIGHT WILL CAN'T come, but I'm going to ask.
b. I reckon I MIGHT SHOULD BETTER try to get me a little bit more sleep.
c. Sorry, we don't carry them anymore, but you know, you MAY MIGHT CAN get one right over there at Wicks.
d. They're saying we MAY SHALL get some rain.
e. We WOULD MIGHT run maybe ten hams a week. [Mayor of Great Falls, SC, interviewed on WIS TV, 11:00 News, Columbia, SC]
f. If I can't help you now, I CAN'T NEVER WOULD

How such variants arise in the mind of S-learners (partly based on the inputs they are exposed to) can be illustrated by

[12]The interested reader can consult the Yale Grammatical Diversity Project: English in North America, https://ygdp.yale.edu/for more documented variants.

the following examples from my Béninois French. In this variety, it is perfectly acceptable to utter the sentence in (13) which includes three instances of the verb *manger* "eat" and whose approximative English translation is given below.

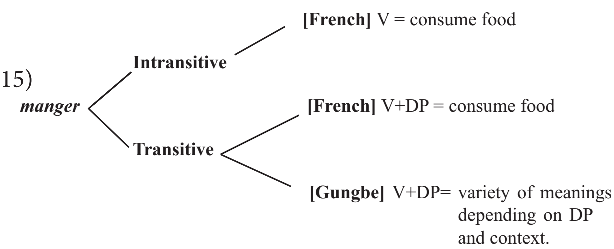
(13)
La boîte nous a offert un super
the firm we have offered a superb
banquet. Nous avons bien ***mangé***,
banquet. We have well eaten,
sauf que le lendemain
except that the following.day
nous avons appris que
we have learned that
les dirigeants avaient ***mangé***
the CEO's had eaten
***tout l'argent*** de l'entreprise.
all the-money of the-firm
Nous avons ***mangé la honte***.
we have eaten the shame
'The company offered us a nice banquet. We ate very well, but the following day we learned that the CEO's misappropriated all the money of the company. We were ashamed.'

The first instance of *mangé* obeys the morphosyntax of this verb in standard French, in which it can also be used intransitively as *eat* in English. The second instance, however, appears a bit distant from the French standard usage. In this case, the verb *manger* is combined with *tout l'argent* "all the money" to mean misappropriate all the money. At this point, one could imagine that this construction is a mere metaphorical use of the verb *manger*, comparable to French idiomatic expressions such as *manger la consigne* (lit. eat the recommendations; "ignore/forget the recommendations"). First, it is important to realize that such French idiomatic expressions are not in the inputs of most Béninois speakers (I had to look this one up in a dictionary, and everyone I asked around me in Benin did not know this expression, and could not even guess its meaning). Second, Béninois French allows a third instance, *mangé la honte* (lit. eat the shame), to mean to be ashamed. Other similar constructions in Béninois French involve *manger la vie* (lit. eat the life) to mean enjoy life. Therefore, the usage of *manger* with non-consumable abstract object DPs to form expressions with unpredictable meanings appears much more productive in Béninois French, than it seems in Standard French. Aboh (2009, 2015b, 2017, 2019a) show that such expressions derive from a combination of Standard French with properties of Inherent Complement Verbs (ICV) found in Gbe and many Kwa languages (cf. Essegbey, 1999; Aboh, 2015a). ICVs are verbs which in their citation form require an accompanying object in the form of an NP. The translations of *manger*, *spend* or *be ashamed* in Gungbe involve a verb of this class in which the verbal element *ɖù* combines with an NP, as indicated in (14).

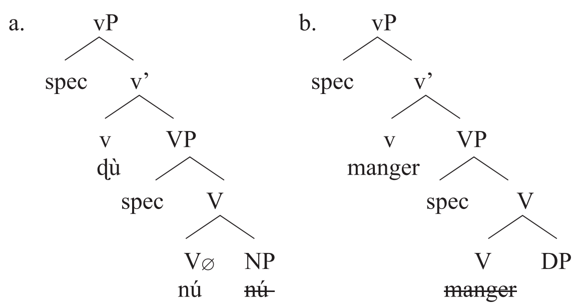
(14) The ICV *ɖù* in Gungbe

| V | | NP | | Equivalent English Meaning |
|---|---|---|---|---|
| | | **nú** | 'thing' | eat |
| | | **kwɛ́** | 'money' | spend money |
| | | **wìnyá** | 'shame' | be ashamed |
| **ɖù** | + | **àɖì** | 'poison' | experience anger (to be angry) |
| | | **àxɔ̀** | 'debt' | go bankrupt or have debts |
| | | **nùgò** | 'mouth' | boast |
| | | **yà** | 'suffering' | experience suffering |
| | | **xwè** | 'year' | celebrate |

The variety of meanings in (14) indicates that the verbal element *ɖù* does not seem to have a clear meaning on its own, since it must combine with various NPs to form different meanings, hence *ɖù* + *nú* "thing" translates as "eat," *ɖù* + *kwɛ́* "money" translates as *spend* and *ɖù* + *wìnyá* "shame" translates as "be ashamed," etc. It is these meanings that are incorporated in French *manger* in example (14). The lexical item *manger* in the idiolect of this speaker can then be described as in (15).

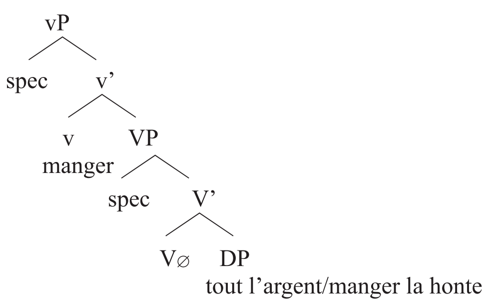
(15)



Aboh (2015a) argues that ICVs involve a functional verb which first merges in *v* unlike lexical verbs which merge in V. Comparing *ɖù nú* in Gungbe to *manger* in French, we reach the contrast in (16a) for Gungbe versus (16b) for transitive *manger* in French.

(16) Functional verb in v Lexical verb in V



The two languages differ in a number of respects: *manger* in Standard French being a lexical verb, it merges in V where it selects a relevant DP. This is different from Gungbe in which the lexical verb is null but has categorial requirement on its bare NP-complement, here *nú* which further incorporates in V. The lexical verb raises to *v* in French, but this movement is impossible in Gungbe in which *v* contains the functional verb *ɖù*, which introduces the external argument. Based on examples such as *ɖù* + *nú* "V + thing" in which the complement NP *nú* is a dummy element, Aboh (2015a) concludes that such a functional verb only encodes that the external argument has some experience/relation with the set referred to by the complement bare NP. The nature of this experience/relation is inferred from the context. This is why the meaning of the verbs in (14) is not compositional and cannot be entirely predicted based on the NP complement. I refer the interested reader to Aboh (2015a) and references therein for further discussion on ICVs. What matters, however, for the present discussion is that the usage of *manger* in the expressions *manger tout l'argent* and *manger la honte* in example (13) results from the integration of structure (16a) into French. These expressions involve a functional usage of the verb *manger* which first merges in *v*, while V has no phonological content. Note, however, that the combination of Gbe and French yields a new empty V that selects for a full DP, hence the occurrence of the quantifier *tout*, and the definite determiners *le*/*la* in these examples (17).

(17)




Recombining properties of *manger* in French to those of ICVs in Gbe, and therefore coining a functional verb *manger* in Béninois French, leads to a new structure not found in the two languages. This, in turn, is a point of change between Standard French and Béninois French. In the new structure $V_{\emptyset}$ has no phonological content, and it is not spelled out because its complement, a DP or QP blocks N-to-V incorporation, unlike bare NPs in Gbe (or Kwa in general). Structure (17) can therefore generate *manger tout l'argent* or *manger la honte*; but not **manger argent* or **manger honte* which would be perfect replicas of Gungbe as in (16a).

*Manger* in French arguably spells out two nodes within the vP: v-V. However, in the Béninois French usage of *manger* in a way similar to ICVs, this lexical item only spells out v, leaving V unpronounced. This suggests the description below.

| | |
|---|---|
| Standard French (manger) | v: external argument Agent |
| | V: means consume. Selects eatable DPs |
| Béninois French (manger) | v external argument Agent |
| | V: means consume. Selects eatable DPs. |
| | v external argument Experiencer |
| | V: has no proper semantics. Selects for (affected) DPs |

## Recombination, Grammaticality Judgment, and Limits on Variation

The discussion in previous sections shows that recombination accounts for S-learners' variation as resulting from the acquisition of the lexicon, and sheds new light on the notion of acceptability judgment as a formal notion central to the inquiry of S-learners' competence (Chomsky, 1965). **Figure 3** indicates that the common notion of "grammaticality" involves two aspects. One, understood as acceptability, relates to the lexicon and can be defined as the conventions allowed within a speech community. For instance, there is no computational or UG principle that bans verbal *rather* (11) in American English or functional verb *manger* in French (13). Though excluded from the pool of "close variants" in Standard American English and Standard French, respectively, these "distant variants" (cf. **Figure 3**) nevertheless represent well-formed linguistic objects involving specific bundles of features. Studies investigating this type of acceptability are only informative to the extent that they expose the conventions at work within a particular speech community. Consequently, so-called grammaticality judgment tasks that tap into S-learners' knowledge of such conventions do not directly inform us on the constraints on the computational system which may translate into constraints on linguistic variation. By tracking such conventions within a community, we actually gather knowledge on E-language, and may not immediately deduce any broad generalization about the human language capacity unless we take a broader comparative typological perspective that can help identify gaps, which in turn inform us on possible constraints on the language faculty.

The present discussion on recombination may give some readers the feeling that any combination is possible, yet this cannot be true, as clearly indicated by the relatively small number of structural types discussed in typological books. This makes sense if variation of the structural type is constrained by properties of the computational system. This brings us to the second side of grammaticality: which relates directly to the limits of the computational system. Violations on principles of the computation (e.g., Minimality effect, feature mismatch) hold universally, but they are extremely difficult to investigate (as any fieldwork linguist would recognize). For instance, we saw in previous sections that aphasic patients showing pathological code-mixing produce patterns which, even though unacceptable from the point of view of a specific lexicon, are well formed syntactic objects sometimes conventionalized in so-called new languages (e.g., mixed languages). Accordingly, constraints on the computational system can only be studied experimentally or through introspection, rather than based on naturalistic data or corpora. If we consider the role of Minimality in recombination, for instance, I'm not aware of any instance of non-local recombination[13] in neuro-typical populations engaged in creative language use in which an affix may be recombined across an

[13] A reviewer correctly remarks that such "ungrammatical" recombination may well be observed in some neuro-atypical speakers, e.g., in patients with Huntington's disease (cf. Németha et al., 2012). I thank this reviewer for bringing this to my attention and I hope that future work will shed better light on this question.

intervening affix (e.g., recombination of an affix and a root across another blocking affix, as in greed-ness-y for greed-i-ness). I'm also not aware of speech errors involving such Mimimality violations (cf. Pfau, 2009). It therefore seems that Minimality violating (or formally "ungrammatical") recombination is generally absent in spontaneous productions of neuro-typical populations. Minimality, therefore, is a strict condition on the computational system. The interaction between grammaticality constraints on specific lexica and formal constraints on the computational system yields the range of variation observed cross-linguistically, as well as the strong commonalities that human languages display. These two levels of grammaticality are not always systematically distinguished in the literature, sometimes leading to confusions or misunderstandings as to the relevance of naturalistic data versus controlled experimental data. In this paper, grammaticality over the lexicon informs us on the contours of patterns on the population level and how that relates to some conventionalized forms in a specific lexicon. Grammaticality over recombination informs us on limits of the computational system itself, that is, what is humanly possible, and arguably learnable.

## Constraints on Variation

In this regard, Aboh (2015b, 2019a) reports a fact discussed in the literature since the early 80s by typologists as well as creolists (e.g., Bickerton, 1981, 1988; Muysken, 1981a; Foley and Van Valin, 1984; Baker, 1985; Bybee, 1985; Hengeveld, 1989) and further formalized recently by Cinque (1999) within the cartographic framework: All human languages described to date display a fixed ordering of Tense, Mood, and Aspect (TMA) expressions as schematized in (18a). In this schematic sequencing, each label stands for a more articulate domain involving distinct tense, mood, or aspect expressions. An illustrative Gungbe sentence is given in (18b), whose sequencing is described in (18c) (cf. Aboh, 2004).

(18) a. ... MOOD1 > TENSE > MOOD2 > ASPECT.

| | | | | | |
|---|---|---|---|---|---|
| Sɛ́ná | má | ná | sìgán | nɔ̀ | tò |
| Sena | NEG | FUT | ABL | HAB | PROG |

b.

| | | |
|---|---|---|
| mótò | ná | xɔ̏ |
| car | PROSP | buy.PCL |

'Sena will not habitually be in the possibility of buying a car.'

c. NEGATION > FUTURE > ABILITY > HABITUAL > PROGRESSIVE > PROSPECTIVE–VERB

Cross-linguistic studies have shown that this sequencing or some variant thereof spontaneously emerges in new languages (e.g., creoles). Likewise, even though such TMA expressions can precede or follow the lexical verb and may display different derived orders, the scope hierarchy in (18a) is always maintained such that no example of random combinations or reordering (e.g., aspect markers being further away from the verb than epistemic modals) has been described for any human language (cf. Baker, 1985; Hengeveld, 1989, 2006; Cinque, 1999; Ramchand and Svenonious, 2014). This is so, even though languages may show extreme morphological variations as to how to express each label, some using affixes, other resorting to free morphemes, while others even use tones. Given our previous observations about recombination and limits on computation, it seems reasonable to assume that the absence of cross-linguistic structural variation within the so-called INFL domain is due to Minimality. TMA elements can only be recombined locally, that is, only adjacent heads can recombine and recombination cannot operate across an intervening head (i.e., a TMA). Accordingly, an aspect head (e.g., expressing progressive in 18b) cannot be merged directly to the future head, across the habitual head and the ability head. This is so, even though progressive tends to be used to encode future time reference in many languages, as in *I'm gonna leave* in English. Note that, in this example, however, recombination happens between *going* and *to*, which are arguably adjacent in the derivation. Minimality therefore severely constrains structural reordering patterns within the TMA, hence the astonishing uniformity observed cross-linguistically. The current discussion indicates that human languages are structurally alike with regard to their TMA domain. The question now arises whether this uniformity applies to other structural domains as well, or whether there are loci of structural variation which may be the core of typological variation.

Not much is known about this question as there is not yet a typology of the points of structural variation within human languages. In this regard, Aboh (2019a) reports that the cross-linguistic stability observed within the TMA domain, does not seem to immediately carry over to the CP domain, which Rizzi (1997) analyses as involving the schema in (19). Force encodes clause-typing, Inter expresses interrogative features, Top hosts topic elements, Foc licenses focus phrases, and Fin realizes finiteness properties of the embedded TP.

(19) ForceP. . .InterP. . .TopP*. . .FocP. . .TopP*. . .FinP. . . TP. . .VP.

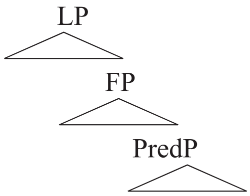
Much work is still necessary before we have a better insight into cross-linguistic variations within the CP-domain. Yet, a cursory look at the existing literature on Information Structure (IS), and its related word order patterns, largely determined by the CP-domain, indicates that IS is the source of sharp cross-linguistic structural variations. Starting with commonly studied languages, a naïve look at Slavic versus Germanic and Romance, shows that while the former can be said to exhibit morphologically rich agreement patterns, these does not make them particularly striking compared to the latter. Instead, what makes Slavic languages stand out typologically is the intricate relation they display between IS and Syntax, which led experts to label them as discourse-configurational languages (e.g., É-Kiss, 1995 and references therein). Germanic languages, however, are well-known for exhibiting V2 phenomena, virtually absent in Romance, for instance. With regard to Niger-Congo, many studies reveal that most languages of this family exhibit a rich set of discourse markers that realize the clausal left periphery and mark discourse-related constituents such as topic and focus. Such left peripheral markers are not typical of Slavic, Germanic, and Romance which rely more on word order and intonation for IS purposes. Indeed, discourse markers in Niger-Congo typically trigger displacement operations which sometimes result in a whole sentence being pied-piped to some left peripheral position (cf. Nkemji, 1995; Aboh, 2010, 2016). Note, however, that heavy pied-piping for the purpose of discourse is not pervasive in Slavic, Romance or Germanic languages.

There is also significant variation within language families. For, instance, while some Romance languages (e.g., Italian) allow recursive topic phrases to precede and follow a unique focus projection (Rizzi, 1997), others (e.g., French) exclude such structures. Within Niger-Congo, some languages display *ex situ* wh-movement only (e.g., Gbe), others involve both *ex situ* and *in situ* strategies (e.g., Gur, Bantu). Finally, some Germanic languages display superficial V3 patterns, while others exclude such sequences. Discussions on IS and its relation to the clausal left periphery therefore suggest that languages tend to vary more structurally within this domain.

Accordingly, the structural rigidity that prevails within the TMA domain does not seem to hold when it comes to the clausal left periphery: the CP-domain. Under the reasonable hypothesis that the licensing of discourse markers, V2, and wh-phrases are all properties of specific heads within the CP-domain, it appears that the range of structural variation within this domain is more pronounced than originally assumed. Finally, there is a wealth of literature on language acquisition within different S-learner profiles (e.g., L1A, L2A, Heritage learners, learners with Developmental Language Disorder) showing that while (advanced) S-learners may be target-like with regard to properties of the TMA domain, they may experience more difficulties with IS-related constructions (Haznedar and Schwartz, 1997; Lardiere, 2000; Prévost and White, 2000; Goad and White, 2004; Sorace, 2005; Tsimpli and Sorace, 2006; Sorace and Serratrice, 2009; Polinsky, 2018). Accordingly, there appears to be a fundamental asymmetry between the CP-domain and the TMA domain.

Translating this asymmetry in phase theory (Chomsky, 2000, 2001), let us assume the label L to be a shorthand label for all left peripheral phases, including the clause and nominal phrase. Under the traditional view of phrase structure (e.g., Bowers, 1993), this would mean that clauses and noun phrases can be assumed to involve the abstract structure in (20), which consists of a predicate phrase PredP, a functional layer FP (including specific projections hosting TMA and modifiers), and an LP (including specific projections hosting discourse particles e.g., focus, topic, cf. Aboh, 2004).

(20)




The observations in the previous paragraph suggest that structural linguistic variation is mainly driven by phase properties of LP. The point here is not about a phase parameter, that is, which specific functional head (e.g., D, T, Force) may constitute a phase cross-linguistically. Instead, the relevant point here is that variations within LP expressions point to variations in the internal structure of LP, which may impact FP cross-linguistically. With regard to the clausal domain, such variations seem to correlate with word order patterns, subordination, and possibilities of wh-extractions which have far reaching consequences on the structure of languages. Within the nominal domain, variation within LP can be attributed to licensing of argument DPs cross-linguistically, and how this correlates with bare NP languages versus languages with determiner-NPs, and how these properties relate to other clausal aspects (cf. Bošković, 2008). In the context of our discussion, this amounts to saying that recombination creates more distant structural variants when it comes to the LP. In this regard, a noticeable and well-studied example is Modern English: What makes Modern English a typologically unique West Germanic language is not its FP (i.e., expressions of TMA) but rather the fact that it lost V2: a property of West Germanic LP. It is interesting, however, to note that despite not being a typical V2 language, English does exhibit what Rizzi (1996) refers to as "residual verb second", that is, the fact that the finite verb (or auxiliary) must occur in second position in certain constructions involving interrogatives or negative inversion (cf. Haegeman, 1995). That English shows such a hybrid property constitutes further evidence in support of the view developed here in terms of recombination and hybrid grammars.

## CONCLUSION

In this paper, I argue that language acquisition involves contact of idiolects (i.e., contact between individual S-learners leading to contact between different linguistic features in the mind of individual S-learners). Building on Aboh (2015b), I propose that grammars emerge through *recombination*: a fully automated cognitive process which allows S-learners to select linguistic features and recombine them into new syntactic objects as part of their mental hybrid grammars. Immediately observable instances of recombination are illustrated by code-mixing which appears a capacity present in all S-learners. In this regard, I have shown that both neuro-atypical and neuro-typical S-learners exhibit similar production (and arguably processing) patterns, a conclusion already reached by Perecman in the early 80s. What this paper adds to the discussion is the distinction between the role of executive functions as necessary for vocabulary selection, while recombination appears an innate capacity.

Building on this, I further show that while recombination within the TMA domain, traditionally referred to as the INFL-domain, is immune to structural change due to strong Minimality constraints, this does not seem to be the case when it comes to the left periphery, that is, the phase level. I therefore conclude that structural variation of the type that leads to typological variation is a phase-level property. This view accounts for the fact that even though recombination appears "free," its effects vary depending on the structural domain that it applies to. While the discussion here mainly focuses on syntax, one can imagine similar recombination patterns in semantics and phonology, and how these are constrained cross-linguistically.

The approach developed in this paper makes clear what core aspects of language are common to neuro-typical and neuro-atypical S-learners. There has been a tendency in the literature to study neuro-atypical S-learners only from the perspective of what they "lack" or "fail to exhibit." By focusing on what is common to both neuro-typical and neuro-atypical S-learners, this paper sheds light on the relation between fundamental aspects of language and peripheral ones, that is, what is core and undamageable versus what is peripheral (and presumably damageable and variable).

The discussion in this paper mainly focuses on mixing patterns found in certain aphasic patients. A more comprehensive work is needed to establish a typology of the different neuro-atypical cognitive phenotypes, and in conjunction with this, a typology of their mixing patterns. Such a typology is necessary to establish the degrees to which neuro-typical and neuro-atypical cognitive phenotypes exhibit (dis)similar recombination patterns.

Another important question that arises under the theory of clause structure and recombination presented here, and which merits further investigation, is how the different domains identified in (20) are processed. Recent studies suggest that syntactic processing involves several brain regions which are also involved in other cognitive tasks even though together they may form a tight network specialized in linguistic computation (e.g., Vigliocco, 2000; Kaan and Swaab, 2002; Friederici, 2011). If syntactic processing results from a diffuse network, we may further wonder whether phrase structures, i.e., LP, FP, and PredP are all processed similarly. While this question is not discussed in current Minimalist theories, the view of recombination developed in this paper is compatible with the assumption that LP versus FP/PredP might be processed differently. There is now a body of literature demonstrating a more articulate neurobiology of language that suggest such a possibility, and I hope this paper will generate further discussion on the matter.

## AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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# Fragments Along the Way: Minimalism as an Account of Some Stages in First Language Acquisition

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We discuss two instances in which the minimalist model of syntax offers a potential account of children's linguistic behavior: the Merge analysis of phrase structure and the analysis of pronominal structures and other long distance dependencies. In each case, we need to understand the relationship between performance mechanisms (the mechanisms for language production and comprehension) and the syntax on which these mechanisms draw.

**Keywords: first language acquisition, minimalism, performance mechanisms, merge, pronoun interpretation, questions**

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In this article we will explore some of the potential that comes out of Minimalist syntax for an account of stages in language acquisition, focussing on the early emergence of word order, and the role of interface conditions in explaining children's behavior. Our discussion does not aim to be a comprehensive account of language acquisition in a Minimalist framework—such an account would require far more research, which is (to our knowledge) yet to be done. However, we can point to a common thread in the examples we discuss: In each case, we need to understand the relationship between performance mechanisms (the mechanisms for language production and comprehension) and the syntax on which these mechanisms draw.

## MERGE IN SYNTACTIC THEORY

In the work of Chomsky (1995, and subsequent publications), the operation of Merge is fundamental to structure building. It is an operation that combines two syntactic units into a constituent. Asymmetric Merge determines which of the two elements is the head of the unit: in languages such as English, it is the left element that is the head and determines the category label of the constituent; in language such as Japanese, it is the right element that is the head and determines the category label.

### Merge as an Account of Early Stages in Language Development

Braine (1963) provides an early report of the young children's attempts to combine words. Braine gives evidence of the three children (Gregory, Andrew and Steven) he studied producing "Pivot" and "Open" classes of words[1]. Pivots are words such as *allgone, byebye,* and *see* that occur in the majority of word combinations, and to which other words from the open class are attached, e.g., *allgone shoe* and *allgone egg*, or *byebye plane* and *byebye man.* The data from the three children reported in Braine's article is given in **Table 1**, in abbreviated form. Braine observed a period

[1] Braine used the term "X" for "Open" class words.

of about 4 months (from the first occurrence of two word utterances at approximately 19 months) in which the Pivot-before-Open (hereafter Pivot-Open) pattern predominates for Gregory and Andrew; Steven also had a Pivot-Open pattern in examples tape-recorded in the fourth and fifth months after the first occurrence of two word utterances.

It is possible to interpret Braine's data in terms of the earliest occurrences of Merge. The children in Braine's study combined two words together, and moreover these children favored the Pivot-Open pattern (although Open-before-Pivot did occur; see the next section), consistent with the children having adumbrated, if not mastered, the Head—Complement/Modifier pattern of English.

## Is Headedness Immediately Evident?[2]

Although Braine's evidence favors the order Pivot-before-Open, these are not the only orders that occur. The opposite order (Open-before-Pivot in Braine's analysis) is also found, as shown by the data with *it* in Braine's data for Gregory; *off, by, come and P-there* for Andrew; and *do* for Steven. More recent research has shown that in early stages word order can be variable: strings that must be interpreted as Subject—Verb, Verb—Subject, Object—Verb and Verb—Object are attested in languages with SVO order (Tsimpli, 1992 [quoted in Galasso, 2001], Galasso, 2001). Thus, it may be the case that at a very early stage the child combines two words without attention to headedness. Nonetheless, the evidence favors the rapid development of a system in which asymmetric Merge is found in child language[3].

This conclusion is supported by the only study we are aware of a language that is head-final. Jordens et al. (2008) examined the development of one child speaking Japanese, Jun, and found indeed that there was a pattern that can be interpreted as Open-Pivot[4]. Jordens et al. report that in his utterances Jun used a pattern in which the utterance final position was occupied by a particle, as in (1),

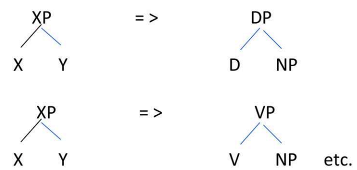
1a ookii densha ya
big train insistence particle
"It's a big train"

b zoo ookii yaa
elephant big confirmation particle
'The elephant is big'

We can take such utterances as a realization of the pattern Open-Pivot, with the particle serving as the pivot. The context makes clear that the child is not simply mimicking the adult('s) speech; the child latches onto a pattern with an utterance final particle as Pivot despite the absence of such a particle in the immediate speech context. Jordens et al. observe that at an early age (the files when Jun is 1;11) the order we are interpreting as Open-Pivot accounts for half the analysable utterances (the remaining half mostly consists of one word utterances when Jun is engaged in naming pictures, objects, etc.). And so, the evidence suggests that the order Pivot-Open is preferred in English, but Open-Pivot is preferred (for the admittedly small amount of data) in Japanese, in accord with the branching pattern of the language being learned.

## Some Issues With Data Interpretation

Assuming that headedness is present, one question that arises with respect to the data is what the labels associated with the heads are. Braine (1963) observes that Gregory appears to adumbrate a Noun/Adjective vs. Verb distinction. It is mainly nouns and adjectives that serve as Open words in the Pivot-Open order, and only verbs that serve as Open words in Open-Pivot order. Tentatively, we can assume a progression from an unspecified head to categories that resemble the specific categories of English:




Such a progression does not imply that the categories all at once switch from a general category label to specific categories. The development may be dependent on the lexical categories merged and may be piecemeal. For example, the child Gregory in **Table 1** may have a nascent category VP in his utterances with the final pivot *it*, and a nascent category AP in his utterances with the initial pivots *big* and *pretty*.

The development takes place within two or three months in the second year, and may vary from child to child. The data from Allison in **Table 2** shows a fairly clear breaking point between 22 and 24 months. At 22 months she produces almost no utterances longer than two words and at 24 months she is capable of producing an utterance of six words. However, Allison also shows typically telegraphic speech, with almost no articles or prepositions, as the examples of her utterances illustrate. The data from Abigail in **Table 2** shows that at more or less the same age as Allison and the three children in Braine's data she has already plausibly developed a rich repertoire that enables significant sentence complexity. At 24 months, she produces sentences with auxiliary verbs, including the sentence with the (presumably epistemic) modal *must*: *Mummy must have gone shopping.*

It has been more or less a given assumption in child language studies that the one word stage is followed by a two word stage, but that there is no separable three word stage. This is broadly consistent with the data from Allison in **Table 2**, and would follow from a picture of development in which the child first "practices" with two word utterances (the output of simple Merge) and subsequently commands the operation of Merge sufficiently well for several applications of it to occur in a single utterance. Consistent with this, Braine reports an increase in utterance length at around the fifth and sixth months

[2]Our thanks for a reviewer for his/her comments on the issue of headedness.
[3]See Yang and Roeper (2011, p. 563–464), for a similar point. Yang and Roeper cited in Drozd (2001). Their bibliography includes the reference to Drozd (2001) in our bibliography, but it seems that the reference should be 2002. Yang and Roeper's interpretation in terms of asymmetric Merge differs from Drozd' (2002) own interpretation in terms of a reduction of adult forms, although the two are not incompatible.
[4]Jordens et al. (2008) use the terms "Predicate" and "Link," respectively.

**TABLE 1 |** Analysis of speech data from three children (Braine, 1963).

| Pivot-Open | Open-Pivot | Other |
|---|---|---|
| **Gregory (age 19–22 months)** | | |
| BYEBYE [31] *byebye plane, byebye man*, *byebye hot*,..<br>SEE [14] *see boy, see sock, see hot, …*<br>ALLGONE [5] *allgone shoe, allgone vitamins, allgone egg*, *allgone lettuce, allgone watch*<br>MY [3] *my mummy, my daddy, my milk*<br>BIG [3] *big boss, big boat, big bus*<br>PRETTY [2] *pretty boat, pretty fan*<br>NIGHTNIGHT [2] *nightnight office, nightnight boat*<br>HI [2] *hi plane, hi mommy*<br>MORE [2] *more taxi, more melon* | IT [5] *do it, push it, close it, buzz it, move it* | 20 unclassified combinations (e.g., *mommy sleep, milk cup, oh my see*) |
| **Andrew (age 19–23 months)** | | |
| ALL [12] *all broke*, *all buttoned*, *all dry, …*<br>MORE [11] *more cookie*, *more hot*, *more read, …*<br>NO [10] *no bed*, *no home*, *no fix, …*<br>OTHER [10] *other bib*, *other pants*, *other piece*<br>I [3] *I see*, *I shut*, *I sit*<br>SEE [3] *see baby*, *see pretty*, *see train*<br>HI [3] *hi Calico, hi mama, hi papa*<br>COME [2] *mail come*, *mama come* | OFF [6] *boot off*, *light off*, *water off*<br>BY [2] *airplane by*, *siren by*<br>PREPOSITION THERE [11] (e.g., *clock on there*, *milk in there*, *light up there*) | 20 unclassified combinations (e.g., *all done milk*, *byebye back*, *off bib*) |
| **Stephen (age 23–24 months)** | | |
| WANT [16] *want baby, want do, want up, …*<br>IT [14] *it ball, it daddy, it fall …*<br>THERE [11] *there ball, there doggie, there byebye car …*<br>THAT [5] *that box, that Dennis, that doll*<br>SEE [4] *see ball, see doll, see record, see Stevie*<br>HERE [4] *here bed, here checker, here doll, here truck*<br>MORE [2] *more ball, more book*<br>BEEPPEEP [2] *beeppeep bang, beeppeep car*<br>WHOA [2] *whoa cards, whoa jeep* | DO [4] *bunny do, daddy do, momma do, want do* | 16 unclassified combinations (e.g., *bunny do sleep, pon baby, Betty byebye car*) |

*Pivots are shown in capital letters, followed by the number of occurrences in square brackets in the files listed for each child, and examples of the Pivot-Open or Open-Pivot structures from the child's speech.*

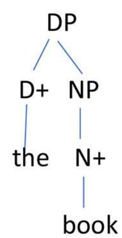
of his study. However, he does not specify the proportions of two vs. three and more word utterances before and after the upsurge.

We examined some CHILDES files and found that utterances with pivots are not as frequent as we might have expected on the basis of Braine's data, although they are not completely absent. For example, in the file for the child Eric at 1;10 (MacWhinney, 2000, Bloom 1970 files) Eric has a pivot utterance *no more X*, which accounts for 18 out of 21 three word utterances. Overall, it is possible that the diary method used by Braine may be more revealing of stages than the method of short recordings that characterizes the CHILDES files.

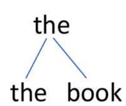
## Bare Phrase Structure

To what extent is (asymmetric) Merge superior to the traditional X-bar theory of phrase structure in explaining children's behavior? Chomsky (1995, pp. 241–249) sketches the "bare phrase structure" theory, of which Merge is the essential component, and compares the bare phrase structure approach to X-bar theory. Chomsky proposes that X-bar structures along the lines of (2a) be replaced by (2b) (his 8a and 8b),

2 a.




b.




The components of (2b), *the* and *book*, are abbreviations for the set of features in the lexicon that make up those words. We have described a child's development as a progression from random (unordered) conjunctions to the headed combinations of asymmetric Merge. This development will surely take account of frequency in the input of various structures. The child does not need to construct intermediate layers of representation of X-bar theory unless the input motivates these layers. Thus, the acquisition of bare phrase structure can be argued to provide a simpler account than X-bar theory of the move from fixed

**TABLE 2 |** Analysis of the speech from Allison (MacWhinney, 2000; Bloom 1973 corpora files 1–4) and Abigail (MacWhinney, 2000, Wells corpora files 1, 2, and 3).

| Utterance length | 1-word | 2-word | 3-word | 4-word | 5-word | 6-word |
|---|---|---|---|---|---|---|
| **ALLISON** | | | | | | |
| Example(s) | *Wiping;<br>chair;<br>eat* | *Baby eat;<br>mommy open;<br>blouse on* | *Baby down chair;<br>baby eat cookies;<br>eat apple juice* | *Put away Allison bag;<br>help cow in table;<br>drink apple juice again* | *Drink apple juice<br>right here* | *Sit down right here<br>next truck* |
| File 1, 16 months (1;04.21) | 347 | 39 | 7[1] | | | |
| File 2, 19 months (1;07.14) | 345 | 11 | | 1[2] | | |
| File 3, 20 months (1;08.21) | 375 | 49 | 2 | | | |
| File 4, 22 months (1;10,00) | 154 | 81 | 28 | 5 | 1 | 1 |
| **ABIGAIL** | | | | | | |
| Example(s) | *bike;<br>writing;<br>mummy* | *a bang;<br>this way;<br>baba mummy?* | *I want mummy;<br>this cut it;<br>goes on there* | *do it for me;<br>this is a boot [= boat];<br>the bell ring Mummy* | *Mummy must<br>have gone<br>shopping* | |
| File 1, 18 months (1;05.28) | 30 | 11 | 2 | 1 | | |
| File 2, 21 months (1;08.27) | 29 | 22 | 6 | 4 | | |
| File 3, 24 months (2;00.01) | 41 | 26 | 16 | 10 | 1 | |

[1]*All involve [wi(deh)]. [wi(deh)] is a sequence of sounds that occurs in Allison's speech which have no identifiable referent.*
[2]*Repetition of mother's utterance.*

and limited combinations to grammatically licit productive combinations that result from asymmetric Merge.

## Summary

What are the advantages of the analysis of phrase structure in terms of the operation of Merge? As stated in the previous section, the Merge account obviates the need for intermediate layers of structure. Other than that, the Merge account of language development must be blended with an account that includes properties of the perceptual interface in a Minimalist model. In the Minimalist framework, the interfaces between syntactic representation and the sensory-motor system (phonetic form) and conceptual-intentional system (logical form) are constrained by extra-linguistic factors (Hauser et al., 2002), including cognitive structures, pragmatics and memory limitations. In order to use asymmetric Merge, the child must take onboard distributional evidence from the language s/he is learning, and an individual child may differ in the rapidity with which he or she moves from the simple operation of Merge to the capacity to execute multiple cases of Merge in a single utterance, as illustrated by the contrast in behaviors between Allison and Abigail. The change from X-bar theory to Merge does not in any obvious way change the puzzle of what the connection is between the evidence of the child's perceptions and his or her construction of a grammar, although the recognition of the role of interface conditions in the Minimalist model provides a framework for exploration.

# MORE ON INTERFACE CONSTRAINTS

In this section, we look at another area of grammar in which we argue that interface constraints are needed for a full explanation of language development.

## The Interpretation of Pronouns and the Organization of the Processor

Reuland (2001) develops a minimalist alternative to the Binding Theory of Chomsky (1981), building on earlier work by Reinhart and Reuland (1993). In Reuland's analysis, principles A and B (governing the distribution of reflexive pronouns and definite pronouns, respectively) are replaced by a requirement that verbs are interpreted reflexively only when they are combined with a reflexive pronoun, i.e., verbs that are interpreted reflexively do not permit a definite pronoun with a reflexive interpretation. This excludes a sentence such as (3) from having an interpretation in which *de man* and *hem* corefer.

3 *De man$_i$ heeft hem$_i$ geknepen
The man has him pinched
"The man pinched him"

A separate analysis is required by Reuland to exclude co-reference in exceptional case marking (ECM) contexts, such as (4). This is achieved by a condition on A-chains (chains formed between arguments) requiring that at most one member of the chain (the head) is marked as +R(eferential), where +R items are those that carry full specification of φ-features and case. Since both pronouns and lexical NPs are +R, (4) is ungrammatical.

4 *De man$_i$ zag hem$_i$ voetballen
The man saw him playing soccer
"The man saw him playing soccer"

Reuland draws a distinction between the levels of grammar required to determine the ungrammaticality of (3) vs. (4). The ungrammaticality of (3) can be determined in the narrow syntax, by virtue of the requirement that a predicate, if interpreted reflexively, excludes a definite pronoun from its domain. (3) is also ungrammatical because it violates the condition on A-chains. The ungrammaticality of (4) relies solely on the condition on A-chains, which in turn mandates access to discourse structure. Reuland argues that the degree of crosstalk between levels of representation determines the complexity of a sentence: the ungrammaticality of (3) can be determined by reference to the narrow syntax requirement on reflexive predicates, whereas the ungrammaticality of (4) is determined by the narrow syntax rule governing the well formedness of chains, which in turn requires access to a discourse related phenomenon (the referentially of the pronoun).

Ruigendijk et al. (2011) provide striking evidence that Dutch, Spanish and Italian children aged 4–5, draw a distinction between sentence types (3) and (4) in their native languages, with many more errors in the case of sentence type (4). Ruigendijk et al. take this as an indication that Reuland's analysis is correct, in contrast to the analysis of Chomsky (1981), which treats both (3) and (4) as violations of principle B of the binding theory (in which the domain for computing reference of pronouns was the whole sentence in both 3 and 4). See also Brunetto (2012) for further experiments on ECM constructions in child Italian.

Ruigendijk et al. propose that the ungrammaticality of (4) is known to children, but that a lack of processing resources intervenes to produce errors on that sentence type. Part of the evidence they cite is a study by Sekerina et al. (2004) on the processing of sentences such as (5), in which both a pronoun and a reflexive are acceptable with reference to *the boy*.

5 The boy has placed the box behind himself/him

Sekerina et al. found that children aged 4–7 years as well as adults were aware of both, in a task in which the participants had to choose between two pictures, one representing the internal reading of the reflexive/pronoun (i.e. the boy with the box behind his own back) and the other representing the external reading (i.e. the boy with the box behind the man's back), while their fixations on each picture were recorded. After a period in which both internal and external fixations were about equal, both child and adult groups fixated on the picture representing the sentence internal reading more than on the picture representing the sentence external reading. However, the children took longer to establish the pattern of fewer fixations for pronouns. When asked to choose one of the two pictures, the adults chose the picture representing the sentence external reading in about one fifth of their responses to pictures with pronouns, whereas the children almost never chose the picture representing the sentence external reading. Thus children in this study showed awareness of the grammaticality of the pronoun as well as the reflexive in sentences such as (5), as evidenced by their fixation pattern, but failed to reflect that awareness in a more resource-intensive picture pointing task, in which they consistently chose the internal reading[5].

A widely accepted (but far from uncontroversial) model of sentence processing places access to discourse representations toward the end of the chain of operations in comprehending a sentence (see for an early example of such a model, Forster, 1979). Thus, we can see a parallel between Reuland's analysis and a processing model. If operations that are at the end of the comprehension sequence are less efficiently executed (for reasons of, for example, lower working memory), then we have the potential to explain why children do worse on sentences such as (4) than they do on sentences such as (3).

## Is the Minimalist Program an Advance on the Government and Binding Model?

Notice, however, that the parallelism is not exact between Reuland's analysis and a processing model which entails that sentence-external reference is less easily accomplished than sentence-internal reference. A Minimalist-friendly processing model would not only provide an explanation of the pattern of findings with respect to Principle B summarized in the preceding section, but also be extended to other results with Principle C of the binding theory and the interpretation of control structures described in the following paragraphs.

In an act-out experiment, Goodluck and Solan (2001) required 3–6 year old French-speaking children to act out to sentences such as (6–7),

6 Il touche le cheval avant que le zèbre mange
"He touches the horse before the zebra eats"

7 Le cheval le touche avant que le zèbre mange
"The horse touches him before the zebra eats"

Principle C of the Chomsky's binding theory blocks coreference between *Il* and *le zèbre* in (6), since *il* c-commands *le zèbre*. In (7), however, coreference is possible between the pronoun *le* and *le zèbre*, since the pronoun is contained within the main clause VP, and does not c-command the adjunct clause. In acting out sentence type (6), there was a difference between the younger children (3–4s) and the older children (5–6s). The younger children were inclined to act out (6) as if it was (7), whereas the older children were more able to select an unmentioned animal as referent of the pronoun. Thus, the younger children gave a response that was incorrect for the stimulus (but nonetheless corresponded to a grammatical sentence type); they did not go outside the sentence for a referent of the pronoun.

An additional result argues that younger children have problems with accessing material not mentioned in the sentence. Goodluck et al. (2001) studied the acquisition of controlled complements in Spanish. In the adult grammar, the null subject (E[mpty] C[ategory]) of the complement to *quiere*

[5]Ruigendijk et al. also cite several studies that show slowed processing by brain-damaged patients.

("want") obligatorily refers to an unmentioned entity when the complement is subjunctive,

8 Papá quiere que EC de una voltereta
Dad wants-3s that EC do-3p-subjunctive a somersault
"Dad wants someone else to do a somersault"

In an experiment in which adults and children acted out sentences with dolls, adults *never* gave a response in which the main clause subject was made co-referential with the EC. Four to five year old children gave such a response in 89% of cases; even by age 6–7, there were 46% of such responses. The younger children failed to take into account the requirement to go outside the sentence in the case of subjunctive complements[6].

Thus, we have evidence from different areas of grammar (Principles B and C of the binding theory and control) that children slip up when the grammar requires them to look outside the local domain to analyze the input. We need a model that allows for:

a) the limitations (individual and particular to groups) in working memory;
b) the limitations (perhaps relating to [a]) in span which can be accessed, such as the "sentence/clause bound" properties of responses to (5–7).

The Minimalist program here offers an advantage over the Government and Binding model. By recognizing the need for interface conditions such as working memory capacity, we can provide a unified explanation of the phenomena from different areas of grammar. Concomitantly, there is potentially a reduction of the role of learning in acquisition. For example, Hamann (2011) reviews the extensive literature on the acquisition of the binding theory (Principles A and B), including debates concerning whether pragmatic principles are learned/develop over time to account for the slower mastery of pronouns as opposed to reflexives. By placing the burden on the processing mechanism in explaining children's problems in understanding the grammar of pronouns, we can reduce (but not eliminate) the need for learning. We can reduce it partly by explaining the errors children make as a consequence of the limited span (b, above), but we cannot eliminate the need to learn, for example, the language particular distributions of clitic vs. non-clitic pronouns, which may be affected by their frequency, *inter alia*. Moreover, this allows for a picture in which the hierarchy of operations where narrow syntax takes precedence over operations that involve cross modular specification, such as access to discourse content and non-linguistic context (Grillo, 2008, cited in Hamann, 2011) to be preserved for children, as we would expect if the basic organization of the processor is the same for children as for adults[7].

One may ask, is pushing the explanation of development in terms of interface conditions an advantageous move? Another example is found in the development of wh-movement. The error of construing a question such as (9), in which lower clause extraction is blocked by the wh-island constraint, with a referent suitable for the lower wh-word (e.g., *Cookies*) has been found in studies of child language, beginning with de Villiers et al. (1990). The studies used a variety of techniques and suggested that the child's grammar was not adult-like at some stage (Thornton, 1990; McDaniel et al., 1995; de Villiers et al., 2011). Slavkov (2015) also found the difficulty with wh-islands for adult second language learners.

9 How did the Mother ask what to bake?

Jakubowicz (2011) outlines a Derivational Complexity Metric, which states that the number of movements involved in the derivation of a sentence determines its difficulty. The error of construing the lower wh-word as an answer to a question such as (9), and the error of producing questions with a medial copy of a wh-word (incorrect for the adult language), can be accounted for under a phase based complexity metric, which starts the computation at the lowest cycle, and founders for lack of processing capacity. Jakubowicz makes appeal to working memory capacity:

"…the number of phases that the wh-phrase needs to go through on its way to the left edge of the matrix CP exceeds the limits of processing resources/working memory capacity" (p. 344)[8].

Working memory capacity is variable (children and adults differ in their capacities), and the calculation of the number of phases by the performance mechanism yields a potential explanation of children's behavior. This contrasts with an explanation in terms of a non-adult grammar for the child. Parallels with adult languages that permit intermediate copies of a wh-word have been drawn to suggest that the child has a different grammar; see for example, McDaniel et al. (1995). Although it is not clear that Jakubowicz' theory can handle all the data, the advantage of an explanation of children's behavior in terms of interface conditions on working memory is that the theory of language acquisition does not have to account for the unlearning of an incorrect grammar[9].

[6] Brunetto (2012) writes:
"As previous studies on the acquisition of control suggest, it is very unlikely that children's problems in the interpretation of the embedded subject consist in assigning PRO an external referent. These errors, in fact, are very rare already at age 3 and much evidence seems to indicate that subject control is mastered very early (Goodluck et al., 2001)" (p. 190).
This seems to us to miss the point. The sentence internal response of Spanish-speaking children is an error. The source of this error is potentially underdetermined. It could be that Spanish children lack the requisite knowledge subjunctive morphology, or that (as we contend) they lack the capacity to go outside the sentence for a referent of the EC. Castilla-Earls et al. (2018) summarize evidence that typically developing Spanish children correctly produce the subjunctive from as young two years.

[7] This is in contrast to the position that Hamann takes:
"For explaining acquisition facts, it has to be assumed that the hierarchy is not in place yet. In particular, narrow syntax is not the cheapest option for the child, perhaps because full automatization or the step from the particular to the general is not achieved yet." (p. 260–261).

[8] The data from Jakubowicz' article is complex and requires additional assumptions to be made; however, the basic point concerning the role of processing limitations holds.

[9] A similar analysis to that of Jakubowicz' is also made by de Villiers et al. (2011); de Villiers et al. suggest that a phase-based movement of a lower wh-word to the semantic/interpretative component may lead to errors such as that found for sentences such as (9).

## CONCLUDING REMARKS

We have suggested that the Minimalist model of bare phrase structure may offer a superior account of the early stages of acquisition of word order than traditional X-bar theory.

The Minimalist model includes interface conditions. The combination of theoretical principles with the mechanisms for producing and understanding sentences can result in a simpler theory of acquisition: the interface condition account of children's behavior reduces the need to posit grammars that must be corrected in the course of acquisition. To the extent that the Minimalist model explicitly recognizes interface conditions, the Minimalist framework is superior to previous frameworks, such as Government-Binding theory.

The examples discussed here are just two of the examples of how children's behaviors might be accounted for in Minimalist terms. Other areas of language development have scarcely begun to be explored from a Minimalist perspective. For example, the rich morphology of some polysynthetic languages such as Inuktitut is learned at a very early age, under 12–14 months (Crago and Allen, 2001), in contrast to the impoverished morphology of languages such as English, which may take until 4 years to be mastered (Brown, 1973). Is it the case that the early mastery of Inuktitut derives from the direct access to material in the numeration (the list of words and morphemes at the beginning of a derivation), without the need for movement operations to match up the morphology with the functional categories that are needed in a language such as English? Or is it the case that the input in languages such as Inuktitut is richer than in English, leading to earlier acquisition? Or do both factors play a role? These questions are unanswered, but offer the promise of a rich future for the Minimalist theory and language acquisition data.

## DATA AVAILABILITY STATEMENT

The Childes data files in **Table 2** were analyzed for the study.

## AUTHOR CONTRIBUTIONS

HG drafted versions of the paper. NK revised the drafts, suggesting revisions and additions.

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# Formal Syntax and Deep History

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We show that, contrary to long-standing assumptions, syntactic traits, modeled here within the generative biolinguistic framework, provide insights into deep-time language history. To support this claim, we have encoded the diversity of nominal structures using 94 universally definable binary parameters, set in 69 languages spanning across up to 13 traditionally irreducible Eurasian families. We found a phylogenetic signal that distinguishes all such families and matches the family-internal tree topologies that are safely established through classical etymological methods and datasets. We have retrieved "near-perfect" phylogenies, which are essentially immune to homoplastic disruption and only moderately influenced by horizontal convergence, two factors that instead severely affect more externalized linguistic features, like sound inventories. This result allows us to draw some preliminary inferences about plausible/implausible cross-family classifications; it also provides a new source of evidence for testing the representation of diversity in syntactic theories.

**Keywords: phylogenetics, formal syntax, parameters, language reconstruction, biolinguistics**

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## INTRODUCTION

### The Conceptual Roots of Parametric Comparison

A theory of human language aiming to be part of cognitive science (see Everaert et al., 2015) should try to argue that the structural representations it proposes are: (i) learnable under realistic acquisition conditions; (ii) historically transmitted under the conditions normally expected for the propagation of culturally selected knowledge. The classical theory of generative grammars set itself (i), i.e. the *ontogenetics* of grammars, as its main standard (explanatory adequacy, Chomsky, 1964). We believe that (ii), the *phylogenetics* of grammars, may also provide crucial evidence for the problem of realistic grammatical representations; thus, we test a theory of syntactic diversity inspired by minimalist biolinguistics precisely against the standard in (ii).

### Our Goals

We explore the relationship between the historical signal of different levels of linguistic analysis (referred to as *Humboldt's* problem by Longobardi and Guardiano, 2009, and as the problem of the *fabric* of human history by Gray et al., 2010; also see Greenhill et al., 2017). For this purpose, we especially try to assess the historical tree-likeness (the problem of the *shape*, in Gray et al.'s 2010 terms) of syntax. In pursuing these goals, we combine some methods of the quantitative revolution in phylogenetic linguistics[1] with the deductive approach to syntactic diversity that has emerged since Chomsky (1981), and we ask if formal syntactic differences can serve as effective characters for taxonomic purposes, contrary to a long line of skepticism.

## Syntax, Cognitive Science, and Historical Taxonomy

Over the past decades, increased attention has been paid to deep-time investigations of human history.[2] A central role in this trend has been played by developments in biology, prompted by the use of genetic evidence for reconstructing the diversification of populations.[3] In the meantime, the rise of cognitive science has produced important breakthroughs in the understanding of human mind as a system of symbolic computations, instantiated e.g., by rules of natural language syntax, most notably in the so-called formal biolinguistic framework.[4] Against this background, a broad methodological question is: can modern cognitive science side with biological anthropology in contributing to a science of long-range history?

As a matter of fact, the study of language pioneered deep historical investigation: linguistic taxonomies and the discovery of remote proto-languages have crucially contributed to pushing back the time limits of human history and prehistory. However, the levels of linguistic analysis that have best substantiated recent cognitive and computational theories have not yet played a part in this enterprise, and the practitioners of formal grammar and phylogenetic linguistics have formed nearly disjoint communities of scholars. In particular, syntax has never been seriously used for reconstructing phylogenies and proto-languages. Morpurgo-Davies (1992/2014) stresses how the earliest researchers[5] already rejected syntax as a tool for language phylogeny on the grounds that it would entail the presence of similar features in languages that can be easily proved to be unrelated, i.e., that it would be subject to pervasive homoplasy.[6] Since the late 18th century, this assumption appears not to have changed, even after Kayne (1975) laid the basis of modern comparative syntax. Consider, for instance the following statement:

(1) "In fact it is quite possible – even likely – that English grammars might be more similar to grammars with which there is less historical connection. From this perspective, looking at the parameters in the current linguistic literature, English grammars may be more similar to Italian than to German, and French grammars may be more similar to German than to Spanish. *There is no reason to believe that structural similarity should be even an approximate function of historical relatedness...*" (Anderson and Lightfoot, 2002, pp. 8–9: our italic)

## The Historical Signal of Syntax

Positions along these lines are widely held in the field (cf. Newmeyer, 2005; Anderson, 2012, a.o.).[7]

Interestingly, at a small scale it is commonly accepted that syntactic variability aggregates across individuals in time and space.[8] For instance, an important facet of the logical problem of language acquisition (Hornstein and Lightfoot, 1981; Lightfoot, 1982, a.o.) makes crucial reference to this kind of similarity among I-languages (how do the children of *a community* converge on the *same* target grammar in certain subtle details, in spite of individual and idiosyncratic primary data?).

It is at a larger scale (e.g., of Romance or Indo-European) that this simple assumption becomes progressively controversial, neglected or altogether rejected, for non-obvious reasons. Normally, culturally transmitted phenomena leave a longer-term historical trace (e.g., some notion of "common Romance vocabulary"). Therefore, that even syntax does so should be the null hypothesis.

It is true that individual syntactic changes may be "catastrophic" and unpredictable: this discovery (Lightfoot, 1979, 1997, 2002, a.o.)[9] has been very instrumental in overcoming the epistemological pitfalls of classical linguistic historicism and reducing inquiry to its appropriate "molecular" units: individual parameters. Yet, if several syntactic parameters are considered at the same time, a historical signal might well emerge. Notice that if such a signal were completely irretrievable, then someone could even argue that generative syntax is inadequate as a model

[1] Ringe et al. (2002); Gray and Atkinson (2003); McMahon and McMahon (2005); McMahon (2010), and the stream of subsequent work.

[2] E.g., Braudel (1958) and subsequent work, Diamond (1997); Smail (2008).

[3] Cavalli-Sforza et al. (1994), as well as subsequent work.

[4] Cf. Hauser et al. (2002); Boeckx and Piattelli-Palmarini (2005); Di Sciullo and Boeckx (2011); Berwick and Chomsky (2015), a.o.; for some specific applications to language diversity see Biberauer (2008); Karimi and Piattelli-Palmarini (2017); Roberts (2019) and much cited literature.

[5] E.g., Kraus (1787; see Kaltz, 1985 for details), Adelung (1806–1817) or Balbi (1826a,b). "Balbi (1826a, xlii f., note) ... stated that grammatical comparison cannot be used to establish kinship and quoted as an example the fact that English and Omagua, a language of Brazil, were clearly not related, though their grammars contrasted in similar ways with the grammars of other languages in their families (ibid., 28)." (Morpurgo-Davies, 1992/2014, p. 51).

[6] Morpurgo-Davies (1992/2014) points out that even Hervás (1778–1787, 1800–1805) or Gyarmathi (1799), though interested in grammatical features, did not go beyond the examination of traits such as declensions, conjugations, degrees of comparison of adjectives, suffixes used to mark comparable functions, pronouns, etc., i.e., the lexically arbitrary coding of form-meaning in functional elements. She notices that later and more established names in comparative reconstruction (Schleicher, for example) equally considered that only phonology and morphology were relevant for historically oriented work.

[7] After the programmatic concepts in Klima (1964, 1965), the question of the potential of grammatical features for historical relatedness was not fully resumed until Nichols (1992); Longobardi (2003); Dunn et al. (2005); Guardiano and Longobardi (2005); Wichmann and Saunders (2007), and a first systematic use of formal syntactic traits was only attempted in Longobardi and Guardiano (2009). An interesting exception regarding syntax as an indicator of relatedness is Chapin (1974), kindly pointed out to us by R. Kayne.

[8] It is normally assumed to be like further features of language and culture, and unlike certain other cognitive faculties (there is a sense to the notion "French syntax," no less than to "French vocabulary," or "French cuisine," though not to "French memory" or "French visual perception").

[9] All this foundational work of Lightfoot's on diachronic syntax, as well as that inspired by Kroch (1989 and subsequent: especially see Pintzuk and Kroch, 1995 on dating) has not been concerned with relatedness, as noted. Nonetheless, this line, along with Kayne's (1975, 2000 and subsequent) insights on comparative syntax, has been essential for conceiving of generative grammars as tools of historical knowledge.

of language transmission (i.e., acquisition across generations), hence as a realistic cognitive model *tout court*.[10]

## Syntactic Data and Taxonomic Problems

Two general problems of linguistic taxonomic methods (cf. Guardiano et al., 2020) are especially relevant for our purposes:

(2) a. The *globality* problem
b. The *ultralocality* problem

(2)a refers to the fact that comparative procedures may aspire to long-range or, ideally, global coverage; thus, they should rely on universally definable taxonomic characters, that can apply to any set of languages. (2)b is the converse issue: even if some type of characters does not saturate at the macro-comparative level, it could still fail in resolution when applied to discriminate close dialects, or just fail to correlate altogether with the reduction of their differences in other linguistic aspects.

Even if promising advances in cross-family comparison have recently been made (Jäger, 2015), procedures based on vocabulary data and lexical arbitrariness are generally not appropriate for (2)a, because they mainly rely on family-internal etymologies.[11] Therefore, the development of a non-lexical method is a theoretical *eldorado* in the pursuit of deep language history (Nichols, 1992). Parameters in the theory of generative grammars should lend themselves well to this goal, as they are grounded in a model of the language faculty explicitly designed in universal terms.

Thus, we focused on: (i) a set of syntactic traits modeled along the lines of Longobardi and Guardiano's (2009) Parametric Comparison Method (PCM) and including macro-, meso-, and micro-parameters (Biberauer and Roberts, 2017; Roberts, 2019);[12] (ii) a language sample to test these traits against family-wide taxonomies, but also with respect to cross-family and dialect comparison.

Importantly, we assumed some idealizations about the adopted comparative characters:[13]

(3) a. *Modularity*: they are all purely syntactic traits, drawn from a single module of syntax (the internal structure of nominal phrases);
b. *Deductivity*: they are all coded as abstract primitives of the generative device;
c. *Interdependence*: their known and plausible dependencies are spelt out and built into the parametric structure.

These three properties of our input data are different from those attributed to the structural traits recently used to address similar issues, e.g., in Greenhill et al. (2017). We will explore some consequences of using traits with these three properties for the pursuit of long-range comparison (cf. Section "Input data and phylogenetic results").

# MATERIALS AND METHODS

## Parameters and Schemata

In classical Principles-and-Parameters models (Chomsky, 1981) it was assumed that variability in human grammars is reducible to a finite list of binary choices, extensionally present in every speaker's mind at the initial state of language acquisition. This "preformistic"[14] view has been criticized recently. In particular, it has been associated with an implausible model of language learnability, as it imposes too heavy a burden on the initial state of the human mind.[15]

Here we 'presuppose' a model of variation which does not necessarily rely on lists of parameters, but rather sketches a universal set of simple possible syntactic relations (i.e., *schemata*: Longobardi, 2005, 2014, 2017; Gianollo et al., 2008); whether, in each language, they apply or not to specific categories and features determines a number of binary choices epigenetically rather than preformistically. This minimalist parametric model (Principles and Schemata in Longobardi's, 2005 terms) has the effect of intensionally defining parameter lists with their familiar properties (including universal definition and ease of value collation for comparative purposes: Roberts, 1998), without attributing such lists extensionally to the common initial state of the language faculty.

Our parameters are formally coded using two symbols, "+" and "−". Specifically, we adopt the system proposed in Crisma et al. (2020): cognitively, just "+" is viewed as an addition to the initial state of the mind. The "−" state of a parameter is not an entity attributed to the speaker's mind, though it is used by the PCM as a symbol to code a difference with "+" at that parameter in another language.

We call "manifestation(s)" the empirical evidence that sets a given parameter. Most parameters have a clustering structure, i.e., are associated with a set of co-varying surface manifestations,[16] with different degrees of saliency. As a consequence of such clustering structure, identifying just one core manifestation (a trigger or *p-expression* in Clark and Roberts', 1993 sense) per parameter will suffice for the learner (and the linguist) to set the parameter to "+." If no relevant

[10]In fact, there have been sporadic, though insightful, suggestions that syntax may be even more conservative than other linguistic levels, at least as a source of primitive diachronic change. This is basically the content of Keenan's (2002, 2009) notion of Inertia, i.e., the hypothesis that linguistic structure tends to stay stable through time "unless acted upon by an outside force or DECAY" (Keenan, 2009, p. 18). "Decay" here refers to phonological erosion and lexical-semantic impoverishment. A slightly more articulated definition of the Inertia hypothesis has been adopted in Longobardi (2001): "...syntactic change should not arise, unless it can be shown to be *caused*—that is, to be a well-motivated consequence of other types of change (phonological changes and semantic changes, including the appearance/disappearance of whole lexical items) or, recursively, of other syntactic changes..." (Longobardi, 2001, p. 278).

[11]For progress in the automatization of lexical comparative methods also see List (2014).

[12]Crucially, we do not use nano-parameters, which involve extensional definitions in terms of lists of lexical items.

[13]See Longobardi and Guardiano (2009) for an extensive justification of these methodological assumptions.

[14]In the terms of early modern biology.

[15]See especially Boeckx and Leivadá (2014); Fodor and Sakas (2017); Lightfoot (2017), and the various problems summed up in Longobardi (2017).

[16]Rizzi (1978, 1982); Taraldsen (1980); Chomsky (1981); Kroch (1989); Kayne (2000), a.o.

manifestation for "+" is present in the data, the grammar's *default* state does not change.

P-expressions are by definition *positive* evidence, i.e., grammatical phrases of a language. In the formulation of the parameters we made sure that the non-default value "+" can be set in all the languages from positive evidence in this sense.

## The Syntactic Dataset

In this article, we used the 94 binary syntactic nominal parameters identified in Crisma et al. (2020) by a set of YES/NO questions which define the manifestations of each of them.[17] They are set in 69 contemporary Eurasian languages from up to 13 traditionally irreducible families.[18] Full information about the languages and the parameter states is available in **Supplementary Table 1** and **Supplementary Figure 1**.

The languages were chosen to investigate three different levels of historical depth: the relations of the deepest established families, their internal articulation, and dialect microvariation. To explore the latter, we rely on the sample of Romance[19] and Greek[20] dialects included in the dataset.

## Some Numerical Properties of the Syntactic Data

The parameters of our system display an intricate implicational structure (Guardiano and Longobardi, 2017), i.e., many parameter states turn out to be predictable, or completely irrelevant, given the states of other parameters.[21] In the dataset used in this article, 2925 states out of 94 × 69 (= 6486) are null, perhaps the most impressive instantiation of the insight (sometimes attributed to Meillet, but cf. Toman, 1987) that natural languages are "un système où tout se tient." The effect of such null states on the number of possible languages has become measurable since Bortolussi et al. (2011), proving to reduce it by several orders of magnitude (cf. Section "Possible Languages" in **Supplementary Material**).

A related numerical feature of the syntactic dataset is that in a system with two non-null states ("+" and "−") and a null state (coded as "0" and representing no independent information) the only relevant comparisons for a pair of languages are provided by parameters for which neither language displays a "0": namely an identity ("+/+" or "−/−") or a difference ("+/−" or viceversa). The average number of parameters for each language pair that does not display "0" in either language is 39 (in the range of 14 to 66). Thus, the historical signal which can be found in this dataset will be generated by an average of taxonomic characters no higher than 39 (a figure much lower than that of the taxonomic units investigated)[22]: if a significant signal is indeed found, this will suggest that the selected characters have a high degree of resolution.

From a practical viewpoint, it is also important to stress that, thanks to the structure of the parameter system, in order to fill in the states of the 94 parameters for each language it is only necessary to find positive evidence for the "+" values; this is so because "0" is totally deducible information and "−" is a default state. In our dataset the total amount of "+" is 1386, thus, the mean is 20 "+" per language; the median is also 20. Hence, the amount of parameter values which must be set from positive empirical evidence is only about one quarter of the whole parameter list.[23]

## Taxonomic and Phylogenetic Methods

We have performed a series of experiments using some standard computational tools, although none of them was conceived for − or specifically adjusted to − syntactic, rather than biological or lexical data. Such tools belong to two major types: distance-based and character-based programs.

### Distance-Based Methods

We used three distance-based tools: heatmaps,[24] PCoAs,[25] and UPGMA phylogenetic trees.[26]

Heatmaps can be used to identify clusters in a distance matrix: in the heatmap, each cell (corresponding to a language pair) is assigned a color according to its distance value; then, through a hierarchical clustering algorithm, cells can be arranged on the basis of their color: language pairs which share small distances are arranged along the diagonal of the square matrix.

Principal Coordinate Analyses (PCoAs) represent a distance matrix on a Cartesian plane by plotting the taxa on a bidimensional space, using a linear transformation of the distance matrix.

[17] Several parameters concerning the Determiner category and Genitive Case used in this article are analyzed in syntactic detail in Crisma and Longobardi (in press) and in Crisma et al. (to appear). Notice, however, that, in order to conform to the requirement that the "+" state must be settable on the basis of positive evidence only, the formulation of some parameters here can have reversed the "−" and "+" values (see Crisma et al., 2020).

[18] Considering Turkic, Mongolic, Tungusic, Japanese, and Korean as separate families, since there is no consensus in the field about their genealogical relatedness (see e.g., Ceolin, 2019).

[19] The Italo-Romance dialects of our sample belong to three major groups (Pellegrini, 1977; Loporcaro, 2009): (1) Gallo-Italic: Casalasco (Vezzosi, 2019), Reggio Emilia, Parma. (2) Extreme southern: Reggio Calabria (Southern Calabria dialects are usually clustered with Sicilian dialects), Salentino (traditionally classified as an Extreme southern dialect but geographically separated from the rest of the Extreme group, while it has enjoyed an uninterrupted road connection to Rome and Naples since the Via Appia was built between 312 and 264 BC), two dialects from Sicily (Ragusa and Mussomeli; see Guardiano et al., 2016). (3) Upper southern: Teramano, Campano, Barese, and Northern Calabrese. The latter belongs to a particularly conservative area (Lausberg, 1939) characterized by morpho-phonological features which single it out from the rest of Italian dialects (Rohlfs, 1972; Rensch, 1973; Fanciullo, 1988, 1997; Martino, 1991; Romito et al., 1996, a.o. and also Silvestri, 2013 and Guardiano et al., 2016 about its nominal syntax).

[20] In the Greek group, we selected the following varieties: Standard Modern Greek, Cypriot Greek, and three varieties of Italiot Greek (one from Salento and two from Calabria which display different degrees of conservativity, Guardiano and Stavrou, 2014, 2019, 2020; Guardiano et al., 2016).

[21] Also see Baker (2001); Roberts (2019), a.o.

[22] This figure goes down to 20 if only "+/+" is computed as an identity: cf. footnote 29.

[23] The language that has the highest amount of "+" is Romanian (29), while the language with the smallest amount of "+" is Cantonese (9).

[24] Eisen et al. (1998); Cordoni et al. (2016).

[25] Davis (1986); Podani and Miklos (2002).

[26] Sneath and Sokal (1973).

The distance-based algorithm that is typically used to generate phylogenetic trees from a distance matrix is Neighbor-Joining.[27] Previous work on syntactic data showed that identifying a root and imposing the same branch length between a root and the leaves (i.e., assuming a molecular clock) through an updated version of Neighbor-Joining (the UPGMA algorithm) improves the classification.[28] Hence, for our distance-based phylogenetic experiments, we adopted UPGMA (using the package PHYLIP, Felsenstein, 2005).

## Measuring Syntactic Distances

One of the main challenges about our data is dealing with null characters ("0"). Distance-based methods allow us to do so in a simple way: whenever one of the languages of a pair has a "0" for a certain parameter (cf. Section "Some numerical properties of the syntactic data"), we can just ignore the parameter in calculating the distance of the pair. To deal with this problem, we first normalized a standard distance metric (Hamming, 1950) by dividing, for each pair of languages, the number of differences by the sum of their identities and differences.

Our background parameter theory (cf. Section "Parameters and Schemata") assumes that, of the two potential states of a parameter, the value "−" instantiates a default state: thus, identities on two "−" should *a priori* be less marked than identities on two "+." In other words, the former could be less likely than the latter as shared innovations in the phylogenetic history. However, it is difficult to assess the actual weight of the potentially less informative "−/−" correspondences: therefore, we explored the radical idealization of counting as identities only the "+/+" ones. This amounts to using a Jaccard (1901) metric:[29]

(4) $\Delta$ Jaccard (A, B) $= [N_{-+} + N_{+-}]/[N_{-+} + N_{+-} + N_{++}]$

where $N_{XY}$ indicates the number of positions where the string A has value X and B has Y.

To measure the impact of the idealization, we performed experiments both through a Jaccard distance and a normalized Hamming distance (in which "+/+" and "−/−" are both counted as valid identities) and the results are slightly worse for Hamming[30] (cf. Section "Phylogenetic Analysis – Hamming Distances" in **Supplementary Material**); therefore, we decided to simply proceed with the more restrictive Jaccard formula.

The heatmap, the PCoAs and the phylogenetic tree shown in **Figure 3** were generated from the Jaccard distance matrix inferred from the parametric characters of **Supplementary Figure 1**.

## Character-Based Methods

Character-based methods were specifically devised to reconstruct the sequence of changes in the character states of a dataset.[31] Character-based phylogenetic methods have mostly been used to calculate linguistic splits and dates.[32] In particular, Bayesian inference has been recently implemented to evaluate the probability of different evolutionary models: for instance, whether the rate of change is uniform across branches and across characters, or whether it can be modeled according to some mathematical distribution. Evolutionary models are then used to generate phylogenetic trees. We employed the software BEAST 2 (Bouckaert et al., 2019), which is the most up-to-date tool to perform Bayesian phylogenetic analysis.

Finally, we calculated two tree-likeness metrics, $\Delta$-scores and Q-residuals,[33] from a network generated through the algorithm NeighborNet, from SplitsTree.[34] These measures estimate the robustness of the vertical signal, and indicate which taxa are weaker due to the possible presence of horizontal convergence or homoplasy.

## Some Problems With Current Methods

Both methods require some idealization about the data structure, and therefore either methodological choice can be expected to misrepresent some aspect of the information contained in the dataset.

When using distance-based algorithms, reducing all pairs of strings (languages) in the dataset to a distance matrix implies that the exact position of identities and differences between them becomes irretrievable. Moreover, the choice of distance metrics has an impact on how differences are weighted against identities.

Character-based algorithms, on the contrary, are the closest automatic analog to the linguists' consolidated procedure of reconstructing all ancestral states (e.g., sounds and etymologies) and changes, and of postulating taxa on this basis (Greenhill et al., 2020); however, a straightforward exploitation of their potential for our data is still partly hampered by at least two features of these algorithms.

First, these methods assume character states and their changes to be independent, an assumption which is not true in our case. Therefore, they do not offer any intuitive solution to deal with implied values ("0"), because they were not devised to incorporate interdependence among characters. Coding the state "0" as a third, independent value, would be an arbitrary manipulation of the data, because "0" represents completely predictable information rather than additional information or points of uncertainty.[35] To mitigate this problem, we coded the

[27] Saitou and Nei (1987).

[28] Rigon (2009); Longobardi et al. (2013).

[29] The average number of parameters that are comparable in our dataset according to the Jaccard metric (i.e., parameters where either language displays a "+" without the other displaying a "0") turned out to be 20, with a range between 7 and 30.

[30] Cf. Franzoi et al. (2020) for an attempt to develop metrics alternative to Hamming and Jaccard in order to capture structural dependencies among characters. Their work interestingly shows that variation in the choice of distance formulae produces limited perturbations of the robustness of the signal when applied to syntactic data.

[31] Cf. Swofford (2001); Schmidt et al. (2002); Ronquist and Huelsenbeck (2003); Yang (2007); Drummond and Rambaut (2007); Tamura et al. (2011); Rambaut et al. (2018), a.o.

[32] E.g., Gray and Atkinson (2003); Bouckaert et al. (2012); Chang et al. (2015).

[33] Gray et al. (2010); Greenhill et al. (2017).

[34] Bryant and Moulton (2004).

[35] So coding "0" would force the method to postulate multiple changes when in fact a single one occurs, and in many cases this would lead the algorithm to reconstruct the wrong node for a certain group, and then spreading the error through the tree.

implied states ("0") as missing characters, to allow the algorithm to ignore redundant characters as a source of information.[36]

The second problem is that character-based algorithms are not *a priori* informed about asymmetries in the likelihood of state transitions. Historical phonology clearly shows several cases of this kind: for instance, Honeybone (2016) shows that a change from the voiceless interdental fricative [θ] to the labial fricative [f] is common, but the reverse is virtually unattested outside of contact areas. Other classic examples are [p] > [f], [p] > [h] or [p] > Ø, all recurrent changes in Indo-European and beyond, and [f] > [p], [h] > [p] or Ø > [p], all extremely rare. With respect to our parameters, we know that there are, for example, several cases of languages acquiring grammaticalized definiteness and no cases of languages dropping this feature,[37] something likely to be reduced to principled explanation, based on the combination of general conditions on change like *Inertia* (Keenan, 2002, 2009) and *Resistance* (Guardiano et al., 2016). An efficient character-reconstructing algorithm will have to be eventually endowed with most such information, but this is not yet the case.

We may expect these problems to affect the topology retrieved by such algorithms. As a consequence, on the other side, any positive taxonomic results retrieved by these methods will attest to the robustness of the signal even *in spite of* the present limitations.

# RESULTS

## Distance-Based Experiments

### Heatmap

The information contained in the syntactic distances was first examined by means of the Heatmap in **Figure 1**. Colors from white to dark blue signal distances lower than the median (spanning from 0 to 0.429), those from yellow to dark red signal distances higher than the median (spanning from 0.430 to 0.857). The overall distribution of colors in **Figure 1** shows that the distances are scattered enough from dark red to dark blue to be potentially informative.

To assess if their distribution has any empirical significance, we considered the maximal aggregations of (white and blue-shaded) cells containing no yellow/red ones which are identified through the clustering option of the program (cf. Section "Distance-based methods"); we compared them to the established genealogical clusters in the sample. In the figure, there are 6 such aggregations which are unambiguous. They correspond to:

(5) a. The Indo-European (henceforth IE) languages.
b. The two Dravidian languages and the two NE-Caucasian ones.
c. Malagasy.
d. The two Basque varieties.
e. The two Sinitic languages.
f. Korean and Japanese.

Two further groups of clusters are also identified along the diagonal. They are more ambiguously interpretable, owing to the fact that they display a partial overlap; in principle, they could single out either the groups in (6) or in (7):

(6) a. Uralic.[38]
b. Turkic,[39] Tungusic,[40] Buryat (i.e., the languages traditionally attributed to the controversial[41] Altaic group) and Yukaghir.

(7) a. Balto-Finnic.
b. The rest of Uralic, Tungusic, Buryat, and Yukaghir.

The clustering algorithm suggests that (6) is the more plausible hypothesis, as highlighted in the tree-like structure on the left and top borders. Hence, the distance distribution in the Heatmap only identifies established taxa (families or isolates: (5)a, c,[42] d, e, (6)a) or supersets of them ((5)b and f; (6)b): thus, no cluster challenges any known historical information, and three of them suggest possible though not yet established supertaxa.

There is also a weaker aggregation of white/pale blue cells next to the sides of the clusters identified along the diagonal. It corresponds to pairs of languages from different families dwelling in the central part of Eurasia (Indo-Iranian, Dravidian, and NE-Caucasian, Altaic, Yukaghir, Uralic except for the three languages now spoken in central and Northern Europe). However, no possible aggregation of white/blue cells displays an average internal distance lower than those of the aggregations identified in (5) and (6) (cf. **Supplementary Material**).

### PCoA

The PCoA obtained from the syntactic distances between all the language pairs of the dataset is in **Figure 2**. The first coordinate, which accounts for 59% of the variance, highlights the split between:

(8) a. Non-IE languages (left area).
b. IE languages (right area).

In the left half, the further split corresponding to the second coordinate (accounting for 18% of the remaining variance) separates:

(9) a. Upper-left quadrant: the four languages of the Far East, Malagasy (which has known roots in the same area), and the two Basque varieties, in a rather scattered shape.
b. Bottom-left quadrant: all the other languages of the dataset, i.e., a cloud containing Uralic, Altaic, and Yukaghir and another one with Dravidian and NE-Caucasian.

[36]Note that this does not prevent the algorithm from considering and sometimes selecting reconstructions of ancestral states incompatible with the implicational structure of the dataset.

[37]Roberts and Roussou (2003); Heine and Kuteva (2005).

[38]More specifically Finno-Ugric, represented by two Balto-Finnic languages, three Ugric varieties, two Udmurt (Permic) and two Mari (Volgaic) ones.

[39]Kazakh and Kirghiz (Kipchak sub-branch, Northwestern Turkic, Johanson and Csató, 1998); Turkish (Oghuz sub-branch, Southwestern Turkic: Menges, 1968; Schönig, 1997–1998, a.o); Uzbek (Karluk sub-branch, Southeastern Turkic, Schönig, 1997–1998, a.o.); Yakut (Northeastern Turkic).

[40]Ewenic: Evenki, Even1, and Even2, Khabtagaeva (2018), a.o.

[41]Vovin (2005); Robbeets (2005); but also see Doerfer (1985); Tekin (1994); Soucek (2000); Shimunek (2017), a.o.

[42]There are no other Austronesian languages in our sample.

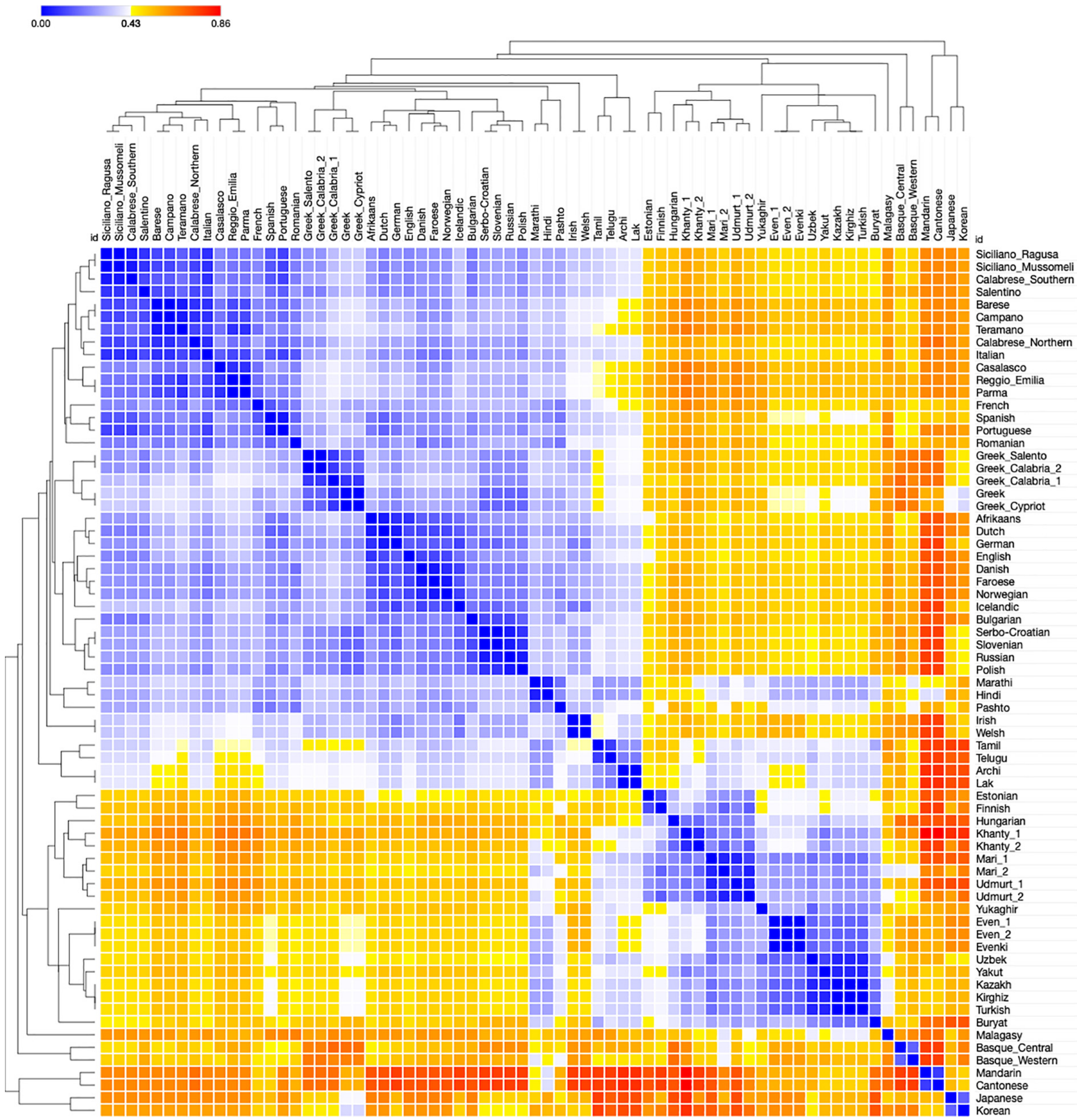


**FIGURE 1 |** Heatmap of syntactic Jaccard distances between the 69 languages of the sample, calculated on 94 parameters.

In order to obtain a higher resolution, we generated a sequence of further PCoAs from the various subsets of languages progressively identified by the previous ones (cf. Section "PCoAs" in **Supplementary Material**), and they continue to distinguish sets and supersets of independently acknowledged taxa.

### Distance-Based Phylogeny

The tests above have preliminarily suggested that a good deal of syntactic diversity is roughly distributed in agreement with genealogical affiliation. Next, we applied phylogenetic algorithms to our data. **Figure 3** displays a (bootstrapped) UPGMA tree. Every cluster identified in the Heatmap also appears in the UPGMA tree.

## Character-Based Experiments

### Character-Based Phylogeny

The taxonomic results obtained from syntactic distances were finally confirmed by a character-based phylogeny even in spite of the limitations pointed out in Section "Some problems with current methods". The phylogenetic tree calculated with BEAST is in **Figure 4**. The best model was determined by comparing different models using the software Tracer (cf. Section

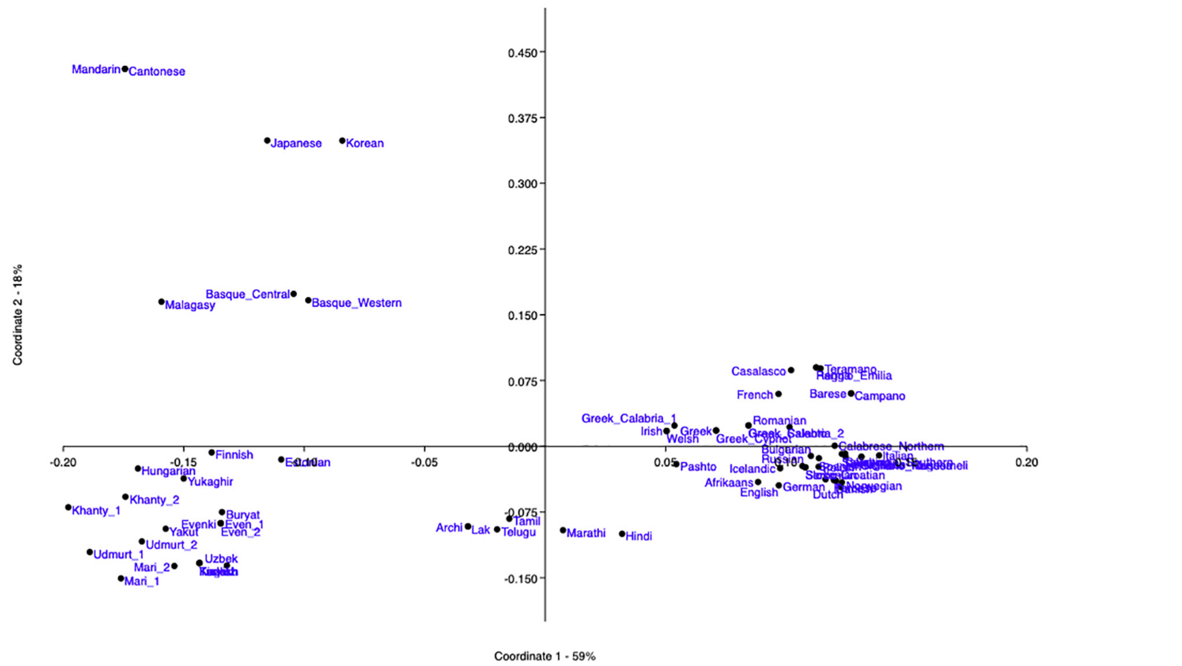


**FIGURE 2 |** PCoA obtained by the software PAST from the syntactic Jaccard distances between the 69 languages of the sample, calculated on 94 parameters.

"Phylogenetic Analysis – BEAST 2" in **Supplementary Material**). We noticed that most of the nodes were robust across different replications, and the variation was limited to the lower nodes, but a salient exception was the node grouping together Finnish and Estonian, which appeared in different positions of the tree in different replications, and almost always outside of the Uralic node. For this reason, in the tree presented here, we placed a monophyletic constraint on the Uralic languages. An unconstrained tree is available in **Supplementary Figure 8**.

Apart from the Uralic issue, the main differences with UPGMA are:

(10) a. The first two splits, singling out Malagasy along with Sinitic, Japanese, Korean, and Basque[43] from all the rest, recalling the other distance-based visualizations (**Figures 1**, **2**).
b. The clustering of the Archi, Lak, Tamil, and Telugu node with that grouping the so-called Altaic languages and Yukaghir.
c. The reversed position of Buryat and Yukaghir.
d. The intermediate node which combines Celtic with Greek.

Differences in the sub-articulation of Germanic and Romance are discussed below (cf. Section "On the genealogical information in the syntactic trees").

Like in the UPGMA tree, Japanese and Korean fall together, with a posterior probability of 1. Interestingly, both trees are able to assign the languages sharing some similarity in Central Eurasia (cf. **Figure 1**) into their different families (e.g., Indo-Iranian, Dravidian, NE-Caucasian, Uralic, Turkic).

### Δ-Scores and Q-Residuals

A graph displaying Δ-scores and Q-residuals (Holland et al., 2002; Gray et al., 2010; Wichmann et al., 2011; Greenhill et al., 2017), along with a SplitsTree network from which they were calculated, can be found in **Supplementary Material**. The median of the Δ-scores is 0.302, and the variance is particularly low (standard deviation: 0.037). The 10 languages associated with the highest values (cf. Section "Network Analysis – NeighborNet" in **Supplementary Material**), i.e., those for which the signal is the least treelike, properly include the languages listed in (9)a, which correspond to the first two outlying branches of the BEAST tree (Mandarin, Cantonese, Korean, Japanese, the two Basque varieties, and Malagasy).

The median of Q-residuals is 0.054, but in this case the variance is quite high, in proportion (standard deviation: 0.021). Again, among the languages with the 10 highest scores, six correspond to the outliers of the BEAST tree (Malagasy has the 11th Q-residual: 0.0805). In particular, while the mean for the Δ-scores is the same as the median, the mean for the Q-residuals is higher (0.058), signaling that the distribution is skewed toward the higher values. In fact, 46 of the 69 languages show a Q-residual lower than the mean, and crucially this subset contains all the 39 Indo-European languages of the sample.

### On the Genealogical Information in the Syntactic Trees

With few exceptions, discussed in Section "Sources of deviation", both the UPGMA and BEAST trees capture all the taxa of our

[43] I.e., the languages of the upper left quadrant of **Figure 2** above.

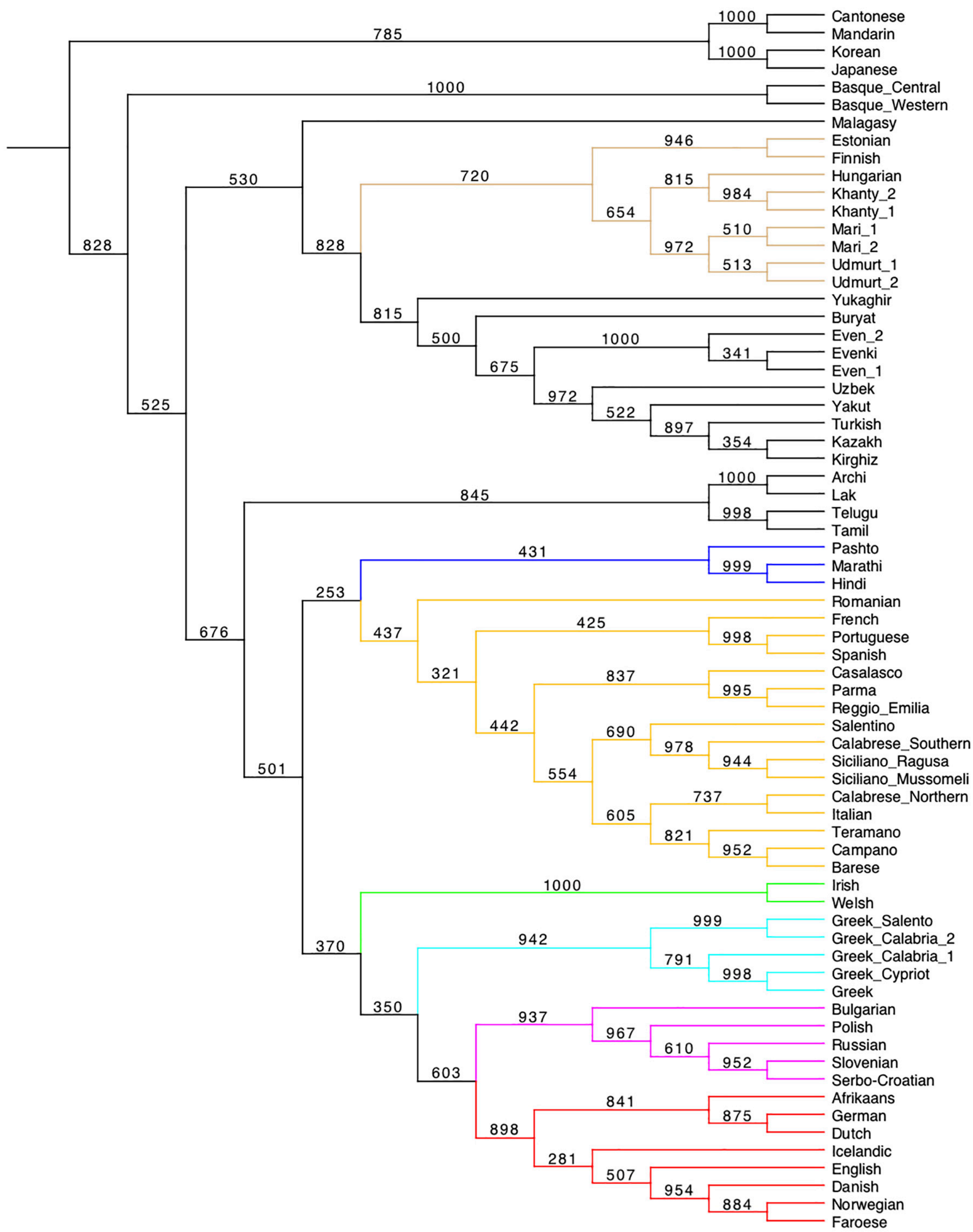


**FIGURE 3 |** UPGMA tree from syntactic Jaccard distances between the 69 languages of the sample, calculated on 94 parameters. The tree has been produced using Mesquite (Maddison and Maddison, 2007). For information on the bootstrapping procedure adopted, cf. Section "Phylogenetic Analysis – UPGMA" in **Supplementary Material**.

sample that are safely acknowledged by the near-unanimous judgment of historical linguists, based on lexical etymological comparison: this set will be referred to as the "Gold Standard".[44] **Table 1** summarizes the Gold Standard nodes (second column from left), and, in the two last columns, specifies if they are captured by our UPGMA or BEAST trees. UPGMA retrieves

[44]This is the most reliable procedure to evaluate the results of a phylogenetic analysis (cf. Greenhill et al., 2020). From the Gold Standard set we excluded the possible clusters of the micro-variation level, throughout all the families, since their identification in traditional literature is often based on non-vertical evidence and involves geographical and sociolinguistic considerations.

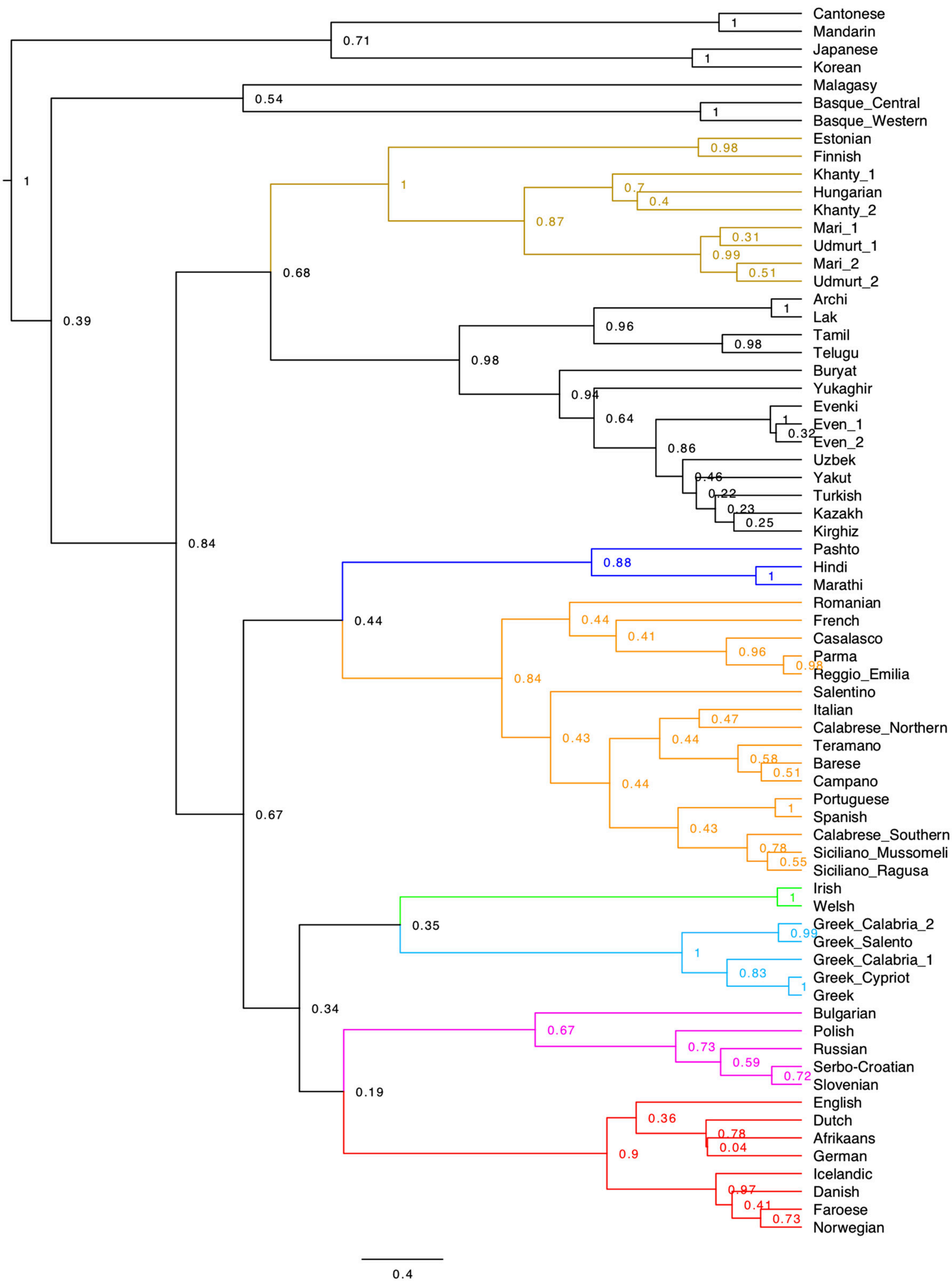


**FIGURE 4 |** BEAST tree from the 94 syntactic parameters set in the 69 languages of our sample. The best model that we determined is a Gamma Site Model with Substitution Rate = 1, a Mutation Death Model with death $p = 0.1$, a Relaxed Clock (Logarithmic) with clock rate = 1, and a uniform Yule model for the birth rate. The Monte Carlo Markov Chain produced 10,000,000 trees, 25% of which were used for the burn-in and discarded for the purpose of the calculation of the consensus tree. The tree is a consensus tree of 7500 different trees sampled through the 7,500,000 trees (with a sample stored every 1000 generated trees) produced by the Monte Carlo procedure.

**TABLE 1 |** Our results against the Gold Standard.

| | Group | Languages | UPGMA | BEAST |
|---|---|---|---|---|
| 1 | Sinitic | Mandarin, Cantonese | YES | YES |
| 2 | Dravidian | Tamil, Telugu | YES | YES |
| 3 | Basque | Basque_Central, Basque_Western | YES | YES |
| 4 | Uralic | Mari_1, Mari_2, Udmurt_1, Udmurt_2, Hungarian, Khanty_1, Khanty_2, Estonian, Finnish | YES | NO[a] |
| 5 | Altaic | Kazakh, Kirghiz, Turkish, Yakut, Uzbek, Evenki, Even_1, Even_2, Buryat | YES | NO |
| 6 | IE | Irish, Welsh, Marathi, Hindi, Pashto, Greek, Greek_Cypriot, Greek_Calabria_1, Greek_Calabria_2, Greek_Salento, Bulgarian, Serbo-Croatian, Slovenian, Polish, Russian, Faroese, Norwegian, Danish, Icelandic, German, Dutch, English, Afrikaans, French, Casalasco, Reggio_Emilia, Parma, Spanish, Portuguese, Romanian, Siciliano_Ragusa, Siciliano_Mussomeli, Salentino, Calabrese_Southern, Italian, Barese, Campano, Teramano, Calabrese_Northern | YES | YES |
| 7 | NE-Caucasian | Archi, Lak | YES | YES |
| 8 | Balto-Finnic | Estonian, Finnish | YES | YES |
| 9 | Ugric | Hungarian, Khanty_1, Khanty_2 | YES | YES |
| 10 | Turkic | Kazakh, Kirghiz, Turkish, Yakut, Uzbek | YES | YES |
| 11 | Tungusic | Evenki, Even_1, Even_2 | YES | YES |
| 12 | Kipchak[b] | Kazakh, Kirghiz | YES | YES |
| 13 | Celtic | Irish, Welsh | YES | YES |
| 14 | Indo-Iranian | Hindi, Marathi, Pashto | YES | YES |
| 15 | Greek | Greek, Greek_Cypriot, Greek_Calabria_1, Greek_Calabria_2, Greek_Salento | YES | YES |
| 16 | Slavic | Bulgarian, Serbo-Croatian, Slovenian, Polish, Russian | YES | YES |
| 17 | Germanic | Faroese, Norwegian, Danish, Icelandic, German, Dutch, English, Afrikaans | YES | YES |
| 18 | Romance | French, Spanish, Portuguese, Romanian, Italian, Casalasco, Parma, Reggio_Emilia, Siciliano_Ragusa, Siciliano_Mussomeli, Salentino, Calabrese_Southern, Barese, Campano, Teramano, Calabrese_Northern | YES | YES |
| 19 | Indo-Aryan | Hindi, Marathi | YES | YES |
| 20 | South-Slavic | Bulgarian, Serbo-Croatian, Slovenian | NO | NO |
| 21 | North Germanic | Faroese, Norwegian, Danish, Icelandic | NO | YES |
| 22 | West Germanic | German, Dutch, Afrikaans, English | NO | YES |
| 23 | Continental West-Germanic | German, Dutch, Afrikaans[c] | YES | YES |
| 24 | Ibero-Romance | Spanish, Portuguese | YES | YES |

[a] *Recall that the Uralic node in the BEAST tree presented in the text is the product of an explicit constraint placed on this set of languages.* [b] *Northwestern Turkic, Johanson and Csató (1998).* [c] *We included the latter subfamily following Hutterer (1975, p. 195).*

20/23 (87%) major families and subfamilies (21/24: 87.5%, if we include Altaic). BEAST retrieves 21/23 (91.3%) of them (or 21/24: 87.5%). Summing up, the two syntactic trees capture ∼90% of the Gold Standard.

# DISCUSSION

## The Historical Signal

The results, which are consistent across all the tests performed (Heatmap, PCoA, trees), are largely at odds with statements such as Anderson and Lightfoot's italicized quote in (1), and with the century-long assumptions behind them: syntax has provided, as a whole, a historical signal very close to that of etymological methods. We will now examine the possible roots of the deviations exhibited by syntactic parametric comparison from the expected genealogy.

### Sources of Deviation

Deviations from the vertical historical signal can in principle be regarded as due to two factors: secondary convergence (language interference) or homoplasy (parallel independent developments produced by chance). Both are normally *a priori* removed from the input data of automatic lexical phylogenies: one wonders, then, which of these factors is really relevant to produce the deviations above. Let us focus then on the few sources of exceptions to the Gold Standard expectations as they emerge from **Table 1**.

The BEAST tree's failure to capture the Uralic unity (taxon 4) is influenced by few characters in Estonian and Finnish (and their implicational consequences on some other parameters), in which these languages have a value opposite to that of the other Uralic languages and coinciding with that of all IE languages of Europe. For Estonian they are three: p15, CGB, p31, GFP, and p58, NRC, of **Supplementary Figure 1**. For Finnish the relevant ones are p15, CGB, again, and p32, GFN. Parameter CGB defines a macro-areal feature whose value in Balto-Finnic is shared with all IE languages of Europe, while the opposite one is shared by the rest of Uralic, the IE languages of Asia, Altaic, Caucasian, and other Asian languages. Parameter GFP has major implicational consequences on the whole Genitive system, including parameter GFN. Finally, the Estonian value of parameter NRC is the same as in all IE languages, except for some Indo-Iranian ones. These changes have assimilated Finnish and Estonian precisely to their

IE neighbors, with whom very ancient loanwords have also been exchanged.[45]

Also, if an Altaic unit (taxon 5) has ever existed, a part of our experiments (cf. **Figures 1**, **4**) expands it, by placing Yukaghir inside the supposed Altaic family. In fact, the differences of Yukaghir from Eastern Uralic are minimally more numerous than those from the Altaic languages, with which a century-long situation of bilingualism/diglossia as a lingua franca in NE Siberia is well documented.[46]

The outlying position of Bulgarian in both trees (which fail to capture the South Slavic unity, taxon 20) can be traced to relatively recent horizontal parametric convergence; in particular, there are two relevant parametric differences making Bulgarian slightly eccentric with respect to the rest of Slavic:[47] Bulgarian is the only Slavic language (with Macedonian) which selects the value "+" for p17, DGR, like its neighbors Romanian and Greek (it has developed a definite article, and indeed an enclitic one, like Romanian: p24, DCN[48]), and has developed a prepositional Genitive/Dative, like Romanian (cf. p41, GAD).[49] These have long been considered among the areal features of the Balkans.[50] So-called Old Bulgarian (Old Church Slavonic) had the value "−" for DGR. Notice also that DGR starts a long sequence of implications, so that its "−" setting in other Slavic languages *a priori* neutralizes a large number of potential similarities with Bulgarian.

Finally, the UPGMA tree fails to identify West Germanic (taxon 22). As a matter of fact, issues concerning the internal classification of Germanic have been acknowledged in all the quantitative literature.[51] In particular English (along with Afrikaans) has historically experienced most contacts with other Germanic and non-Germanic languages. Furthermore, English has also been recently the focus of a debate between Emonds and Faarlund (2014) and their reviewers and critics[52] about whether, from the Middle English period on, it must be considered a prevailingly Scandinavian rather than West-Germanic offspring (if not the continuation of a creolized version of the two). The unstable position in our experiments confirms that the question is at least a meaningful one. Anyway, it is a fact that English was in close contact with Nordic tribes in both its prehistoric[53] and historic dwelling areas.

In all the cases above, two properties hold: (i) the syntactic detachment of a language from a traditionally expected position in the tree correlates with exhibiting similarity with some neighboring languages; (ii) these deviations from the Gold Standard appear to always be tied to situations of horizontal transmission independently witnessed by other linguistic levels.[54] This confirms Thomason and Kaufman's (1988) conclusion that syntactic borrowing takes place in conditions of "intense" contact, quantitatively measurable by other linguistic variables.

Given the binary nature of our syntactic characters, as opposed to the virtually infinite possibilities provided by lexical arbitrariness, one might think that homoplasy (hence accidental failure of the signal) plays the main role in the deviations from the Gold Standard. On the contrary, the picture suggests that the differences between the syntax trees and the accepted lexical wisdom are always imputable to interference (itself a historical factor), and do not necessarily call for the intervention of homoplasy.

## Vertical and Horizontal Transmission

Even horizontal effects have relatively little impact on the general topology of the tree. For instance, under all our experiments, the Italiot Greek varieties cluster with Standard and Cypriot Greek: the protracted contact and documented syntactic interference between Romance and Greek in Southern Italy[55] have not disrupted the overall vertical signal of either family. To measure the conflict between vertical and horizontal information in the signal, we used Δ-scores and Q-residuals. Recall that a lower value of these indices speaks for a sharper vertical signal.

Δ-scores in our experiment, with a median as low as 0.302, yield better results than those obtained in both datasets used in Greenhill et al. (2017), where lexical characters displayed a median of 0.38 and structural characters displayed one of 0.44.

The Q-residuals perform less well: Greenhill et al. (2017) had a median of 0.0062 for lexical characters and 0.0354 for structural characters, against our median of 0.054.[56] Notice, however, that Wichmann et al. (2011) tested the two measures on a group of languages of the Automatic Similarity Judgment Program database,[57] and noticed that Δ-scores distributed uniformly with respect to age and size of the language family; Q-residuals instead correlated with such factors, becoming higher and less informative for chronologically deep and numerous and internally diverse families. Based on these results, they argued precisely in favor of Δ-scores as more accurate measures of non-tree-likeness. This seems to be true in our experiment as well: the highest Q-residuals are associated with languages occurring on the higher branches, whose genetic affiliation is still unclear; but all Indo-European languages display Q-residuals lower than the mean, suggesting that the measure is indeed sensitive to the age and size or diversity of the family (cf. Section "Δ-Scores and Q-Residuals"). This is not true for Δ-scores: while the outliers equally display high Δ-scores, IE languages are more

[45] Kylstra et al. (1991) suggest that the first contacts between Germanic and Balto-Finnic date from around 1000 BC.

[46] Wurm et al. (2011, pp. 970, 978).

[47] Cf. Longobardi et al. (2013).

[48] For this circum-Pontic isogloss see Guardiano et al. (2016).

[49] This, in turn, may have enabled the resetting of p43, GFO, as well, i.e., the disappearing of an inflected Genitive.

[50] See Sandfeld (1930) and now, specifically for syntactic borrowing, Tomić (2006).

[51] Dyen et al. (1992); Ringe et al. (2002); Jäger (2015).

[52] Barnes (2016); Bech and Walkden (2016); Stenbrenden (2016); Crisma and Pintzuk (2019), and the contributions to the 2016 issue, 6.1, of *Language Dynamics and Change*.

[53] Hutterer (1975), a.o.

[54] Even the internal comparison between the UPGMA and the BEAST trees turns out to be informative to confirm cases where the signal is conflicting, i.e., one or more languages can be associated with different phylogenetic histories.

[55] Guardiano and Stavrou (2014, 2019, 2020); Guardiano et al. (2016); Ledgeway (2006); Ledgeway (2013); Ledgeway et al. (2018), a.o.

[56] Greenhill and his collaborators (p.c.) suggest that this difference can be explained as a result of the fact that while Δ-scores might be more sensitive to conflicting signal (i.e., the presence of two alternative histories for a taxon), Q-residuals might be more sensitive to noise in the data.

[57] ASJP, Wichmann et al. (2020).

evenly distributed above and below the mean (23 vs. 16). If Wichmann et al. (2011) are right, then, our result is expected: it is likely that Q-residuals cannot meaningfully apply to long-range classifications across many different families.

## Ultralocality: Hints About Microvariation

The internal articulation of the Romance dialects of Italy retrieved by the UPGMA tree is consistent with their traditional classification.[58] The tree clusters them together, then identifies the Gallo-Italic group (Reggio Emilia, Parma, and Casalasco), the Extreme southern group (Siciliano, Southern Calabrese, and Salentino), and one that clusters three Upper southern dialects (Campano, Teramano, and Barese) but not Northern Calabrese: this may reflect the isolation of this dialect as representative of an area known to exhibit several peculiarities with respect to the whole Italian group.[59]

At this level of microvariation, no taxonomy can be really projected onto a genuine phylogeny, because of the uninterrupted contact and diffusion of isoglosses among contiguous dialects (cf. the network and the PCoA in **Supplementary Figures 14, 16**; also cf. Sarno et al., 2014 on strong genetic admixture in Southern Italy). This may have produced the differences between the UPGMA and BEAST trees: the BEAST tree may rather highlight the actual secondary relations which have occurred between Sicilian and Ibero-Romance, some closeness between Gallo-Italic and French, and also plausible interference of Balkan languages with Salentino, which appears as the outlier of all of Romance.

Thus, even minimally different character strings and very short parametric distances have good resolution power. Moreover, the fact that parametric distances become very low at this level of comparison is exactly what we expect if syntax evolves proportionally to other historical variables.

The resolution we obtain in micro-variation is inevitably based on parameters which must have undergone recent changes, i.e., which, virtually by definition, are not as stable as others. Yet, their instability has not produced any conceivable disruption of the correct topology in other areas of the phylogenies. This very consequential observation is discussed in Section "Input data and phylogenetic results".

## Globality: Hints About Long-Range Relations

The most salient feature of parametric systems is their potential universality. Accordingly, our phylogenetic analyses provide some preliminary insights about possible or proposed long-range groupings. They will eventually have to be evaluated through more elaborate statistical analyses, but provide a list of heuristic suggestions for further testing.

First, nearly all the experiments single out a set of languages as outlying the rest of the sample: Japanese, Korean, the two Sinitic and two Basque varieties, and, except for the UPGMA tree, Malagasy. The other languages are always identified as a monophyletic structure and $\Delta$-scores and Q-residuals suggest that they have a more reliable vertical articulation.

In addition to recognizing all classical families, our data suggest that Indo-Iranian, Dravidian, NE-Caucasian, Turkic, Tungusic, Buryat, Yukaghir, and part of Uralic partake of some similarity, which is especially highlighted in **Figure 1**; however, such similarity turns out to be weaker than the respective family affiliations (cf. the trees in **Figures 3**, **4**). The methods used cannot decide how much of this similarity is secondary and areal, though the fact that (only) the IE languages of Asia share it, and (only) the Uralic languages that dwell in Central-Western Europe (Hungarian, Finnish, Estonian) do not, suggests that part of it must be.

Next, all experiments point to the unity of part of the controversial Altaic family (Turkic and Tungusic), and a weaker connection of this cluster to Buryat (Mongol), but also to Yukaghir.

Even more robustly, the syntactic analysis argues for a Korean-Japanese relation, although sustained by a relatively low number of non-null comparisons (30 pairs; only 12, according to a Jaccard measure). Statistical support is very high, as is only the case, in our sample, for a few safely established pairs/groups. Notice that some studies have proposed that even sound correspondences support the relatedness of Japanese and Korean.[60]

Notice, instead, that the clustering of Korean and Japanese with Mandarin and Cantonese in both trees should not deceive us, because it is likely to be a bias of the tree algorithms (clustering together data points which are both outliers with respect to the main group of taxa is a common error, usually described as Long-Branch Attraction: Bergsten, 2005). This becomes clear from the distance distribution: in **Figure 1**, the two groups are clearly set apart; moreover, if we draw a PCoA specifically focused on the languages of the upper left quadrant of **Figure 2**, Japanese-Korean and the two Chinese varieties clearly fall into distinct quadrants (cf. **Supplementary Figure 3**).

Finally, none of our experiments hints at a Macro-Altaic grouping.[61] However, the syntactic data cannot exclude some genealogical relation between Korean-Japanese and central Asian languages, with secondary influences from the East Asian area.[62]

A worth exploring relation is that between Uralic and Altaic. Uralic languages are scattered in terms of distance but, with the exception of Balto-Finnic in the BEAST tree, they are recognized as a unit. In spite of the noted similarities with IE languages, the syntactic data provide sufficient evidence that Balto-Finnic is indeed a Finno-Ugric family influenced by IE rather than the opposite, and that, if anything, the whole Uralic is closer to Altaic than to Indo-European. First, when we

[58] Pellegrini (1977).

[59] Lausberg (1939).

[60] For instance, Whitman (2012); also see the discussion in Robbeets (2008a), a.o.

[61] Altaic-Korean-Japanese: see the discussion in Port et al. (2019) and the Trans-Eurasian hypothesis of Robbeets (2008b).

[62] The consequence of such influences is reasonably the degrammaticalization of Person and Number features (p5 FGP and p7 FGN), which are rich in neutralizing implicational effects on further parameters. Indeed, after close consideration of the parameter values, the 0s induced by the lack of value "+" for FGP is the main source of peculiar similarity between Mandarin-Cantonese and Korean-Japanese. Beyond this, the parameters in which the four languages share a value in contrast to all the other languages are only two: p27, FGE, about the necessity of a classifier between a numeral and a head noun (itself a property very frequent in languages without a positive value at FGN: see Cathcart et al., 2020), and p61, LKP, about the presence of a special morpheme linking the noun with essentially any of its arguments.

place a monophyletic constraint on the set of Uralic languages in the BEAST phylogeny, the stable result is that Uralic is clustered with the Altaic-Yukaghir node. Second, the other Uralic languages are never separated from the Altaic group in any experiments (cf. Section "Phylogenetic Analysis – BEAST 2" in **Supplementary Material**). Third, the Genitive systems of Estonian and Finnish (and the pronominal possessive system of Estonian), which oppose them to all the other Uralic (but also Turkic and Tungusic) languages (cf. Section "Sources of deviation"), must be regarded as an innovation with respect to the others: it has involved the loss of agreement between the features of a Genitive and those expressed through a dedicated morpheme on the head noun, a common Uralic feature.[63] The weakening or loss of such morphemes is a well-known diachronic phenomenon, attested, e.g., for verbs and adjectives in the history of Romance and Germanic (possibly an instance of what Keenan, 2009 considers phonological "DECAY"); its creation anew is not easily observed. All this is consistent with the possibility of some Uralo-Altaic unity, blurred by the Indo-Europeanization of the Balto-Finnic languages, while it makes any original Indo-Uralic unity excluding Altaic and Yukaghir highly unlikely.[64]

All experiments also point to significant closeness of NE-Caucasian and Dravidian (average distance 0.23). This similarity, which needs to be investigated, connects to another stable outcome of our experiments: the fact that Basque lies outside the group constituted by the other Eurasian languages except for those of the Far East, and, in particular, does not show any trace of the sometimes proposed relation to the NE-Caucasian languages (average distance 0.51).[65]

## The Homology Conjecture

We conclude that (A) syntactic phylogenies are very similar to the lexical-etymological ones, and (B) the small proportion of deviation can be imputed to secondary convergence only (which so far has been *a priori* removed from lexical, though not syntactic, data). These two claims are merged into:

(11) The **Homology Conjecture:** Syntactic and lexical histories provide the same evolutionary topologies once interference is equally taken into account

This hypothesis is in agreement with the expectations of syntactic *Inertia* (cf. Section "Syntax, Cognitive Science, and Historical Taxonomy") and is parallel to the Neogrammarian Regularity hypothesis, in attributing any disruption of an ideal diachronic evolution (in that case, regularity of non-analogical sound change) to dialect admixture.

## A Comparison With Phonemic Inventories

We checked then what kind of signal can be retrieved from our language sample through non-lexical (and potentially cross-family) traits that are not characterized by the three formal properties we used to select our syntactic characters (cf. (3)), and that are more remote from the core generative mechanisms of grammar.

For instance, inventories of autonomous phonemes have been used for comparison across different families, e.g., in Creanza et al. (2015). This work employs two large phonemic databases, PHOIBLE[66] and Ruhlen,[67] in an attempt to align phonemes into corresponding classes based on phonetic similarity.[68] To check whether phonemic characters generate informative phylogenies at our scale/density of sampling, we generated a BEAST tree (**Figure 5**) from the entries in Ruhlen's data corresponding to the languages of our study. The only taxa of the Gold Standard above identified by this tree are the 5 (21.7%) listed in (12):[69]

(12) a. Dravidian
b. Indo-Aryan
c. Tungusic (Even, Evenki)
d. Balto-Finnic
e. NE-Caucasian

These pairs are also geographically close and might in part reflect reciprocal secondary influence, as the cluster Spanish/Basque apparently does. Most other clusters do not reflect historical information at all (e.g., Sicilian-Faroese, English-Pashto, Irish-Buryat, Mari-Cypriot Greek etc.).

Our experiment supports Creanza et al.'s (2015, p. 1269) claim that "phoneme inventories are affected by recent population processes and thus carry little information about the distant past":[70] phonemic data exhibit a much shallower historical signal than syntactic data, and are actually prone to detect secondary convergence (see also Wichmann and Holman, 2009). This result shows the relevance of comparing different input data and prompts some considerations about their historical signal.

## Input Data and Phylogenetic Results

Some previous phylogenetic experiments found less historical signal when looking at structural traits. For instance, Greenhill et al. (2017) compared the evolutionary rate and signal of lexical etymologies with that of some structural properties in 81 Austronesian languages. They found that, on average, structural properties display higher rates of change than lexical

[63] Collinder (1960).

[64] Also see Marcantonio (2002) and the debate ensued.

[65] Starostin (1996) and Bengtson (2017), a.o.

[66] Moran and McCloy (2019).

[67] http://starling.rinet.ru/typology.pdf

[68] Of course, it is plausible that an interesting historical signal can be retrieved from analyses of more abstract phonological processes and constraints rather than just of the physical resemblance of autonomous phonemes. Promising results on this line, which parallel the ones of our approach, are provided in Macklin-Cordes et al. (2020).

[69] Few other clusters with more indirect genealogical content are those formed by two continental West Germanic languages (German and Dutch), two Northern Germanic languages (Danish, Icelandic), four Slavic languages (Bulgarian, Russian, Slovenian, Serbo-Croatian), and two Romance languages (Portuguese and French).

[70] Creanza et al. (2015) complement this claim with pointing out the limited and historically recent correlations found between phonemic distances and genetic distances. Using syntactic parameters, instead, Longobardi et al. (2015) found that genetic differences correlate with linguistic distances more than with geographic distances in Europe.

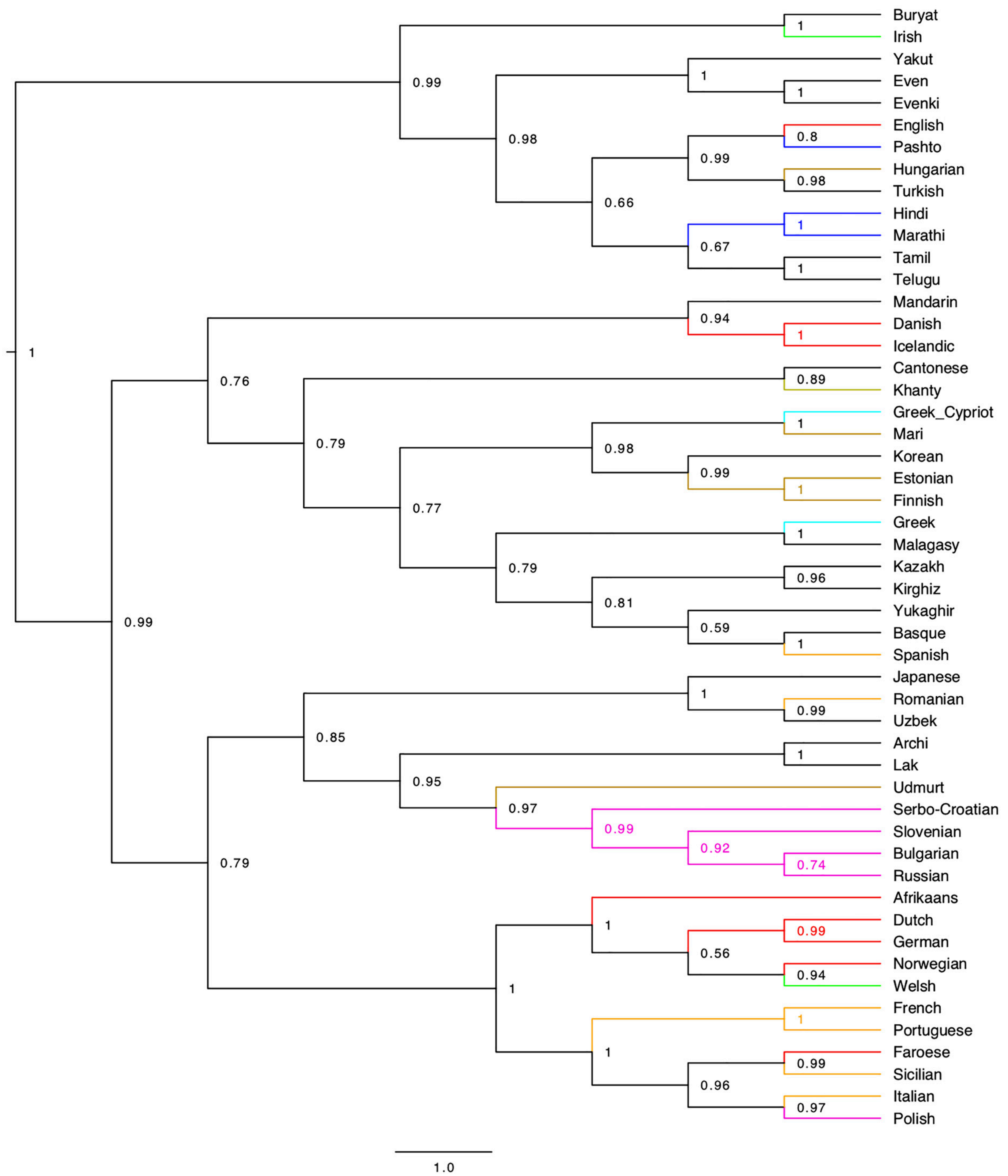


**FIGURE 5 |** BEAST tree from Ruhlen's phonemic dataset. The tree contains a subset of the languages used in Creanza et al. (2015), consisting of the 52 languages overlapping with those used in this article. The color coding is the same as for the previous phylogenies, visually highlighting the differences in the clustering of the families. The best model that we determined is a Gamma Site Model with Substitution Rate = 1, a Mutation Death Model with death $p = 0.1$, a Relaxed Clock (Logarithmic) with clock rate = 1, and a uniform Yule model for the birth rate. The Monte Carlo Markov Chain produced 10,000,000 trees, 25% of which were used for the burn-in and discarded for the purpose of the calculation of the consensus tree. The tree is a consensus tree of 7500 different trees sampled through the 7,500,000 trees (with a sample stored every 1000 generated trees) produced by the Monte Carlo procedure.

sets, and that there are subsets of properties (both lexical and structural) that change much slower or much faster than the average. For instance, number marking on the noun phrase and the presence of tones showed up as conservative, while article properties and vowel length as features that tend to change over time.

Thus, in certain respects, the historical signal retrieved through the syntactic dataset of the present article is more robust and promising than that obtained with their structural traits: the results are not necessarily in contrast, though, because of the different properties of the input data and of the different idealizations made on them (cf. (3a–c)) in Section "Syntactic data and taxonomic problems".

First, one difference is that the structural traits used in Greenhill et al. (2017), like those employed in a preliminary work by Dunn et al. (2005), include not just syntactic characters but also other non-lexical features, some of which (presence of phonetically defined autonomous phonemes) are shown here to contain a shallow and genealogically very disruptive signal. So, this is a potential cause of the different outcome.

Second, parameters are coded as representations of the generative devices in mental grammars, rather than as generated patterns. It is conceivable that this provides them with a high degree of cognitive realism and deductive information, which in turn provide historical resolution. Recall that only an average of 20 parameters (39 if we consider identities on the "−" values) are fully comparable across the language pairs of our sample, due to the redundancies created by the pervasive implicational structure of parameters (cf. Section "Parameters and schemata"). The correctness of the topologies retrieved by so few characters suggests indeed that parameters do have high-resolution.

Finally, a most interesting property brought to light by our experiments is that all the divergences of syntax from the established or expected topologies can in principle be explained in terms of secondary convergence: neither of the syntactic topologies presents clear cases where an incorrect cluster is exclusively determined by homoplasy. Notice that *a priori* we might expect homoplasy to seriously affect syntactic topologies, given that our characters are binary and that we deal with many independent families. However, this is not the case. This may in part be due to the general robustness of the complementary vertical signal; but a relevant role must be played here by the third property of parametric data, their pervasive interdependence: the redundancy provided by parametric implications neutralizes the effects of the most obvious source of homoplasy. The resolution we obtain in the articulation of families and subfamilies, up to recently and minimally differentiated dialects, comes at the cost of considering at least some traits with a high-rate-of-change, which discriminate between close varieties; thus, by definition, they are less stable than parameters that have remained unchanged for millennia all over large families. In principle, their instability might have produced a great amount of homoplasy elsewhere in the trees, disrupting the correct phylogenies across other families. Yet, this has not happened with our dataset. Many parameters in **Supplementary Figure 1** which make finer distinctions within Romance dialects (and other close varieties) are neutralized in most non-Romance (or non-IE) languages, due to their dependence on hierarchically higher parameters. This has reduced accidental similarities between distant families. It is plausible that any attempt to attain globality with grammatical characters, in order not to crash against homoplastic effects, must indeed take into account the pervasive interdependence of such traits.

# CONCLUSION

Five major inferences can be drawn from the results of this article.

## The Historical Signal of Syntax

The syntactic structures of I-languages (Chomsky, 1986: the abstract rule systems of computational theories of mind; also see Everaert et al., 2015) are an effective tool of historical knowledge (*pace* contrary positions in comparative philology and in modern formal syntax, as well as some skepticism expressed in quantitative phylogenetics: cf. Dunn et al., 2011): they retrieve most of the phylogenetic information contained in trees produced by lexical etymologies. Strikingly, the trees obtained from syntax are essentially unaffected by the inevitable amount of homoplasy which must be produced by the binary nature of the characters used. Also, the verticality of the syntactic signal and its chronological depth are far stronger than those of more externalized traits, like phonetic similarity in phonemic inventories (in agreement with Creanza et al.'s, 2015 conclusion that such phonemic characters are not informative about deep-time relations). The phylogenies retrieved through syntax must be relatively deep in time, if they are able to sharply separate, e.g., Basque from IE and other Eurasian families: given the limitations of (non-speculative) methods for investigating deeper language evolution, stressed in Hauser et al. (2014), this empirical, bottom-up approach is a promising perspective for studying the past of human syntax.

## Historical Support for Generative Grammars

The search for a historical signal represents an unprecedented type of evidence to test the format of representation of mental grammars used in syntactic theories, especially in minimalist approaches to parameters. As in the formal grammatical tradition, we have tried to model the dataset used not simply as a set of experiential facts, but mostly as a deductive structure in which surface data (e.g., E-languages) are largely the product of the combination of simpler and less numerous principles (I-languages). The success in retrieving a historical signal corroborates this general approach on a domain different from the usual ones (synchrony, typology, acquisition) used to support formal linguistic theory.

## Generative Grammars and Phylogenetic Evidence

Conversely, this robust historical signal suggests a reconsideration of the practice of formal syntax itself: for example, when a clear deviation of a parameter value occurs in a language from the state of its established family, it will call for an explanation. If the synchronic analysis is correct, then for linguistic theory the question should arise of how, and possibly why, the disconnection from the family pattern has taken place.

## Phylogenetics and Language Distances

Beyond some minor complementarity between character- and distance-based models of syntactic history, the topologies retrieved by the two methods are quite similar. This is in line with Greenberg's (1987) controversial claim that a first approximation to language taxonomy is possible even ahead of step-by-step reconstruction of all ancestral characters.

### Tools and Perspectives

We have used a tool for language description (a list of YES/NO existential questions: cf. Crisma et al., 2020) universally applicable and requiring very limited information (in principle no more than one YES answer per parameter set to "+"): this was mainly possible owing to the redundancy and default settings which characterize a minimalist approach to parameters. Beyond phylogenetics, a system with these properties has obvious consequences for the study of grammatical diversity and language learnability (cf. Sakas et al., 2017).

In sum, we regard these results as a breakthrough with respect to a long tradition in linguistics: they indicate that there exists a signal in syntax which might be used for aiming at progressively more comprehensive phylogenies of human languages. We suggest the possibility of adding less visible taxonomic traits, such as syntactic parameters, to the toolkit of phylogenetic linguistics as the basis for a *qualitative* revolution, which may complement the scope and success of the *quantitative* one.

## DATA AVAILABILITY STATEMENT

The code used to generate the experiments and the figures can be found at https://github.com/AndreaCeolin/FormalSyntax doi: 10.5281/zenodo.4323165.

## AUTHOR CONTRIBUTIONS

GL and CG devised the comparative methodology and the specific parametric structure. GL, CG, MAI, and AC collected the data. AC performed the computational experiments. GL, MAI, and AC wrote the Introduction. GL, CG, and AC wrote the Materials and Methods, the Results, and the Discussion. GL wrote the Conclusion.

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## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2020.488871/full#supplementary-material

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